15 Scapholunate Dissociation

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15.1 Introduction: Anatomy and Histology

The scapholunate interosseous ligament (SLIL) is an intrinsic, C-shaped ligament between the scaphoid and the lunate bones. The SLIL is anatomically divided in three portions: dorsal, proximal or membranous, and volar.

The dorsal SLIL is a taut structure composed of parallel collagen fibers and contributes to most of the tensile strength. Overstraeten et al. described the dorsal capsuloligamentous scapholunate septum (DCSS) [1]. It is an attachment between the dorsal wrist capsule, the dorsal part of the SLIL, and the dorsal intercarpal ligament. It inserts on to the scaphoid, the lunate, and the SLIL and it may play an important role in the stabilization of the scapholunate articulation.

The volar segment is similar in length and width but is approximately half as thick as the dorsal component and contains obliquely oriented fibers.

The proximal portion is histologically distinct because it is composed of fibrocartilage. It is difficult to identify the limits between the ligament and the scaphoid and lunate cartilage [2].

Hagert and Mataliotakis studied the histology of the SLIL. They described the different morphology of every portion of the ligament [3–5]. The dorsal portion is the strongest, rich in dense collagen fibers with few mechanoreceptors. The volar portion is well innervated and vascularized and there are fewer collagen fibers, but it is rich in mechanoreceptors. Finally, the proximal part is formed by conjunctive tissue centrally surrounded by fibrocartilage. There are some mechanoreceptors close to the palmar portion. According to these findings, the SLIL could be divided into a more mechanic dorsal portion and a more sensitive volar portion.

15.2 Pathomechanics

In a normal wrist there is an equilibrium between the flexion force applied over the scaphoid and the extension force applied over the triquetral. Both bones are stabilized to the lunate through the scapholunate and lunotriquetral ligaments. The scaphoid tends to flex the lunate and the triquetrum to extend it (Fig. 15.1).

The dorsal portion of the SLIL is the primary stabilizer of the scapholunate interval. The most important secondary stabilizers are the radioscaphocapitate (RSC), scaphocapitate (SC), and volar scaphotrapeziotrapezoid (STT) liga-

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ments. After complete lesion of the SLIL, there is no visible alteration in normal X-ray. However, under load, in stress X-rays, we can identify signs of scapholunate dissociation. Overstretching of secondary stabilizers with time may cause attenuation and rupture of these ligaments. In normal X-rays, we will identify scaphoid flexion and an increased scapholunate (SL) gap [6].

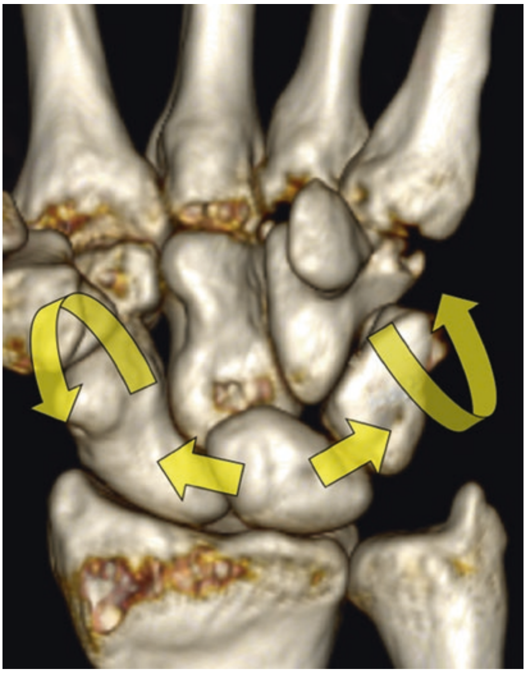

Fig. 15.1 The scaphoid tends to flex and the triquetrum to extend the lunate. The scapholunate and lunotriquetral ligaments stabilize the lunate in neutral position

In these cases, the scaphoid and lunate separate under the application of force, the lunate rotates into extension, and the scaphoid flexes, pronates, and moves dorsally and radially. The scaphoid proximal pole translates dorsoradially causing an alteration in the distribution of forces in the wrist. There is an increase of pressure in the dorsoradial area of the distal radius that may explain the frequent development of degenerative changes in the dorsolateral margin of the radioscaphoid fossa.

The extended lunate remains stable with the radius due to the fact that both articular surfaces have the same radius of curvature. Progression of the degenerative changes in the articulation with time may end in a predictable degenerative pattern termed scapholunate advanced collapse (SLAC) defined by Watson et al. [7]. Classically, it was thought that all SLIL lesions will progress to SLAC wrist. However, it is unclear which patients will end with an arthritic wrist. Some authors have described progressive deterioration of strength and mobility over time in an untreated SL lesion but the speed of progression in still unclear [8] (Fig. 15.2).

Fig. 15.2 Scapholunate advanced collapse (SLAC) classification. On the left: SLAC 1, degenerative changes limited to the dorsum of the scaphoid fossa. On the middle: SLAC 2, degenerative changes in the whole scaphoid fossa. On the right: SLAC 3, degenerative changes affecting the scaphoid and capitate

15.3 Diagnosis

The most common mechanism of injury of SLIL is a fall with the wrist in extension, ulnar deviation, and midcarpal supination. This mechanism can cause several lesions including concomitant fractures of the scaphoid or the distal radius.

Symptoms of SLIL injury may vary depending of the degree of disruption and the time from the lesion. A high index of suspicion is needed to avoid missing this injury. Most common complaints are poor grip strength, decreased mobility, and tenderness over the dorsal SLIL. Pain is variable and usually increased with activity. Sometimes the patients describe a "clunk" in the wrist after some movements due to the dislocation and reduction of the scaphoid.

