Technical Note

Arthroscopy-Assisted Scapholunate Reconstruction With Internal Brace Augmentation

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Abstract: Various surgical techniques exist to repair or reconstruct complete scapholunate (SL) interosseous ligament tears, including capsulodesis, static or dynamic tenodesis, ligament reconstruction with tendon graft, bone-retinaculum-bone reconstruction, and the reduction and association of the scaphoid and lunate (RASL) procedure. The choice of surgical technique depends on arthroscopic assessment using the Geissler classification and European Wrist Arthroscopy Society staging of SL injury. This article describes arthroscopy-assisted extracapsular SL reconstruction using free tendon graft and internal brace augmentation for the treatment of unrepairable complete SL interosseous ligament tears.

Scapholunate (SL) reconstruction is indicated in symptomatic, nonarthritic patients with arthroscopically diagnosed reducible complete scapholunate interosseous ligament (SLIL) tears, defined as grade IIIC, IV, or V SL lesions per the European Wrist Arthroscopy Society classification (Table 1).[1] Various surgical techniques have been described to repair or reconstruct the SLIL, with variable success rates. These procedures include capsulodesis,[2,3] static or dynamic tenodesis,[4] reconstruction using tendon graft,[5-12] bone-retinaculum-bone reconstruction,[13,14] and the reduction and association of the scaphoid and lunate (RASL) procedure.[15]

Open SL reconstruction requires extensive soft-tissue dissection, potentially damaging the soft tissue supporting the SLIL, especially the dorsal intercarpal ligament and the dorsal capsule scapholunate septum.[16-18] To mitigate this, Corella et al.[11,19] described an arthroscopic SL reconstruction technique using distally based flexor carpi radialis (FCR) with a Bio-Tenodesis screw (Arthrex, Naples, FL). Similarly, Ho et al.[9] developed a technique for arthroscopic extracapsular reconstruction of the volar and dorsal SLILs using free tendon graft, preserving the capsuloligamentous structures around the SL joint. Their technique required temporary Kirschner wires to protect the repair.

Internal braces (IBs) have become increasingly popular owing to their ability to allow for an earlier return to function and motion after surgery.[7,10,20,21] Kakar and Greene[20] described an SL reconstruction with IB augmentation without the need for Kirschner wire stabilization and prolonged immobilization. However, their technique required an open dorsal capsulotomy and an extensive volar incision.

This article describes arthroscopy-assisted extracapsular SL reconstruction using free tendon graft and IB augmentation. This technique avoids the need for open capsulotomies that may disrupt the vascular supply of the carpus, extensive dissection of soft tissue, and prolonged immobilization using Kirschner wires.

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Table 1. EWAS Classification of SLIL Tears[1]

Arthroscopic Stage per EWAS Classification	Findings on Arthroscopic Testing of SLIL From MC Joint
I	No passage of probe
II: lesion of membranous SLIL	Passage of tip of probe in SL space with no widening (stable)
IIIA: partial lesion involving volar SLIL	Volar SL widening on dynamic testing from MC joint (anterior laxity)
IIIB: partial lesion involving dorsal SLIL	Dorsal SL widening on dynamic testing from MC joint (posterior laxity)
IIIC: complete SLIL tear, reducible joint	Complete widening of SL space on dynamic testing; reducible with probe removal
IV: complete SLIL tear with SL gap	SL gap with passage of arthroscope from MC to RC joint; no radiographic abnormalities
V	Wide SL gap with passage of arthroscope through SL joint; frequent radiographic abnormalities (increased SL gap and DISI deformity)

DISI, dorsal intercalated segment instability; EWAS, European Wrist Arthroscopy Society; MC, midcarpal; RC, radiocarpal; SL, scapholunate; SLIL, scapholunate interosseous ligament.

