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Introduction

Management of pathology involving the scapholunate ligament complex presents a number of unique challenges. These challenges are derived not only from difficulty in defining the temporal, structural, and biomechanical nature of such pathology, but also from the lack of uniformly good outcomes from a wide variety of existing surgical treatments.

Initially arthroscopy offered the capacity to directly visualize interosseous ligaments within the wrist and even a dynamic evaluation of some intercarpal relationships. A partial tear of the SLIL may be difficult to detect with imaging studies, but is identifiable arthroscopically. In addition arthroscopy allows the assessment of the status of articular cartilage, with greater accuracy than imaging techniques, for planning therapeutic intervention. It continues to remain the gold standard for diagnosis [1, 2]. Improvements in resolution and scanning protocols have seen improved diagnostic utility from Magnetic Resonance Imaging (MRI).

Nevertheless, the utility of wrist arthroscopy has been extended to facilitate treatment options for SL ligament pathology beyond diagnosis.

The indications for wrist arthroscopy continue to expand from Whipple's original description [3] as new techniques and instrumentation develop. Further advances in instrumentation, such as electrothermal shrinkage and pathology specific arthroscopic drill guides, will continue to play a role in the management of pathology of the SLIL.

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Anatomy

Improved understanding of the biomechanics of the carpus and their dynamic relationships has altered the conceptualization of the SL interface. We have moved from considering the SLL in isolation to considering it one component of the "SL ligament complex" (SLLC) that involves both intrinsic and extrinsic ligamentous components [4]. The intrinsic portion of the SLLC includes the palmar, central membranous, and dorsal portions. The dorsal portion appears to be the primary biomechanical functioning component of the interosseous ligament. It is composed of stout transverse fibers to resist rotation. The volar portion of the interosseous ligament is comprised of longer oblique fibers that allow for sagittal rotation. The central membranous portion of the ligament frequently demonstrates perforations, which increase in frequency with age [4, 5].

The extrinsic components include the volar radioscaphocapitate, long radiolunate, and short radiolunate ligaments on the volar aspect [6]. Further secondary stabilizers of the SL interval include the capsule of the scapho-trapezo-trapezoid (STT) joint and the dorsal intercarpal (DIC) ligament [7, 8].

Radiographic abnormalities may not be seen initially until attenuation or failure of the extrinsic stabilizers occurs. This may result in delayed detection of SL pathology on plain radiographs.

Pathomechanics/Mechanism of Injury

Injury is usually caused by a fall onto the outstretched wrist resulting in a dorsiflexion injury. Wrist extension and carpal supination are the primary mechanisms of injury to the SLL. Similar to other ligamentous injuries in the body, the interosseous ligament may stretch and eventually tear. The SL ligament may double in length prior to failure. Mayfield has shown the percent elongation to failure to be up to 225 % [9]. A spectrum of injury is seen to the SLL itself. An isolated injury to the SLL may not yield SL disassociation or widening

on plain radiographs. However, a combined injury to both the intrinsic and extrinsic ligaments will usually cause SL diastasis [10]. The difficulty is that there is a paucity of natural history studies that define the evolution of either acute or chronic SL pathology. Although some patients present with the typical history of a hyperextension injury to the wrist, other patients may not recall an acute injury in a fall, but rather a “popping” or giving way sensation on heavy lifting, or even no history of injury at all. Many patients who present with an established Scapholunate Advanced Collapse (SLAC) wrist do not recall any history of acute injury. It is clear that there is a complex interplay between acute traumatic disruptions, serial lesser injuries, and attenuation over time from subclinical events.

Assessment

History

A history of acute dorsiflexion injury should raise concern about injury to the SLLC. Patients may present with dorsal wrist pain and giving way or mechanical symptoms without a history of serious acute injury.

Examination

Physical examination reveals localized tenderness directly over the dorsum of the SL interval. The principle provocative maneuver to assess SL instability is the “scaphoid shift test” [7]. This test evaluates motion of the scaphoid during radial deviation and wrist flexion while pressure is applied to the tubercle of the scaphoid in a volar to dorsal direction. Partial tears to the SLL may produce pain directly over the dorsum of the SL interval with no palpable click. Pain over the scaphoid tubercle when palpated is not clinically significant. A complete tear of the SLL results in subluxation of the proximal pole of the scaphoid over the dorsal lip of the distal radius. When this occurs, a palpable shift or click is felt. Both the injured and noninjured wrist should be assessed with the scaphoid shift test to evaluate for inherent laxity, particularly in individuals with a classified generalized ligamentous laxity [11]. The radiocarpal joint may be injected with local anesthetic to evaluate for potential shift if pain prevents performance of the test.

Imaging

Plain Radiographs

Radiographs are essential at the initial evaluation to assess the SL articulation. It should be stressed from the outset that all radiographic views may only be definitely interpreted when compared with the opposite side. Standard radiographic

views include the postero-anterior view in ulnar deviation; an oblique, true lateral; and clenched-fist views.

In the PA view, three smooth radiographic arcs may be drawn to define normal carpal relationships [12]. A step off in the continuity of any of these arcs indicates an intercarpal instability at the site where the arc is broken. Any overlap between the carpal bones or any joint width exceeding 4 mm strongly suggests carpal ligamentous injury. A standardized clenched-fist view in 30° ulna deviation has been shown to yield the widest diastasis in ruptured SLL injuries [13].

A “Terry-Thomas” sign is considered present when the space between the scaphoid and lunate appears abnormally wide as compared to the opposite wrist [14]. The SL interval should be measured in the middle of the flat medial facet of the scaphoid. Less than 3 mm is considered normal, 3–5 mm is suspicious and any asymmetric SL gap greater than 5 mm is said to be diagnostic of SL dissociation [15]. The scaphoid ring sign occurs when the scaphoid has collapsed into flexion and has a foreshortened appearance on a PA radiograph. The ring sign is present in all causes of scaphoid flexion, regardless of the etiology [16]. Therefore, the presence of a scaphoid ring sign does not necessarily indicate instability of the SL interval.