15.3.1 Physical Exams

Scaphoid Shift Test or Watson Test: The examiner places four fingers in the dorsum of the radius and the thumb on the distal pole of the scaphoid. The other hand moves the wrist passively from ulnar to radial deviation. In SLIL lesions, pressure over the distal pole of the scaphoid during ulnar to radial deviation prevents flexion of the scaphoid. The scaphoid could be subluxated dorsally in complete lesions. When pressure is released, a painful "clunk" could be felt when the scaphoid reduces into the fossa. It is important to compare both wrists. Watson test could be positive in cases of hyperlaxity [9] (Fig. 15.3).

Scapholunate Ballottement Test: The lunate is stabilized with one hand and the scaphoid is displaced dorsally and volarly. The test is positive when there is pain, crepitus, or increased mobility (Fig. 15.4).

15.3.2 Radiological Examination

Radiological examination should include dorsopalmar, lateral, and stress views. AP fist with 30° ulnar deviation and clenched-fist views have the most consistent increase in scapholunate distance [10]. Contralateral views should be obtained for comparison (Fig. 15.5).

The radiographical signs of SLIL lesions are as follows:

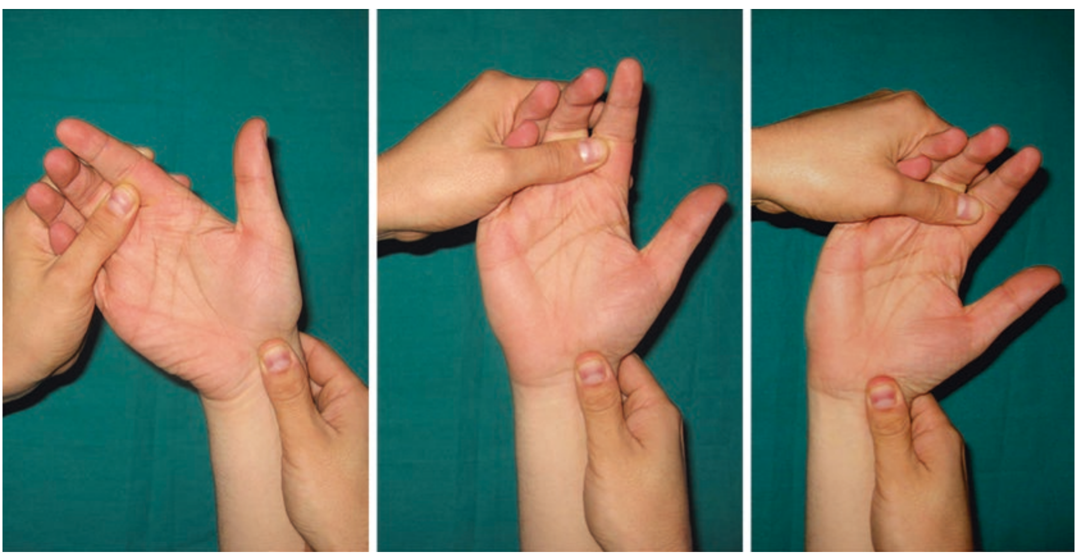

Fig. 15.3 Watson test

- Terry-Thomas sign, defined as a scapholunate distance >3 mm. Nevertheless, significant variability exists between patients.
- Signs of scaphoid flexion as the ring sign and shortening of the scaphoid in the PA view.
- Measurement of radiocarpal angles is difficult because of the irregular shape of the carpal bones. Small changes in wrist positioning can severely change measurements. High-quality views are needed for proper interpretation. Good-quality lateral views should show interposition of the scaphoid tubercle and pisiform and radius. Capitate and third metacarpals should be aligned.
  - Scapholunate angle >70° is considered a sign of abnormal flexion of the scaphoid; normal scapholunate angle ranges between 30° and 60°.
  - Radiolunate angle >15° is a defined sign of dorsal intercalated segment instability (Fig. 15.6).

Fig. 15.4 Scapholunate ballottement test

SLIL injuries could be classified according to the radiological findings in four stages:

1. Pre-dynamic instability: standard and stress radiographs are normal. It corresponds to a partial SLIL rupture that can only be diagnosed by MRI or arthroscopy.
2. Dynamic instability: standard radiographs are normal and only stress views show signs of SLIL instability. It is associated with a complete SLIL rupture.
3. Static instability: there are radiographic signs of SLIL dissociation in standard and stress radiographs. It is associated with a complete rupture of the SLIL and attenuation of secondary stabilizers.

Fig. 15.5 Clenched-fist view showing and increased scapholunate (SL) gap

Fig. 15.6 A positive Terry-Thomas sign (marked as 1) and a ring sign (marked as 2)

4. Scapholunate advanced collapse (SLAC) wrist: Watson et al. described four different stages, which will be described later.

15.3.2.1 Advance Imaging

Magnetic resonance imaging (MRI) is not so accurate as in other joints due to the complex anatomy of the wrist ligaments [11]. According to a comparative study between magnetic resonance arthrography (MRA) and MRI, the sensitivity for detection of SLIL injury of 1.5 T MRI was 45% and 75.7% for 3 T. MRA sensitivity was higher but similar to 3 T MRI at 82.1% [12]. The use of 3 T MRI has improved the visualization of the ligaments of the wrist; however, SLIL lesions are still difficult to identify in MRI. Dietrich et al. published an interdisciplinary consensus on imaging of SL instability [13]. The consensus agreement suggested that radiographs, radiographic stress views, dynamic fluoroscopy, MRA, and CTA are currently the most useful and accurate imaging techniques for SL instability diagnosis.