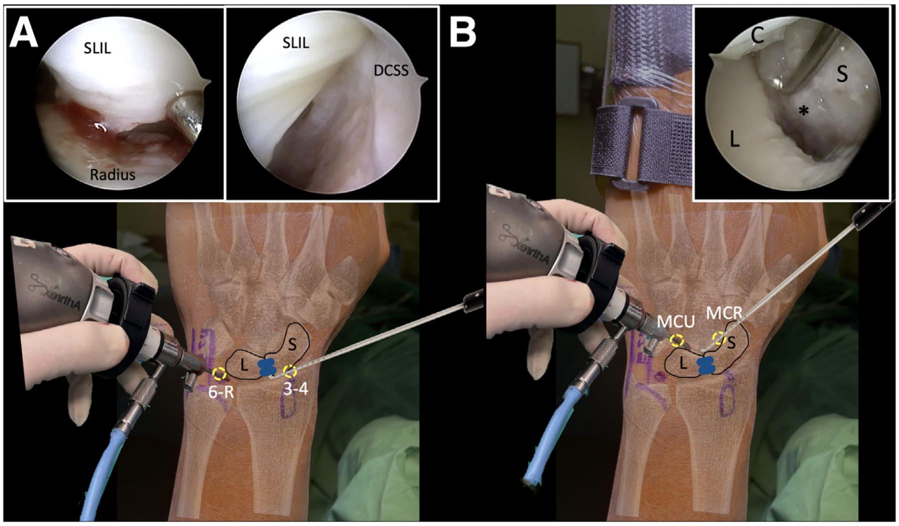

Fig 1. (A) Assessment of scapholunate interosseous ligament (SLIL) through radiocarpal joint (RCJ), with 6-R as viewing portal and 3-4 as working portal of the left wrist. One may visualize and assess the torn SLIL and dorsal capsule scapholunate septum (DCSS) using an arthroscopic probe. (B) Assessment of SLIL through midcarpal joint, with midcarpal ulnar portal (MCU) as viewing portal and midcarpal radial portal (MCR) as working portal. The severity of the SLIL tear is assessed according to the European Wrist Arthroscopy Society and Geissler classifications. Asterisk indicates fibrous scar within the SL joint. (C, capitate; L, lunate; S, scaphoid.)

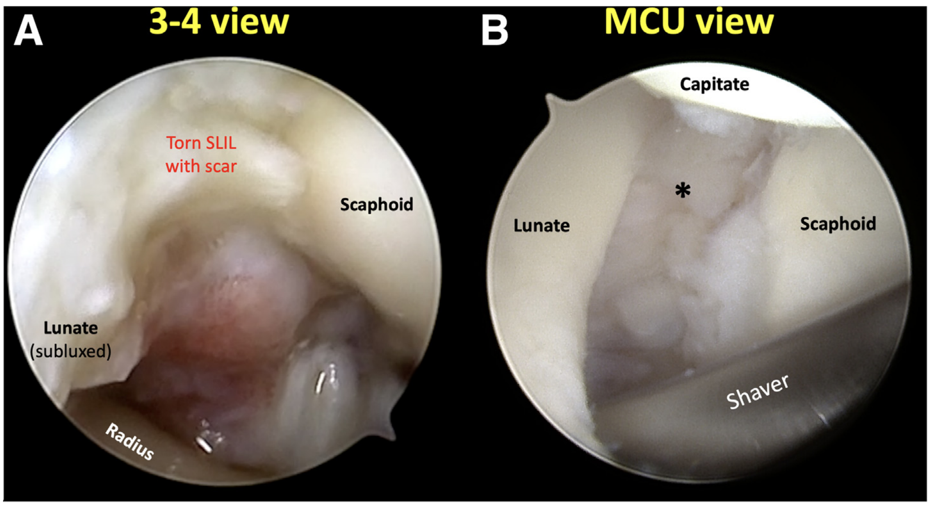

Fig 2. (A) Arthroscopic assessment showing Geissler grade IV scapholunate diastasis with step-off at scapholunate junction from radiocarpal view. (B) Midcarpal view showing positive drive-through sign with thick fibrous scar at scapholunate interval (asterisk). An arthroscopic shaver is used to resect the scar until the scaphoid and lunate are reducible. (SLIL, scapholunate interosseous ligament.)

Surgical Technique

Patient Preparation

The procedure is performed with the patient under general or regional anesthesia by use of a sterile arm tourniquet (Video 1). A fluoroscopic assessment is performed to determine the degree of SL dysfunction and the reducibility of the SL joint. The patient's arm is placed on a standard wrist traction tower, and finger traps are used to apply 5 to 7 kg (11-15 lb) of tension along the arm's axis.

Table 2. Geissler Classification of Intracarpal Ligament Tears Using Arthroscopic Assessment[23]

Grade	Description
I	Attenuation or hemorrhage of interosseous ligament seen from RC space; no incongruence of carpal alignment in MC space
II	Attenuation or hemorrhage of interosseous ligament seen from RC space; incongruence or step-off of carpal space; slight gap (less than width of probe) between carpal bones may be present
III	Incongruence or step-off of carpal alignment as seen from both RC and MC space; probe may be passed through gap between carpal bones
IV	Incongruence or step-off of carpal alignment as seen from both RC and MC space; gross instability with manipulation; 2.7-mm arthroscope may be passed through gap between carpal bones

MC, midcarpal; RC, radiocarpal.