In lateral radiographs, the SL angle is defined by a line tangential to the two proximal and distal convexities of the palmar aspect of the scaphoid. The angle formed by this line and a line through the central axis of the lunate determines the SL angle. Normal values range between 30° and 60°, with an average of 47°. Angles greater than 80° are strongly indicative of SL instability [16]. Assessment of the radiolunate and capitulunate angles may also give an assessment of the degree of intercalated segment instability.

On the lateral radiograph, concentricity between the arc of the proximal pole of the scaphoid and the scaphoid facet of the radius is usually seen. When there is carpal instability dorsal translation of the proximal pole is seen with loss of this concentric relationship. Subtle manifestation of this altered relationship may be identified on sagittal plane high-resolution MRI scanning before plain radiographic abnormality is identified.

Assessing the contralateral side radiographically for comparison is useful. In addition the sensitivity of plain radiographs may be increased by performing so-called “dynamic views.” There are a variety of views described. Although not truly dynamic these static stress views look at changes in carpal alignment with specific wrist positioning and with load from grip. Flexion and extension lateral views and radial/ulnar deviation PA views are most frequently suggested and a standardized clenched-fist pencil view in 30° ulna deviation has been shown to yield the widest diastasis in ruptured SLIL injuries [13, 17].

Fluoroscopy

True dynamic assessment of carpal motion and intercarpal relationships can be achieved with the use of fluoroscopy.

Ultrasound

Ultrasound has been used for assessment of SLL injury. It offers the possibility to assess the pathology dynamically in real time. The SLL and proximal pole of the scaphoid are identified and ultrasound is performed in the transverse and longitudinal planes. The wrist is scanned in ulna and radial deviation, the clenched-fist view, and resisted extension. Ultrasound scans can show osteophytes, a joint effusion, bulging of the SLL, and a degenerate capsule. The technique and the interpretation of the findings can be difficult especially due to the variations in anatomy and kinetics. Its main role is probably to complement clinical examination and other imaging studies. It has the potential to show subtle rotatory instability of the scaphoid [18].

Dao et al. in 2004 reported on the efficacy of ultrasound for evaluating dynamic SL ligament instability and compared it to Arthroscopy [18]. Of the 64 wrists analyzed, ultrasound had a low sensitivity of 46.2 %, a high specificity of 100 %, and an accuracy of 89.1 %. The authors recommended its use as an adjunct to other diagnostic modalities for this purpose [18].

Taljanovic et al. in 2008 described the use of ultrasound for assessment of SL ligaments and its correlation with MR and MRA. For the SL ligament, the results were concordant for all imaging modalities in 15, partially concordant in 3 (18.75 %), and discordant in 1 (6.25 %). The arthroscopic and imaging findings were concordant for three SL ligaments [19].

The preliminary results are encouraging. Sonography may be used at least as a screening imaging modality in evaluation of the SL ligament.

MRI

Patients who are suspected clinically of having a SLL injury, but whose radiographs are normal should undergo MRI scanning of the injured wrist with interpretation by an experienced radiologist. The SL ligament can be challenging to assess on MRI.

High-resolution MR imaging using 3.0 T magnetic strength is optimal for definitively demonstrating the three components of the SL ligament (dorsal, volar, and membranous components) and their integrity [20].

High-resolution MRI of the SL ligament is best performed on a 3 T magnet with a dedicated 8ch or 16ch wrist coil. It is also accepted that interpretation of the MRI should be completed by a radiologist with expertise in wrist imaging [20]. In the unit of two of the senior authors (MR, GC) high-resolution noncontrast MRI is performed on a Siemens 3 T Verio platform using the Invivo 8ch wrist coil. Patients are positioned with the arm above their head while lying prone in the scanner i.e. "Superman position" [20]. The reason for this is that this position is at the isocentre of the magnet providing the best Signal to Noise Ratio possible. Two mm slice



Fig. 10.1 Dorsal scaphoid translation and cartilage loss on proximal scaphoid on sagittal plane MRI

axial views are performed from the proximal radius and ulna to distal to the capitate. Direct coronal views of the wrist are obtained with the slice orientation parallel to the anterior border of the distal radius and ulna. Sagittal views are obtained with the slice orientation perpendicular to the wrist joint. Proton density scans with fat suppression are used. A T1 coronal sequence with 2 mm slices and a 3D axial gradient echo sequence with 0.5 mm slices are also performed.

High-resolution coronal, and axial images delineate whether the dorsal or volar fibers are intact. The intact dorsal band is well demonstrated on the most dorsal of the coronal plane slices that show scaphoid and lunate, with dark linear fibers being visible. Secondary signs of SLL rupture are seen with dorsal scaphoid translation in relation to the scaphoid facet of the radius and cartilage loss, which are best seen on the sagittal views (Fig. 10.1). Widening of the SL interval should not be an exclusive indication that the SLL has been ruptured, as it could still be intact, but redundant. Ganglia are often present with SLL tears, and visualization is best seen on T2 weighted scans with uniform fat suppression.

Computed Tomography

Recently Kakar described a novel imaging technique for 4D CT imaging (3D + time) which has promising clinical utility in accurately diagnosing SL instability [21]. 4D CT allows dynamic image data (4D movies) to be recorded whilst the

patient moves their wrist through various movements including radial-ulnar deviation, flexion-extension, and dart thrower's motion.

Classification of SLL Pathology

This table summarizes the various methods of classifying SL ligament pathology and identifies what level of pathology each type of assessment can ascertain (Table 10.1). Various systems for classifying SLL pathology have been described, both temporally and structurally.

Temporal Classification

There is no clear consensus on what constitutes acute, subacute, and chronic injuries. Whichever criteria are used, the principle aim is to define the potential for healing of the native ligament.

Larsen et al. classified *carpal instability* in a temporal way. Acute was defined as less than a week old, subacute was defined as between 1 and 6 weeks, and chronic was described as more than 6 weeks old [22].

Geissler and Haley defined an acute injury as up to 3–4 weeks old. Subacute was defined as an injury more than 3–4

weeks old and up to 6 months old. A chronic injury was defined as symptoms present greater than 6 months [23].

The current trend has been to consider injuries as “chronic” at an earlier time point due to the observed poorer outcomes in terms of radiographic maintenance of SL gap after direct ligament repair, at relatively early intervals after the apparent index injury.