Fig. 15.7 Wrist arthroscopy. The scope is placed in the 6R portal

15.3.2.2 Arthroscopic Examination

Arthroscopy is considered the gold standard for the diagnosis of SLIL injuries. It allows the diagnosis and treatment of multiple pathologies. Initially, wrist arthroscopy was performed using constant saline flow irrigation [14]. The concept of dry wrist arthroscopy was developed by del Piñal et al. and it is very suitable for the diagnosis and treatment of SL lesions [15] (Fig. 15.7).

Geissler defined a treatment-oriented classification that evaluates the scapholunate interval. SLIL should be evaluated both through the radiocarpal and midcarpal joints [16]. When visualized from the radiocarpal joint, SLIL is best viewed through the 3–4 portal with a probe in the 6R portal. The normal scapholunate ligament is confluent between the scaphoid and the lunate and it is usually difficult to differentiate under direct visualization. On palpation, the scapholunate ligament is softer than the scaphoid and lunate. In the midcarpal joint, the SLIL is visualized through the midcarpal ulnar portal (MCU) and the probe in the midcarpal radial portal (MCR) (Table 15.1) (Fig. 15.8).

The European Wrist Arthroscopy Society (EWAS) modified in 2009 Geissler's classification [17] (Table 15.2):

The arthroscopic scaphoid 3D (dorsal, dynamic, displacement) test was described by Corella et al. to check the abnormal dorsal displacement of the scaphoid. To perform the test, traction should be released and the arthroscope set under the lunate (in the radiocarpal joint) or on the lunate (in the midcarpal joint). The scaphoid is manually pushed dorsally at the scaphoid tubercle. A negative test is defined when all the proximal row bones are minimally displaced, and

Table 15.1 Geissler classification of scapholunate ligament injuries

Stage	Radiocarpal view	Midcarpal view
I	Attenuation and hemorrhage of SL ligament	Tight SL interval. Probe cannot be inserted.
II	Attenuation and hemorrhage of SL ligament	Probe can be inserted but not rotated.
III	Radiocarpal step-off, SL tear	Probe enters SL interval and can be rotated.
IV	Radiocarpal step-off, SL tear	2.7-mm scope can be driven through the SL interval.

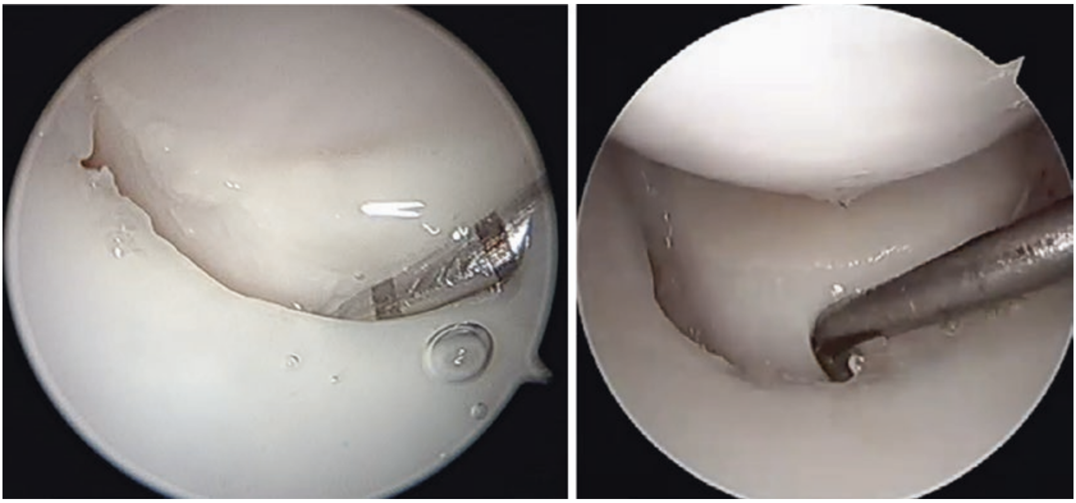

Fig. 15.8 On the left, Geissler grade III lesion; on the right, Geissler grade IV lesion

Table 15.2 European Wrist Arthroscopy Society (EWAS) classification of scapholunate ligament injuries

EWAS	Description	Arthroscopic test
I	As Geissler type I	Tight SL joint space; probe cannot be inserted.
II	As Geissler type II	Entry of the probe but not its rotation.
IIIA	Type II + volar SL ligament disruption	Volar laxity, no tension of the volar ligament when tested with the probe.
IIIB	Type II + dorsal SL ligament disruption	Dorsal laxity, no tension of the dorsal ligament when tested with the probe.
IIIC	Type II + volar and dorsal SL ligament disruption	Volar and dorsal laxity; probe can be rotated in SL interval.
IV	IIIC + SL gap, no misalignment or reducible	A 2.7 mm scope can be driven through the SL interval to the radiocarpal joint
V	IV + misalignment, not reducible	SL gap with radiographic abnormalities.

there is no scapholunate instability. A positive test is found when the scaphoid is displaced dorsally while the lunate remains static; this indicates scapholunate instability [18].

After evaluating SLIL lesions, it is important to check the rest of the joint for the presence of arthritis or other ligamentous injuries. These findings will help us to differentiate an acute lesion from a chronic rupture or a SLAC wrist.