Arthroscopic Assessment

We use the following arthroscopic portals: 3-4, 6-R, midcarpal radial, and midcarpal ulnar (Fig 1). Small transverse incisions are made along the skin creases using a No. 15 blade scalpel for better scar cosmesis. This is followed by blunt dissection with mosquito forceps. Through the 3-4 portal, the scope (30° lens with 1.9-mm diameter) is first introduced into the radiocarpal joint (RCJ), while the 6-R portal serves as a working portal. Both of these portals can be used interchangeably, depending on the situation. By use of the technique of dry arthroscopy with intermittent irrigation described by del Piñal,[22] the RCJ and ulnocarpal joint are assessed. The RCJ inspection may reveal a step-off between the scaphoid and lunate, indicating SLIL injury (Fig 2A). With the use of a 3-mm arthroscopic shaver and 2.9-mm burr, synovectomy and radial styloidectomy may be performed in the same setting if necessary.

The camera is then placed through the 6-R portal to assess the integrity of the dorsal SLIL and dorsal capsule scapholunate septum with an arthroscopic probe (Fig 1A). This is followed by midcarpal joint exploration through the midcarpal ulnar (working) and midcarpal radial (viewing) portals (Fig 1B). One may assess SL instability using the Geissler classification[23] (Table 2) or the European Wrist Arthroscopy Society classification[1] (Table 1) through the midcarpal joint portals. To facilitate reduction of SL malalignment, a shaver is used to resect the intra-articular fibrosis (Fig 2B).

Graft Harvesting and Exposure of Volar Joint Capsule

A volar transverse proximal wrist crease incision is made, extending from the radial border of the FCR tendon to the ulnar border of the palmaris longus tendon (Fig 3B). At least 12 cm of the palmaris longus tendon, trimmed to 2 mm wide (Fig 4), is harvested using a tendon stripper. The tendon is whipstitched at both ends with a No. 4-0 FiberLoop suture (Arthrex).

The anterior forearm fascia and the proximal edge of the transverse carpal ligament are incised through the same incision, exposing the flexor tendons and the median nerve. Care must be taken not to injure the palmar

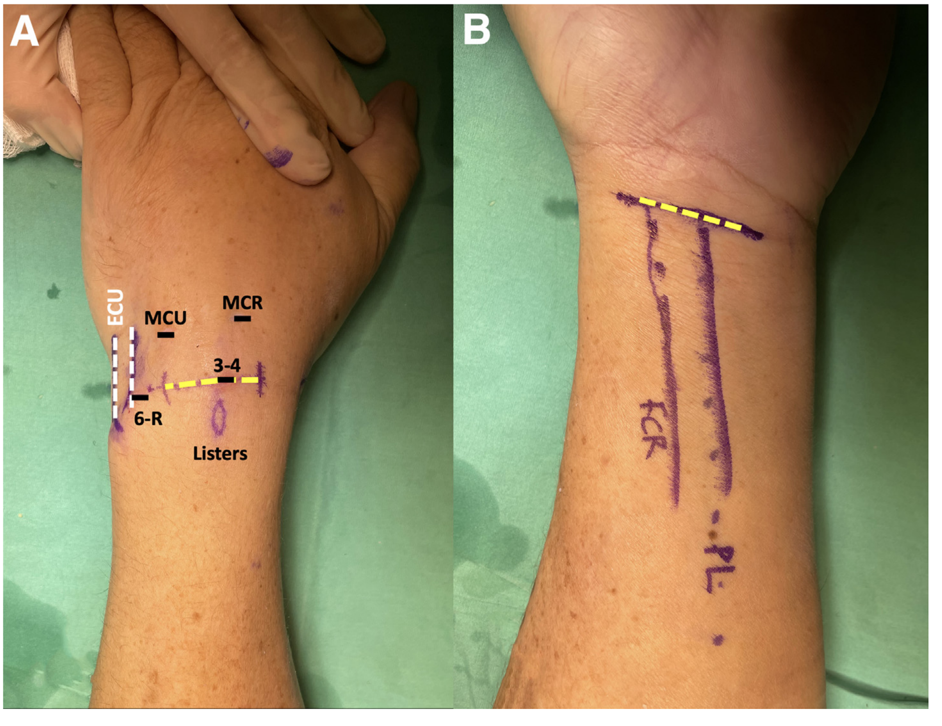

Fig 3. Dorsal and volar views of wrist showing incisions and portals planned for described surgical procedure. (A) The dorsal transverse incision extends from slightly radial to the 3-4 portal incision toward the 4-5 portal (yellow dashed line). (B) The volar transverse wrist crease incision extends from the radial border of the flexor carpi radialis (FCR) tendon to the ulnar border of the palmaris longus (PL) tendon (yellow dashed line). (ECU, extensor carpi ulnaris; MCR, midcarpal radial portal; MCU, midcarpal ulnar portal.)