This lack of consensus as to what constitutes an acute injury means that algorithms for management based on temporal classification remain inconsistent.

Clinical Examination Classification Systems

Clinically we can define four types of instability: (1) predynamic instability; (2) dynamic instability; (3) reducible static instability; (4) nonreducible instability [24]. Predynamic instability was initially termed by Kirk Watson [7] and applies to instability that may be observed clinically on physical examination but not by radiographic studies, and corresponds to a Geissler grade I or II instability [23]. Dynamic SL instability is applied to a complete SL ligament tear, but the secondary scaphoid stabilizers remain intact [25]. SL instability can be observed radiographically under loaded conditions or in specific wrist positions, “clenched fist” or loading the wrist in ulnar deviation. Static reducible SL dissociation occurs when the ligament tear is chronic and irreparable; the secondary stabilizers are insufficient and a DISI deformity results; carpal subluxation is reducible [24].

Table 10.1 Classification of SLL pathology

Classification type	Description		
Temporal	Acute		
	Subacute		
	Chronic		
Structural	Imaging	Radiographs	Static radiographs—complete static dissociation Dynamic radiographs/fluoroscopy—complete dynamic dissociation
		MRI	Incomplete and partial <ul style="list-style-type: none"> • Dorsal band • Membranous • Volar band Complete—dynamic or static
		Arthroscopic	Geissler classification
	Operative	Incomplete	
		Complete	Dynamic Static <ul style="list-style-type: none"> • Reducible • Irreducible

Structural Classification

A structural classification can be based on imaging studies, or arthroscopic or open operative evaluation. Imaging studies may be static X-ray films, stress/positional radiographs, fluoroscopy, ultrasound, or MRI.

Arthroscopic Structural Classification

The key to treatment of SL ligament complex pathology is recognition of what is normal and what is pathological anatomy. Both the radiocarpal and midcarpal spaces must be evaluated arthroscopically when carpal instability is suspected. Wrist arthroscopy is usually not considered complete if the midcarpal space has not been evaluated, particularly with a suspected diagnosis of carpal instability.

The SLL is best visualized with the arthroscope in the 3–4 portal. It should have a concave appearance as viewed from the radiocarpal space (Fig. 10.2). In the midcarpal space, the SL interval should be tight and congruent without any step-off (Fig. 10.3). This is in contrast to the lunotriquetral (LT)

interval, in which a 1-mm step off occasionally is seen which is considered normal and slight motion is seen between the lunate and triquetrum. When it tears, the SLIL hangs down



Fig. 10.2 Arthroscopic view of the normal concave appearance of the SLIL as seen from the 3-4 portal in the radiocarpal space

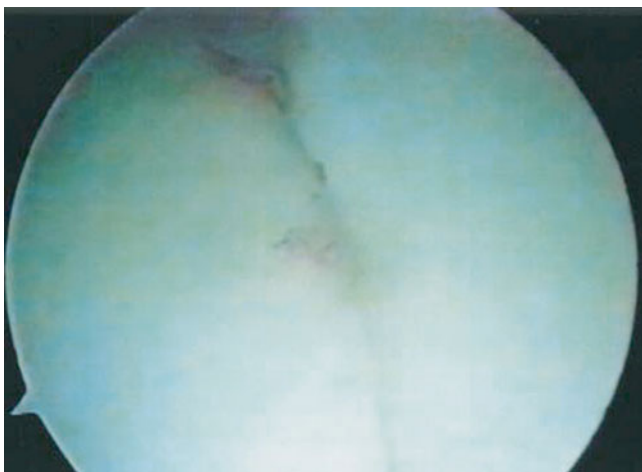


Fig. 10.3 Arthroscopic view of the normal, tight, congruent SL interval as seen from the midcarpal space

and blocks visualization with the arthroscope in the radiocarpal space from the 3-4 portal. The normal concave appearance between the carpal bones becomes convex. However, the degree of rotation of the carpal bones and any abnormal motion or separation is best appreciated from the unobstructed view available in the mid-carpal space.

A spectrum of injury to either the SL or LT interosseous ligament is possible. The interosseous ligament appears to attenuate and then tear from volar to dorsal. Geissler devised an arthroscopic classification of carpal instability and suggested management of acute lesions to the interosseous ligament (Table 10.2) [23, 25]. The management options as listed from this original article have evolved as the understanding of the compromise of ligament healing potential over time has changed.

In *Grade I* injuries, there is loss of the normal concave appearance of the scaphoid and lunate as the interosseous ligament bulges with the convex appearance (Fig. 10.4). Evaluation of the SL interval from the midcarpal space shows the SL interval still to be tight and congruent. These mild *Grade I* injuries usually resolve with simple immobilization.

In *Grade II* injuries, the interosseous ligament bulges similarly to grade I injuries as seen from the radiocarpal space. In the midcarpal space, the SL interval is no longer congruent. The scaphoid flexes and its dorsal lip is rotated distal to the lunate (Fig. 10.5). This can be better appreciated with the arthroscope placed in the ulnar midcarpal portal looking across the wrist to assess the wrist to assess the amount of flexion to the scaphoid. This is analogous to the dorsal translation of the proximal pole of the scaphoid that can be identified on sagittal plane MRI imaging (Fig. 10.1).