Table 15.3 Garcia-Elias classification

	I	II	III	IV	V	VI
Is there a partial rupture with a normal dorsal SL ligament?	Yes	No	No	No	No	No
If ruptured, can the dorsal SL ligament be repaired?	Yes	Yes	No	No	No	No
Is the scaphoid normally aligned (RS <45°)?	Yes	Yes	Yes	No	No	No
Is the carpal malalignment easily reducible?	Yes	Yes	Yes	Yes	No	No
Is the articular cartilage normal?	Yes	Yes	Yes	Yes	Yes	No

15.4 Principles of Treatment

Treatment of SLIL lesions is controversial. There are numerous techniques described supported by limited evidence-based studies. Most treatment recommendations are based on expert opinions.

Garcia-Elias et al. proposed six questions to grade the scapholunate lesions in six stages, from a minor problem (stage I) to severe pathology (stage VI). Treatment recommendations were given for every stage [19] (Table 15.3).

15.4.1 Stage I: Partial SLIL Injury

The SLIL is only stretched or partially disrupted, and the dorsal portion of the ligament is intact. The degree of SLIL lesion varies from a distension (Geissler I) to a partial rupture (Geissler II). Wrist alignment is not altered but there is increased motion between the scaphoid and lunate causing cartilage loading and synovitis.

In standard and stress radiographs, there is no gap in the SL interval or malalignment. The SLIL lesion can only be diagnosed arthroscopically or by MRI. According to the radiographic findings, some authors defined this as occult or predynamic instability [20].

These patients, when symptomatic, could be treated by (1) arthroscopic debridement, (2) arthroscopic debridement and ligament shrinkage, or (3) reeducation of wrist proprioception.

15.4.1.1 Arthroscopic Debridement and Electrothermal Ligament Shrinkage

Synovectomy and debridement of torn and unstable ligament portions is performed in the radiocarpal and midcarpal joints. Electrothermal treatment is administered in short, non-ablative pulses over the SL ligament to produce a visible color and texture change. Specific focus is paid in the dorsal portion of the SLIL. The synovial fluid temperature should be monitored to avoid high temperatures that could cause chondrolysis.

Good clinical results, diminishing pain, and improving function are expectable with this technique, but the duration of the clinical relief is controversial. Lee et al. published good results in Geissler I and II lesions, reducing pain and improving grip strength in 14 patients with a mean follow-up of 53 months [21]. Burn et al. demonstrated excellent results in 9 patients with a follow-up of 5 years [22]. Patients had a mean grip strength equal to the contralateral extremity, near symmetric wrist motion, and a QuickDASH score improvement of 39 points.

15.4.1.2 Reeducation of Wrist Proprioception

Muscles act as carpal dynamic stabilizers; their contraction counteracts the displacement of the scaphoid in disrupted SLIL. Hagert et al. described the presence of mechanoreceptors in carpal ligaments that act as sensors to activate the contraction of the muscles to counteract the forces deforming the carpal bones [23]. Under axial load, the scaphoid tends to flex and pronate. Muscles that supinate the distal row compensate these forces. The abductor pollicis longus (APL) and extensor carpi radialis longus (ECRL) have demonstrated to supinate the carpal distal row, whereas the extensor carpi ulnaris (ECU) acts as a pronating muscle. The flexor carpi radialis (FCR) acts as a pronator muscle that supinates the scaphoid because of its relations to the scaphoid tuberosity [24]. Conservative management should focus on strengthening and proprioception reeducation of the supinator muscles (APL, ECRL, and FCR) while avoiding activation of the ECU. Certain orthosis could be modeled to place the wrist in slight extension, ulnar deviation, and supination to avoid contraction of the ECU [25, 26].

15.4.2 Stage II: Complete SLIL Injury, Repairable

In this stage, SLIL is completely disrupted but the dorsal portion is repairable. Arthroscopically, a complete Geissler grade III lesion is visualized. There is no malalignment and the secondary stabilizers are competent but tend to fail when loaded. There are only radiographic signs of instability in stress radiographs, SL gap or scaphoid flexion. This stage corresponds to a dynamic instability.

Anderson et al. described four types of dorsal SLIL ruptures: avulsion from the scaphoid (42%), avulsion from the lunate (18%), mid-substance rupture (20%), and partial rupture and elongation (22%) [27].

SLIL repairability depends on the quality of the ligament remnant. Mid-substance ruptures tend to degenerate very quickly and are often non-repairable. Bone avulsions are usually more favorable to repair. Lesions occurring after 3–4 months tend to degenerate and are usually not suitable for repair.

Treatment options for direct repair are (1) open reduction and dorsal ligament repair and (2) Arthroscopic repair.

15.4.2.1 Open Reduction and Dorsal SL Ligament Repair

A longitudinal, "Z-shaped," or transverse skin incision is made. The extensor retinaculum is open over the third extensor compartment, protecting the extensor pollicis longus tendon. Capsule incision varies depending of the posterior interosseous nerve. It could be excised, and a capsulotomy is made following the dorsal fiber-splitting approach described by Berger [28] or preserved using a nerve-sparing approach as described by Garcia-Elias. After exposing the SL interval, the ligament rupture is explored. According to the Anderson classification, the repair can be made by direct suture (mid-substance rupture) or by reinserting the ligament to the bone using an anchor. Usually, the repair is protected by transfixing the SL and SC joint with K-wires. Several authors recommend performing a dorsal capsulodesis during closure to reinforce the repair. Wires are removed after 8–10 weeks and a splint is maintained for a total of 12 weeks. A retrospective review of 82 patients showed acute repairs have better results than chronic ones [29]. Rosati et al. reported, in 18 patients with an average follow-up of 32 months, excellent or good functional outcomes in 88% of the patients [30]. Recently, Loisel et al. reported significant changes in carpal bone stability after performing the dorsal fiber-splitting approach in a cadaveric study [31]. They described a "window" approach that preserved the critical dorsal stabilizers and did not alter bone alignment (Fig. 15.9).