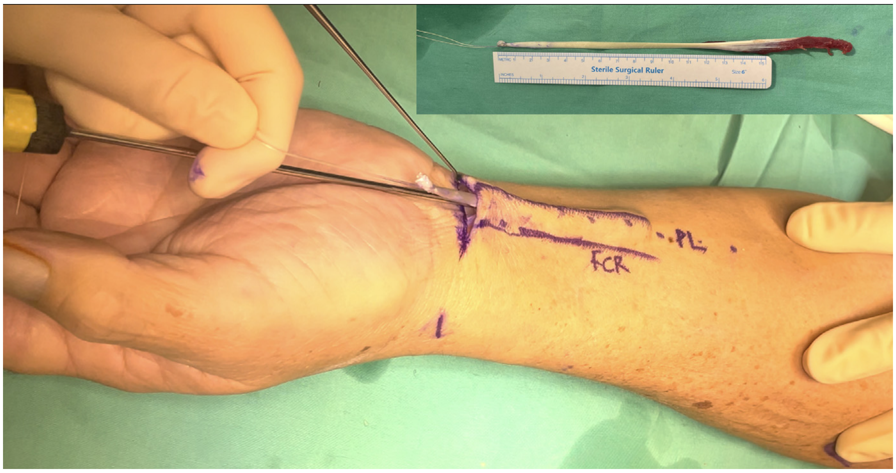

Fig 4. Palmaris longus (PL) free tendon graft harvested using tendon stripper. A length of at least 12 cm, trimmed to 2 mm wide, should be harvested, and the tendon is whipstitched at both ends with a No. 4-0 FiberLoop suture (not shown). (FCR, flexor carpi radialis.)

cutaneous branch of the median nerve. The interval between the FCR and the flexor tendons with the median nerve is created in preparation for the scaphoid bone tunnel without violating the volar wrist capsule, and the interval between the flexor tendons of the index and middle fingers and those of the ring and little fingers is created in preparation for the lunate bone tunnel.

Exposure of Dorsal Joint Capsule and Correction of Dorsal Intercalated Segment Instability Deformity

A dorsal transverse incision is extended from the 3-4 portal incision toward the 4-5 portal (Fig 3A). The distal third of the extensor retinaculum is divided longitudinally, exposing the extensor digitorum communis tendons (Fig 5). Care must be taken not to injure the dorsal capsule of the wrist joint. The extensor digitorum communis tendons are retracted in an ulnar manner to expose the lunate bone. This can be confirmed through fluoroscopy. The interval between the extensor carpi radialis longus and extensor carpi radialis brevis tendons corresponds to the ideal position of the scaphoid tunnel. Dorsal intercalated segment instability deformities may be corrected using the Linscheid maneuver under fluoroscopic guidance.[24] In this maneuver, the wrist is flexed to restore the normal radiolunate (RL) angle, and a 1.6-mm Kirschner wire is passed through the distal radius toward the lunate. The RL wire is inserted into the ulnar half of the lunate, away from the intended lunate bone tunnel (Fig 6). The wrist is then passively extended to correct the radioscaphoid malalignment. If the SL malalignment remains uncorrectable, additional release of fibrous scar at the SL junction arthroscopically with a shaver may be required (Fig 1B).

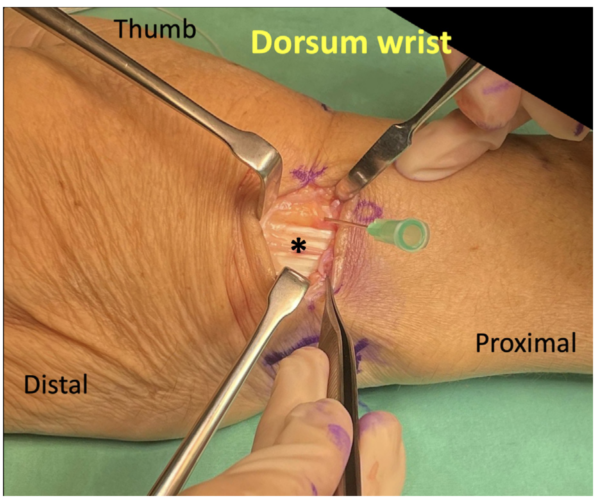

Fig 5. Exposed extensor tendons (asterisk) after division of distal third of extensor retinaculum. The scaphoid and lunate bone tunnels were identified using a hypodermic needle under fluoroscopic guidance.