In *Grade III* injuries, the interosseous ligament starts to separate, and a gap is seen between the scaphoid and lunate from both the radiocarpal and midcarpal space. A 1 mm probe may be passed through the gap and twisted between the scaphoid and lunate from both the radiocarpal and midcarpal spaces (Fig. 10.6). Sometimes the gap between the scaphoid and lunate is not visible until the probe is used

Table 10.2 Geissler arthroscopic classification of carpal instability

Grade	Description	Management
I	Attenuation/hemorrhage of interosseous ligament as seen from the radiocarpal joint. No incongruency of carpal alignment in the midcarpal space	Immobilization
II	Attenuation/hemorrhage of interosseous ligament as seen from the radiocarpal joint. Incongruency/step-off as seen from the midcarpal space. A slight gap (less than width of probe) between carpals may be present	Arthroscopic reduction and pinning
III	Incongruency/step-off of carpal alignment is seen in both the radiocarpal and mid carpal space. The probe may be passed through gap between carpals	Arthroscopic/open reduction and pinning
IV	Incongruency/step-off of carpal alignment is seen in both the radiocarpal and mid carpal space. Gross instability with manipulation is noted. A 2.7 mm arthroscope may be passed through the gap between carpals	Open reduction and repair

Based on data from [25]

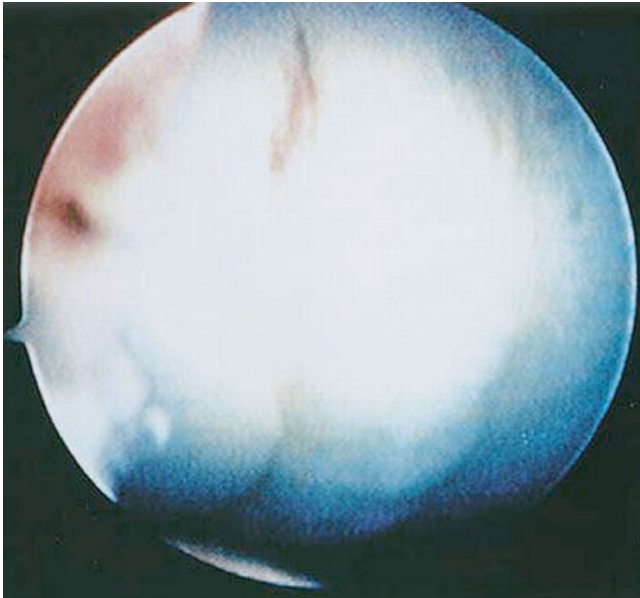


Fig. 10.4 Arthroscopic view of a Grade I interosseous ligament injury to the SLIL as seen from the 3-4 portal in the radiocarpal space. Note that the normal concave appearance at the SL interval has now become convex

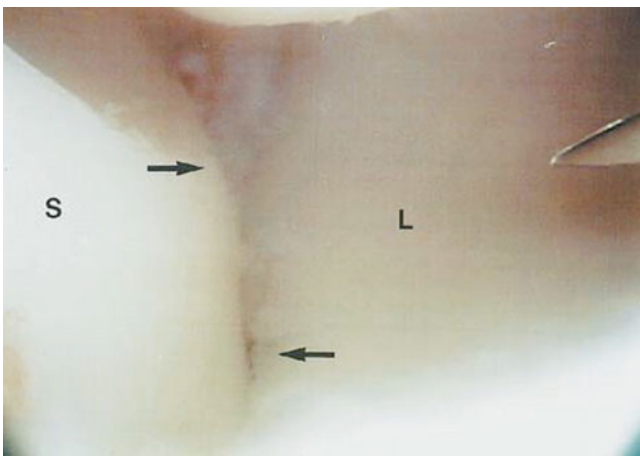


Fig. 10.5 Arthroscopic view of a Type II SLIL injury as seen from the radial midcarpal space. The dorsal lip of the scaphoid is no longer congruent with the lunate as it is palmar flexed. (S scaphoid, L lunate)

to push the scaphoid away from the lunate. A portion of the dorsal SLIL may still be attached.

In *Grade IV* injuries, the interosseous is completely torn, and a 2.7 mm arthroscope may be passed freely from the midcarpal space to the radiocarpal space between the scaphoid and lunate (the drive-through sign) (Fig. 10.7). This corresponds to the widened SL gap seen on plain radiographs with a complete SL dissociation.

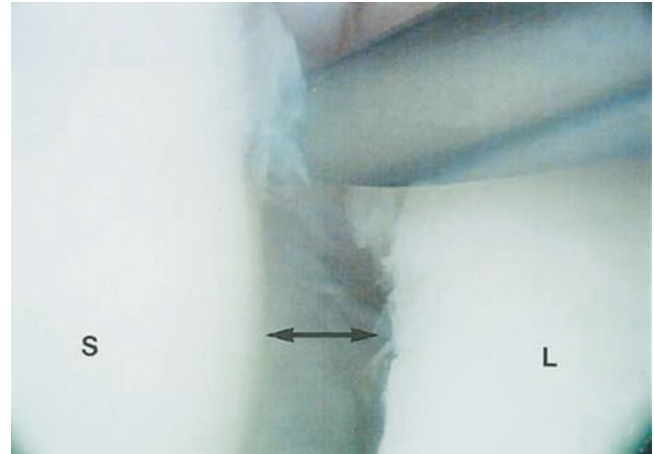


Fig. 10.6 Arthroscopic view of a Type III SLIL tear as seen from the radial midcarpal space. Note the gap between the scaphoid and lunate (S scaphoid, L lunate)

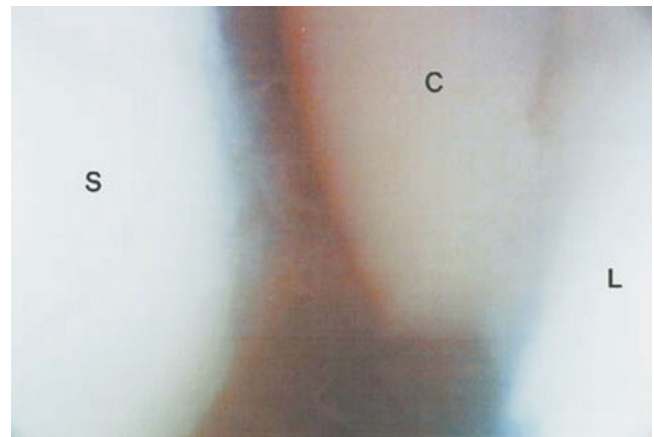


Fig. 10.7 Arthroscopic view of a Type IV SLIL tear. The scaphoid and lunate are completely separated, and the arthroscope may pass freely between the radiocarpal and midcarpal spaces. The capitate is seen between the SL intervals (S scaphoid, L lunate, C capitate)

Radiographic Structural Classification

Incomplete/Partial Rupture: Dorsal, Membranous, Volar Band

Partial rupture—usually only the palmar band of ligament is ruptured or occasionally only the dorsal segment is ruptured.