Fig. 15.9 Berger approach to reach the carpal bone

15.4.2.2 Arthroscopic Repair and Capsular Reinforcement

Arthroscopic repair and capsular reinforcement are performed through the four standard portals: 3–4, 6R, midcarpal radial (MCR), and midcarpal ulnar (MCU). The 6R portal is used for vision and the 3–4 as a working portal. Under direct vision, an anchor is introduced in the scaphoid or lunate upon the insertion of the SLIL, depending on where the SLIL has been detached. One side of the suture is passed through the remaining SLIL and both sutures are tied together. Depending on the lesion, sometimes more than one anchor is needed. The sutures of the implant are used for dorsal capsular plication. One side of the suture is passed to the midcarpal joint through the ligament and recovered to the radiocarpal joint between the capsule and the extensor tendons. Finally, both ends are tied together making a dorsal plication of the capsule. Carratala et al. reported good to excellent results in 79% of 19 patients with a follow-up of 1 year using this technique [32].

Mathoulin et al. described a capsuloligamentous repair performing a direct repair of the ligament and the dorsal capsule [33]. The indications were acute and chronic cases–Geissler 2, 3, and 4. K-wires were added in stage IV cases. Published results were good to excellent in most of cases (Fig. 15.10).

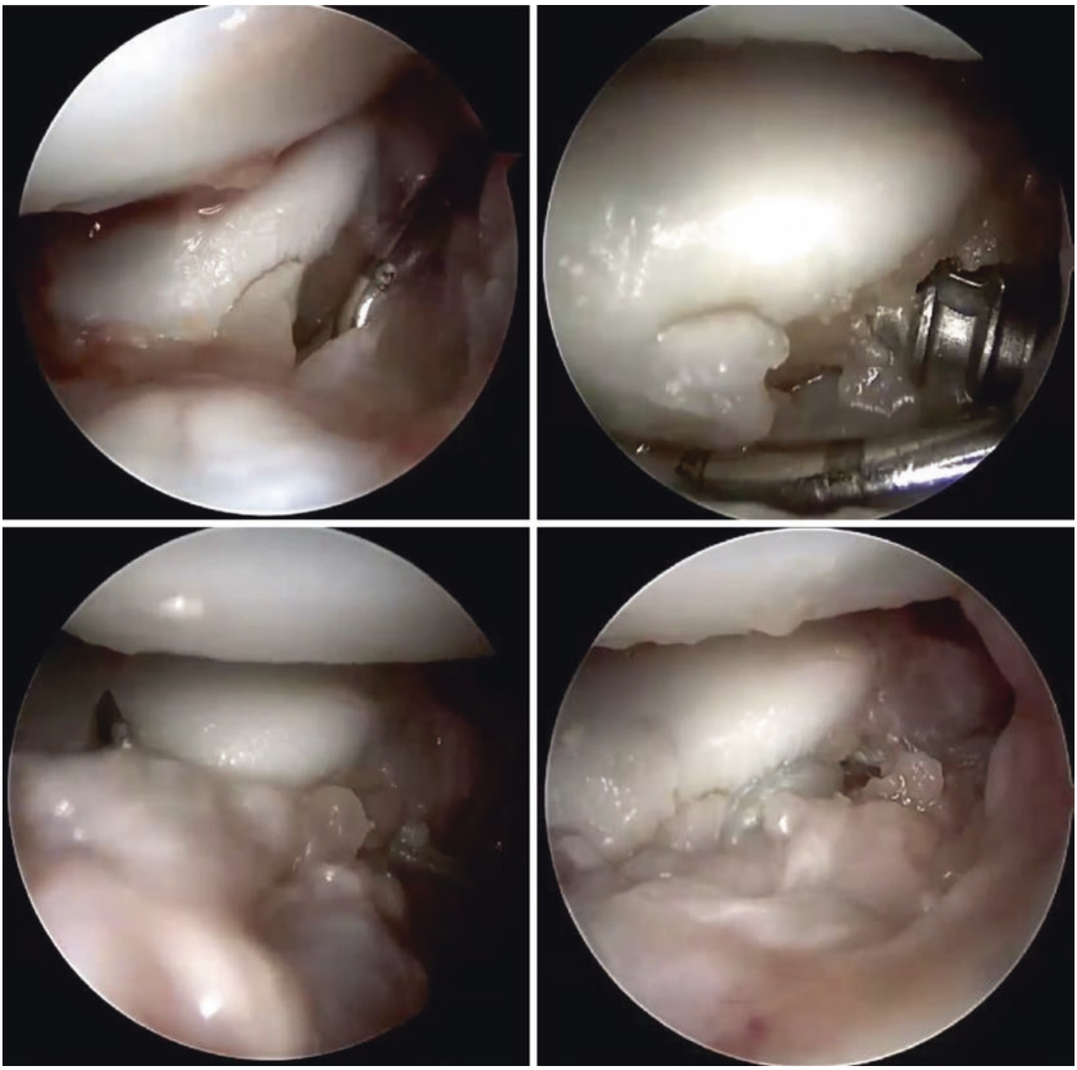

Fig. 15.10 Arthroscopic repair of a torn dorsal scapholunate (SL) ligament. Top left image: avulsion of the dorsal scapholunate interosseous ligament (SLIL). Top right image: anchor placement over the SLIL insertion. Down left image: suture passing through the SL remnant. Down right image: suture of the ligament

15.4.3 Stage III: Complete SLIL Lesion, Non-Repairable, No Malalignment

This is a complete lesion of the SLIL with poor healing potential, irreparable. There is still no malalignment because secondary stabilizers are still competent. This stage is radiographically defined as dynamic instability.