Bone Tunnel Preparation

Under fluoroscopic guidance, a 1.1-mm cannulated Kirschner wire is inserted into the central lunate and proximal third of the scaphoid bone in a dorsal-to-palmar direction. If the scaphoid and lunate are in neutral alignment, the wires should be placed parallel to each other and perpendicular to the long axis of the lunate. However, if the scaphoid alignment is abnormal (flexed scaphoid), the cannulated wire should be inserted in a dorsal distal—to—palmar proximal direction (Fig 7 A and B). If the RL wire is placed using the Linscheid maneuver,[24] the lunate should be in neutral alignment (Fig 6). Alternatively, joystick wires may be inserted away from the intended drill holes in the scaphoid (dorsal distal—to—palmar proximal direction) and lunate (dorsal proximal—to—palmar distal direction), followed by clamp placement to secure the 2 wires together. By use of this method, the SL malalignment can be corrected before cannulated wires are placed for the bone tunnel. The lunate tunnel is created

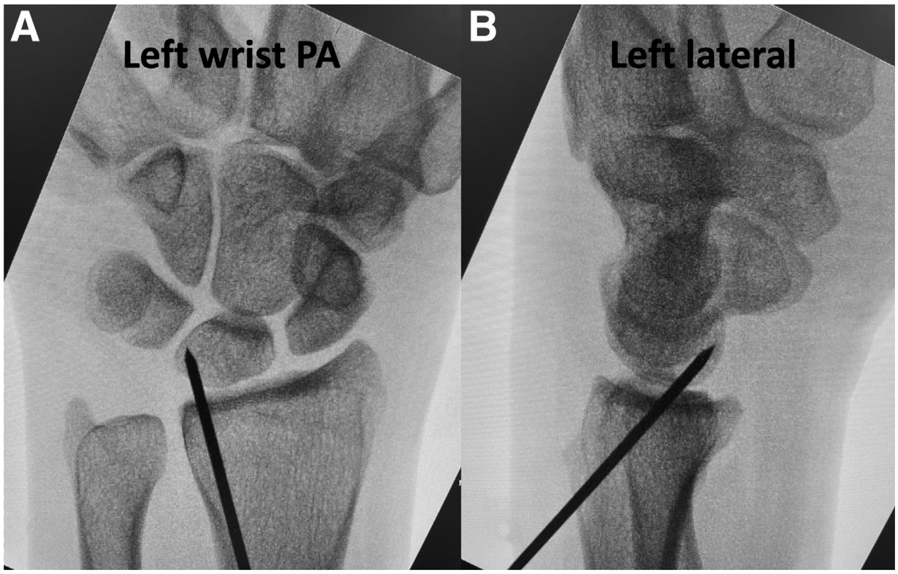

Fig 6. (A, B) Placement of 1.6-mm Kirschner wire into ulnar half of lunate from distal radius using Linscheid maneuver[24] (different case than that presented in this article). When a radiolunate wire is being placed, it should be inserted away from the intended lunate bone tunnel. (PA, posterior anterior fluoroscopic view.)

using a 3-mm drill and the scaphoid tunnel is made using a 2.5-mm drill to facilitate a double passage of tendon graft through the lunate tunnel and a single passage through the scaphoid tunnel.

Tendon Graft Passage and IB Insertion

The tendon graft is now passed through the lunate tunnel in a dorsal-to-palmar direction, through the scaphoid tunnel in a palmar-to-dorsal direction, and back to the lunate tunnel in a dorsal-to-palmar direction (Fig 8). The RL wire is then removed to free the lunate bone. The tendon graft is tensioned on both ends (Fig 8E). A 3 × 8—mm Bio-Tenodesis screw is inserted dorsally into the scaphoid and lunate tunnels while the graft is maintained under tension. Because the Bio-Tenodesis screw is cannulated, both limbs of the 1.3-mm-diameter IB suture tape are passed in a dorsal-to-palmar direction through the scaphoid and lunate screws. Both ends of the tape are then tied (≥4 throws) at the floor of the carpal tunnel (Fig 9). If there