Static and dynamic radiographs are usually normal. Chronicity of the injury and partial healing may also be identified with high-resolution MRI scanning. Dorsal translation of the proximal pole relative to the facet of the radius may be identified on sagittal plane MRI images in spite of normal static plain radiographic alignment and may be an early

indicator of functionally more significant partial injury. Early chondral loss on the proximal pole may also be identified on MRI before plain radiographic abnormality.

Complete Rupture: Static vs. Dynamic

Static vs. Dynamic dissociation is best identified by comparing static vs. stress radiographs, or by fluoroscopy.

1. Complete rupture—dynamic—All components of SLIL are ruptured but the extrinsic ligaments/secondary stabilizers are usually intact. Static plain radiographs may be normal but there is disruption of normal relationships on stress radiographs.
2. Complete rupture—static—Complete SL ligament rupture and extrinsics also injured and static plain radiographs demonstrate widened SL interval on PA radiographs and increased SL angle on the lateral radiographs (modified by Watson) [26].

Static Reducible vs. Static Irreducible

This is determined intraoperatively. Static deformity is present on resting plain radiographs. It may be easily reducible during surgery to repair or reconstruct the SLIL. When deformity is not reducible intraoperatively salvage options should be utilized. This usually follows a temporal relationship with the more chronic ruptures leading to a static deformity, which may then become irreducible.

Treatment

Correct classification of the injury can assist in selection of appropriate treatment options. Nonetheless the greatest challenge is that there is no consensus on which surgical treatment option should be undertaken. Various options exist including pinning, repair, capsulodesis, and reconstruction and each have been applied to virtually all grades of injury. Moreover, surgical interventions can be either open or arthroscopic.

The authors have defined a unified classification system for treatment options of SL ligament complex pathology (Table 10.3).

Closed Pinning: Image Intensifier or Arthroscopically Guided

This surgery may be appropriate for acute lower grade injuries.

The wrist is evaluated arthroscopically for direct visualization of SLL injury and indirect evidence of disordered intercarpal mechanics. Arthroscopic assessment is achieved through the preferred means of arthroscopy and traction. The wrist may be suspended at approximately 10 lbs of traction

Table 10.3 Classification system for treatment options for SL pathology

Treatment options		
Closed pinning	Fluoroscopic guided	
	Arthroscopic guided	
Open repair and pinning		
Capsulodesis, capsulorrhaphy and partial repair	Arthroscopic—volar or dorsal	“Abrasion” capsulorrhaphy Shrinkage Suture
	Open	Dorsal—Blatt/reverse Blatt (often adjunct to open repair or reconstruction)
Reconstruction: defined as an attempt to re-establish a soft tissue relationship between scaphoid and lunate ± stabilisation through other soft tissue augmentation)	Local tissue	Dorsal intercarpal ligament
	RASL (arthroscopic or open)	
	Free tissue grafts—“Bone–Tissue–Bone”	Bone–Retinaculum–Bone Hand/wrist graft options Foot/tarsal graft options Other tissue
	Tendon grafts	Brunelli Three ligament tenodesis Scapholunate axis method Scapho-luno-triquetral tenodesis
Salvage	PRC [59]	
	Partial fusion (arthroscopic or open)	Four-corner fusion ±e/o scaphoid Radio-scapho-lunate fusion Capitolunate fusion STT fusion
	Total wrist fusion	

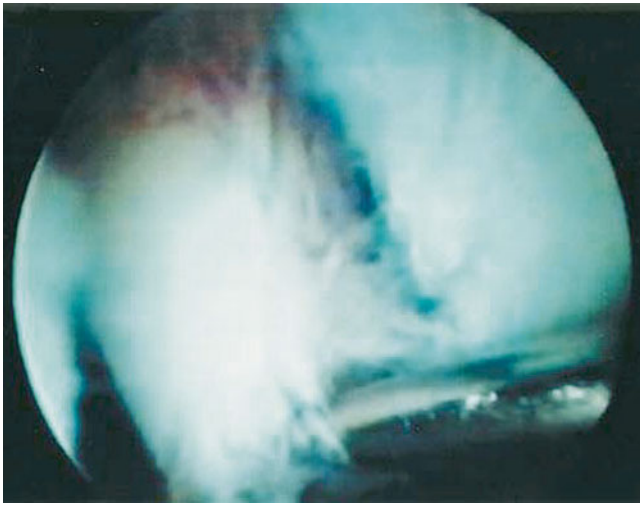


Fig. 10.8 Arthroscopic view of a Type II SLIL tear as seen from the 3-4 portal in the radiocarpal space. A probe is used to palpate the interosseous ligament and the separation which was not initially noted, is identified

in a traction tower [27, 28]. Alternately traction may be applied with the forearm horizontal using a variety of traction devices [28, 29]. The 3-4 portal is the most ideal viewing portal for visualization of the SLL. A working 4-5 or 6-R portal is also used. The wrist is systematically evaluated from radial to ulnar. The SL interval is probed. The degree of injury may not be fully appreciated until the tear is palpated with a probe (Fig. 10.8). Torn fibers of the SLL, if present, are then debrided with the arthroscope in the 6-R portal, and a shaver inserted into the 3-4 portal. A probe is inserted into the SL interval to note particularly any gap between the scaphoid and lunate. Following arthroscopic debridement of a torn SLL from the radiocarpal space, the midcarpal space is then evaluated. The arthroscope is initially placed in the radial midcarpal space. Close attention is paid to any rotational displacement of the scaphoid with the dorsal lip being rotated distal to that of the lunate. This may be best visualized with the arthroscope placed in the ulnar midcarpal portal. Also, any gap where the probe or arthroscope itself can be passed between the scaphoid and lunate is identified. If this is achieved easily then there are serious doubts as to whether closed pinning is appropriate [28].

Patients with a Grade II lesion may be most ideally suited for arthroscopic-assisted reduction and pinning although efficacy of this treatment must be interpreted in the context of the interval since injury, which will affect the healing potential. Alternate treatment options with arthroscopic capsular abrasion or shrinkage have also been advocated for Grade II pathology particularly in more chronic injury and will be discussed later. Use of closed pinning for Grade III injuries is difficult to justify based on current literature.