Most treatments for stage III utilize local tissues, like capsule, ligaments, or bone-ligament-bone autografts, to supplement local stabilizers. Treatment options are (1) dorsal capsulodesis, (2) bone-ligament-bone autografts, and (3) ligamentoplasties.

Dorsal Capsulodesis: It is carried out like the Blatt technique or Mayo Clinic scapholunate ligamentoplasty, using the capsule or the dorsal intercarpal ligament, respectively, to prevent scaphoid flexion. Both techniques showed improvement of symptoms but also significant reduction in range of motion and strength [34, 35].

Bone-Ligament-Bone Autografts: Grafts from the distal radius and dorsal retinaculum, or third metacarpal-capitate, have been used. There is still no long-term evidence of the results, but they have shown limited effect on preserving carpal alignment and preventing wrist arthritis.

Ligamentoplasties: Due poor results and decreased mobility of the aforementioned techniques, there is a trend to directly treat stage III lesions using scapholunate *ligamentoplasties*. These techniques will be described in the next section.

15.4.4 Stage IV: Complete, Irreparable SLIL Injury, Reducible Malalignment

In stage IV, there is a complete, irreparable SLIL lesion. Secondary stabilizers are stretched or disrupted. Plain radiographs show an increased SL gap in PA view and scaphoid flexion in lateral view. There is no cartilage damage. This stage is radiographically defined as static instability. The scaphoid will assume a flexed and pronated position and the lunate will be extended.

Three different treatment options have been described for this stage:

1. Reconstruction of the ruptured ligaments with tendon grafts:
   (a) Open reconstruction
   (b) Arthroscopic scapholunate ligamentoplasty
   (c) Arthroscopically assisted ligament reconstruction
2. Reduction-association of the SL joint (RASL) procedure

15.4.4.1 SLIL Ligamentoplasty Using a Tendon Graft

The "three-ligament tenodesis" uses the flexor carpi radialis (FCR) tendon to reconstruct the SLIL. The FCR is divided proximally, maintaining its insertion in the second metacarpal. A tunnel is made in the scaphoid from the insertion of the dorsal SLIL to the palmar tuberosity. The tendon strip is retrieved dorsally and fixed to the dorsum of the lunate using an anchor. The remainder of the tendon is pulled through the radiotriquetral ligament and sutured back in the lunate. K-wires are placed between the scaphoid and lunate and between the scaphoid and capitate to protect the reconstruction. Wrist immobilization is maintained for 6 weeks, and then a removable splint for additional 6 weeks. K-wires are removed at 8 weeks postoperatively. Garcia-Elias et al. published a series of 38 patients with an average follow-up of 46 months [36]. Pain relief at rest was obtained in 28 patients, 8 patients complained of mild discomfort during strenuous activity, and 2 had pain in most activities. Range of motion was 75% compared with the contralateral wrist and there was recurrence of malalignment in two wrists. Kakar et al. described a 360° reconstruction with tendon graft augmented with an internal brace [37]. The results in a cadaver study showed a significant superior biomechanical stability than tenodesis alone.

15.4.4.2 Arthroscopic Scapholunate Ligamentoplasty

Arthroscopic scapholunate ligamentoplasty combines the advantages of the arthroscopic and open techniques. Corella et al. described an arthroscopic ligamentoplasty that reconstructs the dorsal and volar SL ligament with a strip of the FCR [38]. To perform the technique, seven portals are used, and one more is needed to retrieve the FCR tendon: the four standard portals (3–4, 6R, MCR, and MCU), dorsal central (DC), volar central (VC), and radial distal (RD). A tunnel is created from the dorsal insertion of the SL ligament to the scaphoid tubercle. Another tunnel is drilled in the lunate parallel to the radiocarpal joint line. The tendon is retrieved through the scaphoid tunnel dorsally and then to the dorsum of the lunate intra-articularly. The tendon is then passed through the lunate tunnel volarly, passed extra-articularly to the scaphoid, and fixed to the scaphoid with an anchor. Interference screws are used to fix the tendon to the scaphoid and lunate. A removable splint is used for the first 6 weeks, and a dart-throwing motion is started at 2 weeks and progressive flexion-extension exercises at 4 weeks. At 6 weeks, progressive strength and proprioceptive exercises are started, and after 12 weeks, normal activity is resumed. They recently published the results in 46 patients showing a significant increase in grip strength and decrease in pain scales at 1 and 2 years postoperatively [39] (Fig. 15.11).