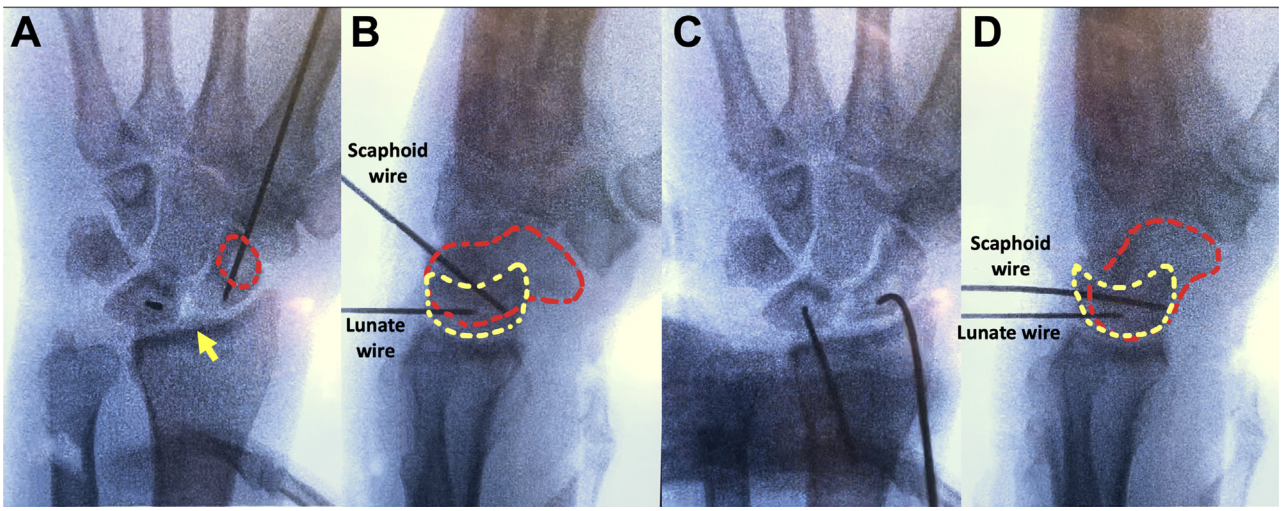

Fig 7. (A) Under fluoroscopic guidance, 1.1-mm cannulated Kirschner wires are inserted within the central lunate and the proximal third of the scaphoid. The scaphoid ring sign (red outline) indicates that the scaphoid is flexed, and the yellow arrow indicates scapholunate diastasis. The lunate cannulated wire is placed perpendicular to the long axis of the lunate. (B) As the scaphoid is flexed (red outline), the scaphoid cannulated wire is inserted in a dorsal distal—to—palmar proximal direction. Because the lunate bone (yellow outline) is already in neutral alignment in this case, the lunate cannulated wire is placed in a neutral direction. (C, D) After insertion of the cannulated wires into the lunate (yellow outline) and scaphoid bones (red outline), the 2 wires are clamped together with large artery forceps. In doing so, we can observe that the scaphoid is more extended (absence of scaphoid ring sign) and that the scapholunate diastasis is no longer present.

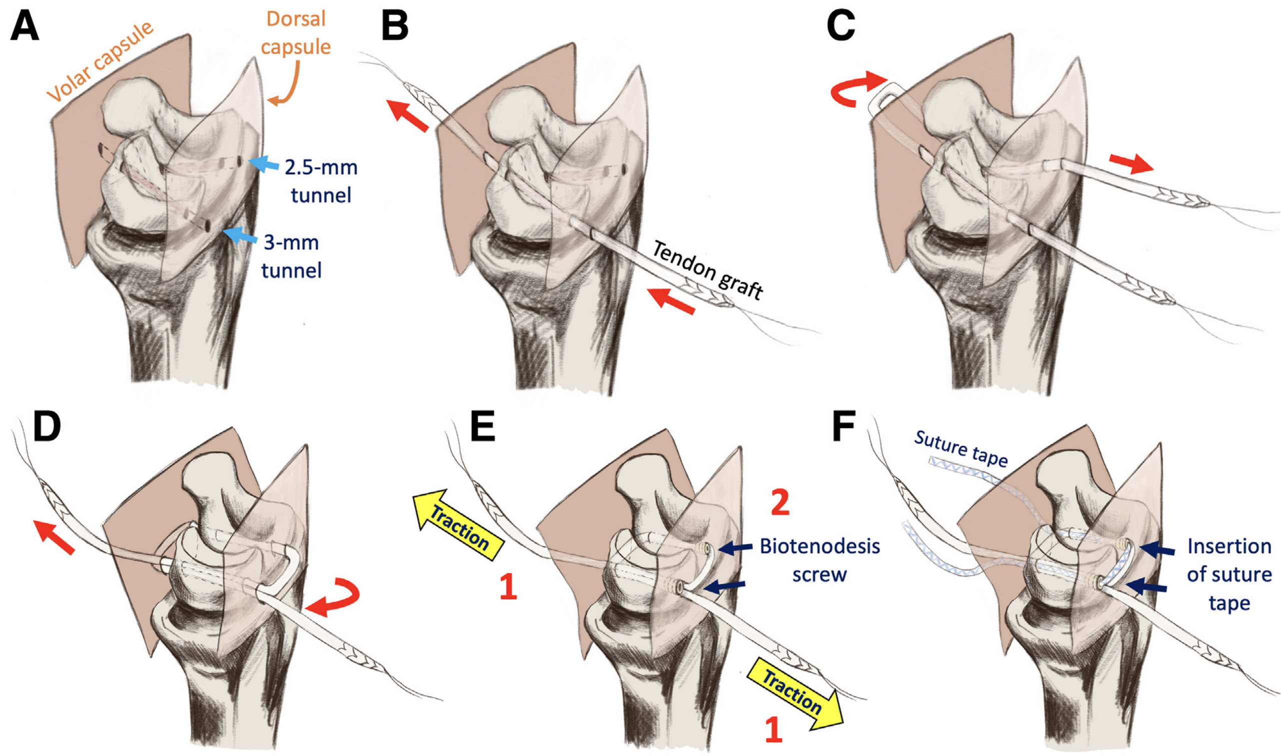

Fig 8. Step-by-step surgical technique. (A) Creation of 3- and 2.5-mm tunnels within lunate and scaphoid bone after placement of cannulated wires. (B-D) Passage of free tendon graft from dorsal to palmar through lunate, from palmar to dorsal through the scaphoid, and back to the lunate tunnel in a dorsal-to-palmar direction. (E) Manual traction on both ends of the tendon graft (step 1 in red) to reduce the SL dissociation, followed by application of Bio-Tenodesis screw (blue arrow) within the scaphoid and lunate bone dorsally (step 2 in red). (F) Placement of internal brace suture tape (Arthrex) through the scaphoid and lunate bones dorsally (blue arrow).