For arthroscopic pinning the arthroscope is placed in the 3-4 portal after the midcarpal space has been evaluated in patients who have an acute or perhaps subacute Grade II SLIL injury. A 0.045 Kirschner wire (k-wire) is inserted through a soft tissue protector or through a 14-G needle placed dorsally in the anatomic snuff-box to the scaphoid. A soft tissue protector may be used in order to avoid injury to the sensory branches of the radial nerve. A small incision is made, and blunt dissection is continued down with a hemostat; a soft tissue protector may be placed directly on the scaphoid.

The k-wire can then be seen as it enters the scaphoid with the surgeon looking down the radial gutter with the arthroscope. In an easier alternative technique, the wrist is taken out of traction and the k-wires can be positioned under fluoroscopic control. If there is concern regarding the reduction then placing the arthroscope in the ulnar mid-carpal portal during stabilization allows the surgeon to look across the wrist to better judge the rotation of the scaphoid in relation to the lunate.

Additionally, a probe may be inserted through the radial midcarpal space to control the palmar flexion of the scaphoid. The wrist may be extended and ulnar deviated to help further reduce the palmar flexion of the scaphoid. After the first wire is placed controlling the reduction, an additional wire may be placed in the SL interval. Placement of wires between scaphoid and capitate remains controversial. A scapho-capitate wire gives excellent control of scaphoid rotation but some authors have questioned the advisability of violating the uninjured scapho-capitate articulation. In addition, immobilization of the midcarpal joint through scapho-capitate wires may be considered undesirable in the context of renewed interest in the “Dart throwing” plane of motion.

The k-wires are best buried under the skin as this avoids secondary infection and need for premature removal. The wrist is immobilized in a below elbow thermoplastic splint. Gentle inner range radiocarpal flexion-extension range of motion exercise is usually possible, as restricted by the wires. The k-wires are then removed in theater after 6–8 weeks. Grip strength exercises for the wrist are initiated at 3 months.

Treatment for patients with Grade III and Grade IV injuries to the SLL, either acute, subacute, or chronic remains unclear. Results of closed treatment for higher-grade injuries have largely been unsatisfactory [30] and the dichotomy between repair and reconstruction has remained difficult to clarify. There has undoubtedly been a trend toward earlier adoption of reconstruction for higher-grade injuries.

Whipple reviewed the results of arthroscopic management of SL instability, utilizing the previously described techniques in patients who were followed for 1–3 years [31]. In his series, patients were classified into two distinct groups of 40 patients each, according to the duration of symptoms and the radiographic SL gap. Thirty-three patients (83 %)

who had a history of instability for 3 months or less and had less than 3 mm side-to-side difference in the SL gap had maintenance of the reduction and symptomatic relief. When symptoms were present for greater than 3 months and there was more than a 3 mm side-to-side SL gap only 21 patients (53 %) had symptomatic relief following arthroscopic reduction and pinning. Patients with less than 3 months symptoms duration and 3 mm side-to-side SL gap were followed for 2–7 years. Whipple found that 85 % continued to maintain their stability and comfort in his series. This report emphasized the need for early diagnosis and intervention prior to the onset of fixed carpal alignment and diminished capacity for ligamentous healing.

Open Repair and Pinning

Patients with acute Grade III and Grade IV injuries to the SLIL are best treated with open repair or reconstruction. The efficacy of direct repair remains controversial; however, there is little doubt that the trend is toward earlier adoption of reconstructive techniques rather than direct repair due to the strong impression that complete ruptures lose the capacity for primary healing very soon after injury. The critical interval has not been defined and indeed it may be that once a complete rupture of the SLIL has occurred the potential for healing may be compromised. Furthermore the tear morphology may influence the healing potential. When the ligament is avulsed from either the scaphoid or lunate, it may have a greater capacity to heal than a midsubstance rupture. Prior to arthrotomy, the wrist is evaluated arthroscopically for any additional injuries, including potential cartilaginous loose bodies, triangular fibrocartilage complex tears, and possible injury to the LT interosseous ligament. Open repair is undertaken through a dorsal 3–4 extensor compartment approach. A Berger ligament sparing arthrotomy [32] is preferred by the authors. It is essential that an intraoperative assessment is made as to the healing potential of the residual ligament and alternate reconstructive or salvage procedures undertaken if the residual ligament is of poor quality or there is concern regarding the cartilage surfaces of the carpus and radius.

Capsulodesis, Capsuloraphy, and Partial Repair

Restraint of scaphoid flexion has long been identified as a desirable intervention in the treatment of SL pathology [33–35]. The dorsal subluxation of the proximal scaphoid and loss of congruence of the distal pole in relation to the radial styloid have long been considered the principal initial biomechanical abnormalities requiring intervention. Procedures that restrict scaphoid flexion have been advocated as an alternative

to repair or reconstruction. There is no consensus as to when such alternate stabilizing procedures should be undertaken in preference to repair or other reconstructive options.

Arthroscopic Techniques for Capsulodesis, Capsuloraphy, and Partial Repair

Abrasion Capsulodesis

Although not previously reported in the literature, a new surgical technique receiving attention is abrasion capsulodesis. Although alternative arthroscopic capsular tightening has been reported with thermal shrinkage there are some concerns given the adverse experience of thermal techniques in the shoulder. Although there have not been reports of similar problems in the wrist, abrasion of the dorsoradial capsule has been considered as a safer alternative. In lower grade injuries this may improve stability by inciting a scar reaction with an increase in the extrinsic restraint to scaphoid flexion. The dorsal radial capsule is abraided with a chondrotome blade to stimulate a scar reaction. Consideration may be given to temporary k-wire pinning (either SL or scapho-capitate) to prevent scaphoid flexion, and flexion is usually restricted for 4–6 weeks with a thermoplastic splint. This technique is currently being studied in a prospective cohort by Ross and colleagues in Brisbane.