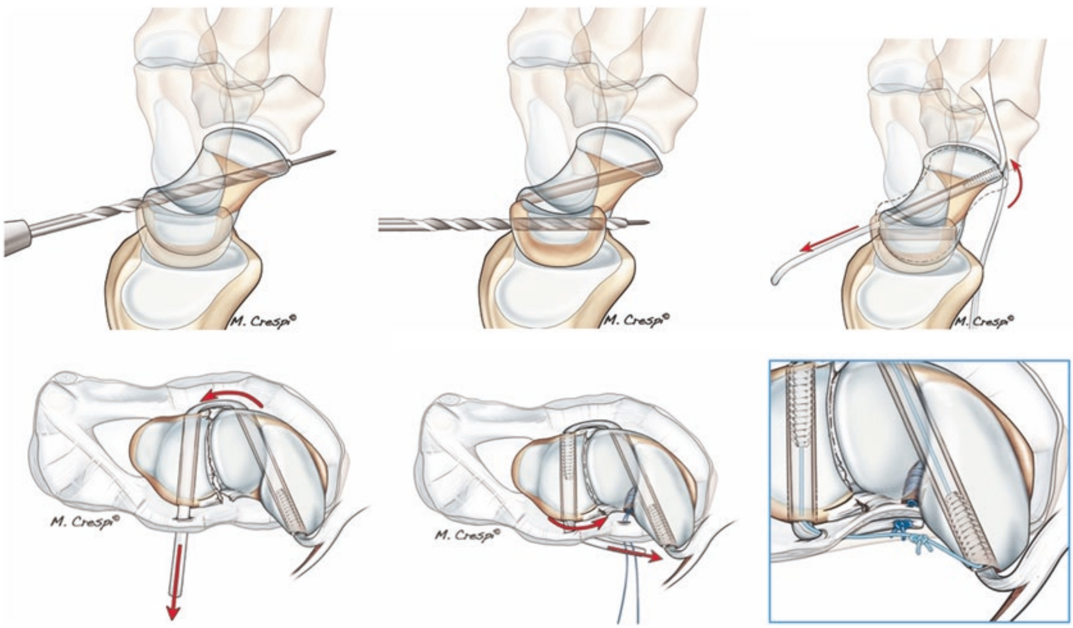

Fig. 15.11 Arthroscopic ligamentoplasty. Scaphoid tunnel is drilled from the dorsal insertion of the scapholunate ligament to the scaphoid tubercle. The second tunnel is drilled parallel to the joint surface of the lunate. A loop is passed from the dorsal to the 3–4 portal. Passage of the graft through the scaphoid tunnel and fixation using an interference screw. The graft is captured in the loop and recovered intra-articularly and dorsally on the lunate. The graft is passed through the lunate dorsal to volar and recovered through the volar central portal. The graft is fixed with a tenodesis screw. The graft is passed extra-articularly to the scaphoid and fixed with an anchor. Reprinted with permission from Corella F, Del Cerro M, Ocampos M, Simon de Blas C, Larrainzar-Garijo R. Arthroscopic scapholunate ligament reconstruction, volar and dorsal reconstruction. Hand Clin. 2017;33:687–707

15.4.4.3 Arthroscopically Assisted Ligament Reconstruction

Ho et al. described a combined limited open reconstruction with the assistance of arthroscopy [40]. They reconstructed the dorsal and volar portion of the SLIL using a palmaris longus tendon graft. The scaphocapitate joint was transfixed with Kirschner wires for 6–8 weeks after surgery. The authors published their results in 17 patients with a follow-up of 48.3 months. Eleven patients had no pain and 6 had some pain on maximum exertion or extreme motion. The mean grip was 120% of the preoperative status and motion improvement between 13% and 27%.

15.4.4.4 Reduction-Association of the SL Joint (RASL) Procedure

The reduction-association of the SL joint (RASL) procedure was initially described by White et al. [41]. They used a Herbert screw placed between the scaphoid and the lunate to develop a soft tissue nonunion that stabilized the bones. The results published with the RASL technique are controversial, and some authors endorse good results using this technique but there are cases describing hardware failure and recurrence of deformity [42].

15.4.5 Stage V: Chronic SL Injury with Irreducible Malalignment and Normal Joint Cartilage

In stage V, there is a chronic, irreparable SL lesion and a fixed malalignment. The cartilage is still preserved. Like stage IV, it is defined as a static instability. Treatment options are limited intercarpal arthrodesis. The goal of treatment is to reduce pain and preserve some range of motion at this stage [43].

15.4.5.1 Scapholunate Arthrodesis

Scapholunate arthrodesis has been attempted with little success, and published union rates are around 50%.

15.4.5.2 Scaphoid-Trapezium-Trapezoid Arthrodesis

Scaphoid-trapezium-trapezoid (STT) arthrodesis has a higher rate of union up to 86% (Stewart) with reduced range of motion and strength. There is a significant limited radial deviation and flexion of the scaphoid due to the arthrodesis. A radial styloidectomy has been described by some authors to increase mobility [44].

15.4.5.3 Radioscaphoid-Lunate Arthrodesis

Radioscaphoid-lunate fusion was developed to restore scaphoid position. Initially, wrist flexion was severely limited due to the scaphoid fixation. Garcia-Elias et al. described the excision of the distal pole of the scaphoid to allow more motion and decrease STT arthritis [45]. The midcarpal joint motion is preserved in the dart-thrower's plane when the distal pole is excised. Garcia-Elias et al. published, in 16 patients with an average follow-up of 37 months, complete pain relief in 10 patients, slight pain in 3 patients, and occasional pain in 3 patients. The average postoperative range of motion was 32° of flexion, 35° of extension, 14° of radial deviation, and 19° of ulnar deviation [45].

15.4.6 Stage VI: Chronic SL Injury with Irreducible Malalignment and Cartilage Damage

In stage VI, the ligament is irreparable, malalignment is not reducible, and the cartilage is damaged. Standard radiographs will show a static dissociation with osteoarthritis changes in the wrist. This stage corresponds to a scapholunate advance collapse (SLAC). SLAC wrist was divided in four stages as defined by Watson et al. [7].

1. Stage I is defined by limited osteoarthritis in the dorsum of the scaphoid fossa in the radius.
2. Stage II exhibits osteoarthritis and joint space narrowing in the whole scaphoid fossa in the radius.