is an additional length of the tendon graft dorsally, it may be used to secure the distal pole of the scaphoid using a suture anchor for better scaphoid rotation control.

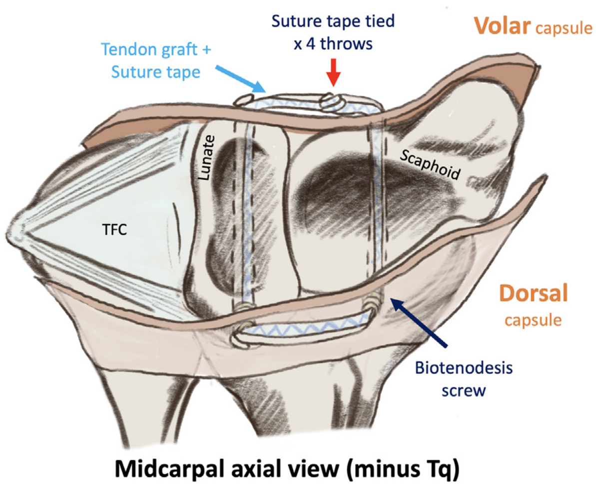

Fig 9. Axial view of midcarpal joint with triquetral (Tq) bone removed. Both ends of the suture tape are tied in a palmar manner at the floor of the carpal tunnel. We place at least 4 throws to secure the suture tape. (TFC, triangular fibrocartilage disk.)

All Kirschner wires are removed. The stability of the SL joint is assessed fluoroscopically and arthroscopically. The extensor retinaculum is repaired with absorbable sutures, and the wounds are closed with nylon sutures after irrigation and hemostasis. A bulky dressing and a volar wrist plaster slab are applied.

Postoperative Care

The patient is immobilized with a volar wrist splint for 4 weeks. Thereafter, the patient begins gentle active motion exercises of the wrist with dart thrower's motion up to week 6, followed by strengthening exercises (FCR and extensor carpi radialis longus) up to week 10. The splint is removed at week 6.

Discussion

Our technique has a few advantages. First, it reconstructs the volar and dorsal SLILs using free tendon graft, which is the current standard of care, given that anatomic studies have shown that the volar SLIL is just as crucial as the dorsal SLIL in maintaining SL stability.[25-27] Second, it is an extracapsular reconstruction technique that preserves all the capsuloligamentous

Table 3. Pearls and Pitfalls of Surgical Procedure

Pearls
Dry arthroscopy with intermittent irrigation is preferred to prevent fluid extravasation and expansion of multiple tissue planes. The risk of soft-tissue injury and postoperative edema are thus reduced.
The diameter of the TG should not be >2 mm because such a diameter will cause difficulty in tendon passage through the bone tunnels and wrist capsule.
To prevent secondary slackening, TG pre-tensioning is recommended.
It is crucial to align the scaphoid and lunate in neutral alignment while creating bone tunnels. If the wrist shows DISI, in which the scaphoid is flexed and the lunate is extended, the cannulated wires should be placed from dorsal distal to palmar proximal for the scaphoid and from dorsal proximal to palmar distal for the lunate.
We use a No. 11 blade to gently stab and twist at the capsule openings of the bone tunnel to facilitate TG passage through the wrist capsule.
Before Bio-Tenodesis screw insertion, the RL wire (if placed) is withdrawn to free the lunate, and manual traction should be placed on both ends of the TG to correct the SL malalignment. A fluoroscopic assessment is then made to ensure that the proximal scaphoid does not subluxate dorsally against the dorsal rim of the distal radius on the lateral view.
Pitfalls
The bone tunnels should be 3 mm from the margins to prevent iatrogenic fracture.
Slow drilling is advised to prevent overheating and avascular necrosis of the bone.
Adequate soft-tissue retraction out of harm's way is necessary to prevent injury to critical structures.

DISI, dorsal intercalated segment instability; RL, radiolunate; SL, scapholunate; TG, tendon graft.

structures essential for SL stability.[28] In a series of patients treated using a similar technique by Ho et al.,[9] 11 of 17 patients returned to their preinjury level, with a mean SL gap of 2.9 mm at an average of 48 months' follow-up. However, Kirschner wires were required as an internal splint for 6 to 8 weeks, requiring secondary removal and a longer period of immobilization.