Arthroscopic Dorsal Capsular Thermal Shrinkage

Thermal capsular shrinkage using a thermal probe has been suggested in the treatment of Grade 2 injuries [36]. Although this technique demonstrated a number of unsatisfactory results in treatment of anterior shoulder instability, it has been argued that the wrist capsule behaves differently and that it is easier to immobilize the wrist and allow adequate healing.

In Geissler grade 1 and 2 SL instability, Danoff et al. in a small series have used arthroscopic thermal capsular shrinkage [37]. Using the fact that collagen shrinks with heat, nonablative thermal energy was also applied to the palmar SLIL in predynamic instability to effectively tighten up the ligament. Seven of eight patients had improved pain and preserved mobility, one patient failed this treatment and progressed to fusion.

Darlis et al. performed arthroscopic debridement and capsular shrinkage on 16 patients with 14 reported good to excellent results (8 of those pain free) and 2 failures [38]. Similarly, Hirsh et al. reported on a cohort of ten patients with 90 % pain free at an average follow-up of 28 months [39]. In contrast, Geissler reported on his findings in the management of 19 patients with chronic partial tears of the SLL (Geissler Grade II or III) or LT tears [36]. He reported variable results from poor to excellent using the Mayo wrist score at 6–22 months post-operation. Grade II tears appeared to have better results than Grade III injuries. However, as these are preliminary studies with small samples, no firm conclusions can be drawn.

Arthroscopic Suture Capsulorrhaphy, Capsulodesis, or Partial Repair

In the circumstance where complex open reconstruction is considered undesirable then arthroscopic reconstruction of chronic tears may be considered.

Mathoulin et al. describe an arthroscopic dorsal capsule-ligamentous repair for chronic reducible SL ligament tears [40, 41]. The technique involves passing a 3/0 PDS suture through a needle visualized arthroscopically and passed into the remnants of ligament and capsule between the scaphoid and lunate at the distal capsular reflection of the SLL and then tied to form a capsuloplasty. In his series of 36 patients with a mean 13-month follow-up, the results of the technique were generally excellent. The main advantage of the technique appeared to be the reduction in postoperative stiffness related to minimizing the dorsal capsular dissection needed during conventional surgical exposure with open techniques and hence the minimizing of scar tissue. Patient's pain scores were generally excellent, they regained 96 % grip strength compared to the contralateral side and seven of the sports persons were able to return to the same level of sport postoperatively.

Del Pinal et al. [42] describe an all inside technique for arthroscopic suturing of the volar SL ligament. This technique used sutures introduced volarly via a Tuohy needle to plicate the volar ligament remnants and the long radiolunate ligament. Although this appears a favorable procedure, the technique had been applied to four patients with minimal follow-up reported, hence no meaningful conclusions for this technique can be made.

Recently, van Kampen and Moran reported on a new technique of a volar capsulodesis used to reconstruct the volar SLL using a portion of the long radiolunate ligament [43]. Although only results from a preliminary cadaveric study are published, they found that this approach allowed a strong repair with no compromise to the vascularity of the scaphoid or lunate.

Open Capsulodesis

Blatt's original description [33] in 1987 used a dorsal radial flap of wrist capsule to differentially restrict scaphoid flexion. He left the flap of capsule attached to the radius and advanced it dorsally on the scaphoid. In his original series of 12 patients of late rotatory subluxation, he reported excellent recovery of range of movement, average grip strength recovered to 80 % and the majority returning to the preinjury work. Later Muermans and colleagues reported on 17 cases (11 cases of preradiographic instability; 3 dynamic; 3 static) with an average age of 30 years [44]. Patients had previously undergone conservative management and were on average 23 months post injury at the time of surgery. On blinded examination, they reported ten patients with excellent to good outcomes (pain and ADL) and six had fair to poor

results. Sixteen patients had a negative Watson test. However, X-rays failed to reveal any significant improvement in SL gap or angle.

The reverse Blatt procedure leaves the capsule attached to the scaphoid and advances it proximally on the dorsal radius. It has been employed as an adjunct to various other open repairs and reconstructions [32]. Megerle et al. followed up 59 patients for an average of 8 years following dorsal capsulodesis [45]. A Berger flap was performed and a slip of the proximal aspect of the dorsal intercarpal ligament left attached distally onto the scaphoid and either sutured to the lunate (36 untethered cases) or distal radius (16 tethered cases) periosteum or attached with an anchor. K-wires were used to transfix the reduced SL interval while the capsulodesis healed. The k-wires were removed at 12 weeks. Carpal reduction was not maintained over time and 78 % went on to have radiographic evidence of Arthritis and an average SL angle of 70°.

Reconstruction

We have defined this as an attempt to reestablish a soft tissue connection between scaphoid and lunate that may be augmented by other secondary stabilizing soft tissues to provide additional stability.

The various techniques described use local tissue or tendons as grafts, such as flexor carpi radialis (FCR), the majority of which are still left attached to the wrist distally, and others use autologous free tissue grafts as a bone-tissue-bone construct.

Local Tissue: Dorsal Intercarpal Ligament

Dobyns et al. [13] described the early technique for reconstruction in 1974. The Mayo capsulodesis in 1982 [2] used half of the dorsal intercarpal ligament left attached to the distal pole of the scaphoid but detached from its ulna side and reattached to the dorsal lunate with suture anchors and to the dorsal radiocarpal ligament. Moran and colleagues reported on an update of results of 14 patients who had a Mayo capsulodesis, and compared these to 15 patients who had a modified Brunelli tenodesis procedure [46]. They reported similar wrist range of movement (63 % and 64 % of the unaffected side, respectively) and grip strength (91 % and 87 % of the unaffected side, respectively) in both groups. No failures were reported in the capsulodesis group.

More recently, Gajendra et al. reported on the long-term outcomes of dorsal intercarpal ligament capsulodesis (DILC) for chronic SL dissociation [47]. The DILC was followed up in 16 patients for on average 84 months and despite a 58 % satisfaction rate thus far, radiographic signs of arthrosis was present in 50 %. Despite this it is still advocated by the authors for the treatment of reducible static SL dissociation.