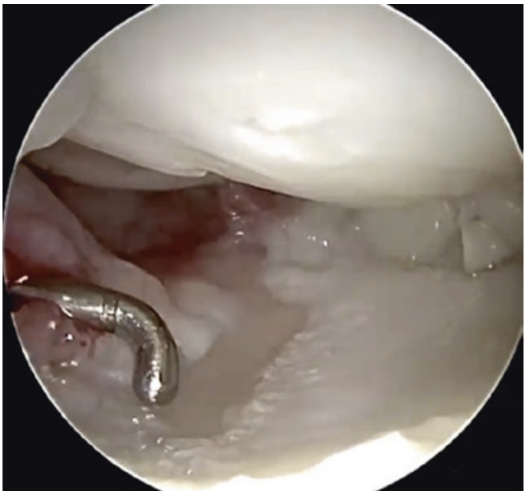

Fig. 15.12 Degenerative changes limited to the dorsum of the scaphoid fossa (scapholunate advanced collapse [SLAC] 1)

3. Stage III adds to stage 1 and 2 osteoarthritis between the lunate and capitate.
4. Stage IV is defined by the presence of osteoarthritis in the radiolunate fossa.

15.4.6.1 SLAC 1 Treatment

In stage I SLAC, the recommended treatment for symptomatic patients is a styloidectomy of the dorsum of the radioscaphoid fossa. It has been described as open or arthroscopically. In the arthroscopic technique, the 1 and 2 portals are commonly used to perform the styloidectomy [46] (Fig. 15.12).

15.4.6.2 SLAC 2 Treatment

Main options of treatment are a proximal row carpectomy (PRC) or the "four-corner arthrodesis."

PRC is performed by excising the scaphoid, lunate, and triquetrum bones. A new joint between the proximal pole of the capitate and the radius is created. Wall et al. published that in 16 patients, 35% required another surgery in a minimum follow-up of 20 years [47]. A 72% grip strength compared to contralateral wrist and an average flexion-extension arc of 68° was reported.

The four-corner arthrodesis (4CA) involves excision of the scaphoid and fusion of the capitate, hamate, lunate, and triquetrum. Arthrodesis could be performed open or arthroscopically using screws or specific plates. Traverso et al. followed 15 patients for an average of 18 years [48]. They reported a wrist flexion/extension arc of 68° and QuickDASH scores of 7.8 on average. Bain et al. reported significant pain relief and no reduction of grip strength in 31 patients at 1 and 10 years after surgery [49].

When comparing 4CA and PRC, there are no significant clinical differences between both techniques. In practice, although the decision is based on the etiology and extent of joint involvement, it is mostly influenced by the patient's functional demands and state of the wrist. PRC is contraindicated in stage III SLAC wrist due to the arthritic capitate that would become the focal point of wrist loading causing pain. PRC results are slightly better in terms of motion. Four-corner arthrodesis patients have higher grip strength with less mobility than PRC ones. Usually PRC is preferred in older patients who prefer mobility over strength and four-corner arthrodesis in younger patients who need a stronger wrist [50].

15.4.6.3 Stage III SLAC Treatment

Stage III SLAC wrist should not be treated by PRC. Four-corner arthrodesis is recommended.

15.4.6.4 Stage IV SLAC Treatment

Stage IV SLAC wrist has degenerative changes in the radiolunate joint. In cases of significant pain, a total wrist arthrodesis is frequently indicated. Published results show significant pain relief and functional grip strength [51]. Loss of wrist motion is well tolerated in selected patients. Wrist arthroplasty may be indicated in certain patients with SLAC IV wrist (Table 15.4).

Table 15.4 Scapholunate advanced collapse (SLAC) treatment

SLAC	Treatment
I	Dorsal styloidectomy
II	PRC or 4CA
III	4CA
IV	Total wrist arthrodesis

Table 15.5 Author-preferred treatment summary

Instability	Garcia-Elias	EWAS	Geissler	Treatment
Pre-dynamic	1	I, II, or IIIa	I or II	Synovectomy
Dynamic	2	IIIb or IIIc	III	Suture and capsular plicature
Dynamic	3	IV	IV	Ligamentoplasty
Static	4			Ligamentoplasty
Static	5	V		Limited arthrodesis
SLAC	6			Salvage procedure

15.5 Authors' Preferred Treatment

Wrist arthroscopy has improved the knowledge of SLIL lesions, allowing a precise diagnosis. In addition, it permits to repair carpal lesions without extensive approaches that may damage secondary stabilizers, blood vessels, and wrist proprioception. We systematically performed wrist arthroscopy in cases of suspected SL lesions.

Stage I: In cases of symptomatic partial lesions, we usually perform a synovectomy and limited debridement of the torn ligament.

Stage II: Cases of complete reparable disruption are treated by direct repair. Suture and dorsal capsule plicature are used as described by Carratala et al. or Mathoulin.

Stages III and IV: In cases of complete, irreparable rupture or reducible malalignment, we performed a ligamentoplasty as described by Corella et al.

Stage V: We usually recommend observation and perform a radiolunate-scaphoid partial arthrodesis in cases of intolerable pain.

Stage VI: In SLAC wrists, we do salvage procedures according to the stage of SLAC. In stage I arthroscopic dorsal styloidectomy, stage II arthroscopic proximal row carpectomy or four-corner fusion, stage III arthroscopic four-corner fusion, and stage IV total wrist arthrodesis (Table 15.5).

15.6 Conclusions

Injury to the scapholunate interosseous ligament (SLIL) is the most common cause of carpal instability and can cause important functional impairment to the patient. Initially, SLIL lesions are well tolerated due to the function of the secondary stabilizers. Nevertheless, chronic lesions may cause instability and osteoarthritis, as evidenced by clinical conditions such as dorsal intercalated segment instability (DISI) and scapholunate advanced collapse (SLAC).

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