Furthermore, our technique uses a 1.3-mm braided polyethylene IB suture tape (Arthrex) as an internal splint to reinforce the SL reconstruction. This permits earlier mobilization and a biomechanically stronger repair without needing Kirschner wires.[29] It has been shown that using an IB results in better functional outcomes, a higher satisfaction rate, and an earlier return to work.[21] In a series of patients assessed by Kakar et al.,[10] dart thrower's motion was started from week 4. The mean SL gap improved from 4.9 mm to 2.1 mm, and pain scores and range of motion improved significantly at 16.4 months after surgery. Finally, our technique is minimally invasive and does not require extensive dissection of soft tissues, reducing the risk of stiffness and pain associated with open surgery.

One of the risks associated with the described procedure is scaphoid and lunate bone fracture during tunnel creation (Table 3). At least 3 mm should be left between cannulated wires and bone margins to prevent fracture and avascular necrosis (Fig 10). It is also imperative to be aware of all the critical structures,

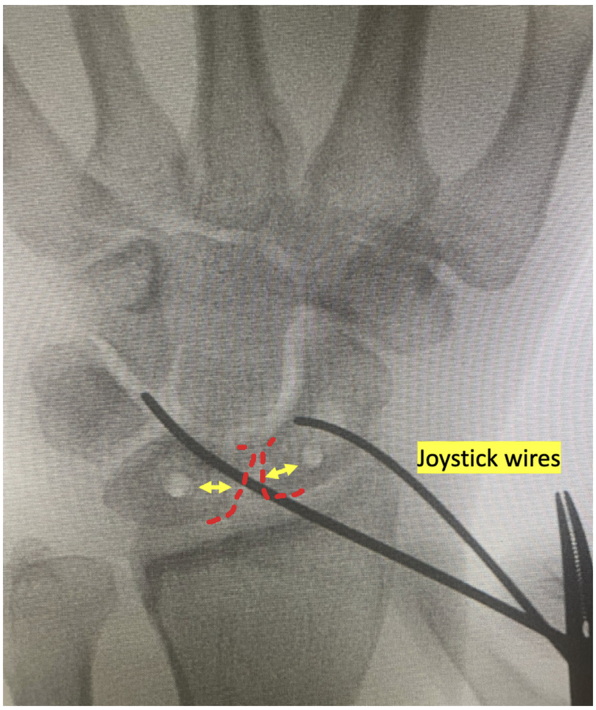

Fig 10. Intraoperative imaging. The scaphoid and lunate tunnels are located well away from the bone margins (red outline) (≥3 mm) to prevent iatrogenic fractures. The yellow double arrow shows the distance from the bone margin to the bone tunnel, which should be at least 3 mm.

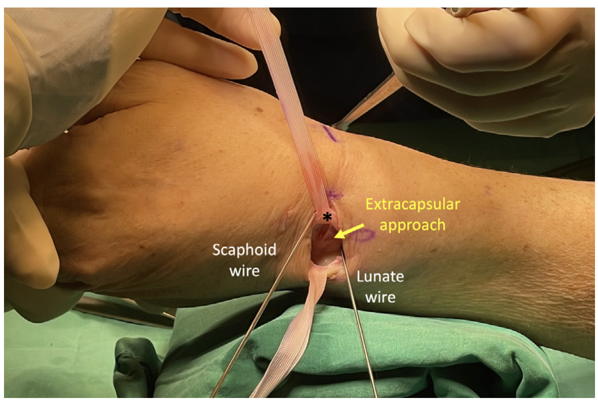

Fig 11. Dorsal view of wrist exposure, in which the extensor tendons (asterisk) are retracted with nylon tape. The cannulated wires are placed by an extracapsular approach and are guided by intraoperative fluoroscopy.

Table 4. Advantages and Disadvantages of Surgical Procedure

Advantages
The joint capsule and blood supply to the carpus are preserved with extracapsular reconstruction.
The IB suture tape obviates Kirschner wire insertion as an internal splint, permitting earlier mobilization and commencement of therapy.
A single-stage procedure is performed, without the need for secondary implant removal.
The procedure is minimally invasive with better scar cosmesis.
Disadvantages
Because the procedure is technically challenging, the surgeon must have a good amount of experience in wrist arthroscopy to perform it successfully.

IB, internal brace.

especially the tendons, median nerve, and cutaneous nerves, during this surgical procedure (Fig 11).

The described technique has the advantages of a minimally invasive approach with preservation of the capsuloligamentous structures around the SL joint. Furthermore, adding the IB allows earlier mobilization and return to function without secondary procedures (Table 4). A larger series of patients will be needed to study the outcomes of our technique.

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