Local Tissue: RASL

This technique is difficult to classify and may be considered a variation on repair. Nevertheless we consider it more analogous to a reconstruction, particularly where the cartilage between the scaphoid and lunate is removed to encourage fibrous tissue growth between the two surfaces. The "Reduction and Association of the Scaphoid and Lunate" (RASL) procedure reported by Rosenwasser et al. involves open reduction of the SL diastasis and holding the reduction with a headless compression screw [48]. Thirty-two patients with an average follow-up of 6.2 years results have now been reported. Range of motion was maintained at 80 % of the unaffected side and grip strength at 90 %. Radiographic reduction parameters were well maintained at follow-up with two failures resulting in SL advanced collapse and salvage.

The RASL procedure has also been described as an arthroscopic technique and a modified articulated screw (SLIC screw) has been proposed by Geissler to decrease problems with screw breakage.

Free Tissue Grafts: Bone–Tissue–Bone

These techniques harvest ligament or ligament like tissue as free grafts with their bony origins from sacrificeable locations elsewhere in the body

Bone–Retinaculum–Bone

Weiss et al. described the bone-retinaculum-bone autograft technique of reconstruction in 1997 [49]. The graft was harvested from Listers tubercle between second and third compartments and the overlying retinacular tissue, and the bone plugs were inserted into the scaphoid and lunate. This technique was initially advocated in dynamic instability but not in static cases.

The long-term follow-up at an average of 11.9 years has now been reported [49–51].

Clinical and radiographic outcomes deteriorated moderately from the initial report. There were three failures, resulting in one proximal row carpectomy and two total wrist arthrodeses. Findings at repeat surgery in the failed group included an intact graft without any apparent abnormalities, a partially ruptured graft (after a subsequent reinjury), and a completely resorbed graft.

This bone–retinaculum–bone reconstruction may be a viable treatment option for dynamic SL instability in which the scaphoid and lunate can be reduced. Results may deteriorate but are similar to those reported previously from other techniques. Problems with graft strength or stiffness may necessitate further surgery.

Bone–Tissue–Bone: Hand/Wrist Options

Harvey and Hanel [52, 53] tested the SL ligament in cadavers against bone tissue bone grafts taken from cadaveric second metacarpal–trapezoid ligaments, third metacarpal–capitate ligaments, and the dorsal retinaculum. The third metacarpal–

carpal bone–tissue–bone technique in a clinical series was published in 2002 [54]. Although used in chronic SL ligament injuries, with numbers of cases not included in the report, the results were documented to be best when there was a shorter period between injury and reconstruction and when there was a dynamic deformity with a radiolunate angle no more than 30°. The complications were related to bone fragmentation at the screw site acutely or at a later date secondary to trauma.

Harvey et al. later described lack of healing with graft pullout and graft stretching as complications from his non vascularized bone–tissue–bone reconstructions and developed the third metacarpal–carpal vascularized pedical graft from the radial sided intermetacarpal artery to address these short-comings [55].

Capitohamate autografts have been advocated by Ritt and colleagues in 1996 [56].

Bone–Tissue–Bone: Tarsal options

Svoboda et al. [57] in 1995 tested bone-ligament-bone grafts from cadavers as potential ligament complex grafts to reconstruct the SL ligament using the dorsal ligament of the fourth and fifth metatarsals, a dorsal tarso-metatarsal ligament graft and a dorsal calcaneo-cuboid graft. The tarso-metatarsal ligament graft produced in vitro results closest to the SL ligament.

Davis et al. in 1998 described a bone-ligament-bone graft harvested and biomechanically tested from the cadaveric foot [58]. They used the dorso-medial portion of the navicular-first cunieform ligament.

Free Tissue Grafts: Tendon

Four Bone Technique

Almquist et al. described a four bone technique of SL ligament reconstruction in 1991 using a graft harvested from extensor carpi radialis brevis [59]. The ECRB tendon remained attached distally. Tunnels in the capitate, scaphoid, lunate, and distal radius allowed passage of the tendon graft from its attachment distally to its reattachment proximally on the radius. The graft is passed first from dorsal to volar through the capitate tunnel. It is then passed through the scaphoid tunnel from volar to dorsal. In this way it allows tendon graft to pass between the dorsal scaphoid and dorsal lunate before passing through the lunate tunnel exiting on the volar aspect of the lunate. Finally the graft passes from here onto the volar aspect of the distal radius or through a tunnel into the volar distal radius to be tensioned and finally anchored in the tunnel or to suture anchors. The SL interval is also stabilized with a wire loop.

The results of this technique have been published for the first 36 patients with an average age of 34 years at an average of 4.8years follow-up. Average flexion was 37 degrees and average extension is 52 degrees. Grip strength remained on average 73 % of the contralateral side. A return to preinjury levels was noted in 86 % with no evidence of advancing arthritic changes on X-ray.

Brunelli Technique

In 1995, Brunelli and Brunelli described a technique using local tissue for a tenodesis effect with a partial FCR tendon graft [34, 60]. It was left attached distally and passed through a tunnel in the scaphoid from volar to dorsal and then sutured to the dorsal capsule of the radius. This aims to address the rotary subluxation of the scaphoid with scaphoid flexion and proximal pole subluxation dorsally. Although this does not attempt to anatomically reconstruct the SL ligament, we mention it in the reconstructive tendon graft section because it introduced the concept of harvesting a portion of the FCR left attached distally and passing the tendon volar to the STT joint and through to the dorsal aspect of the wrist via a transosseous tunnel in the scaphoid. This has formed the basis of many of the subsequent successful techniques for reconstruction.

Three Ligament Tenodesis

The “modification” of the Brunelli technique popularized by Garcia-Elias and Stanley in 2006 as the three ligament tenodesis (3LT) eliminates the tether to the radius [61]. It reinforces the volar capsule of the STT joint to add restraint to scaphoid flexion, in keeping with the Brunelli technique, while reconstructing the dorsal band of the SL ligament and reinforcing the dorsal intercarpal ligament. They published a series of 38 patients with an average age of 31 years with symptomatic SL dissociation (21 wrists stage 3; 8 stage 4; 9 stage 5). The majority had dynamic instability (79 %). At an average follow-up of 46 months (7–98 months) satisfactory pain relief was achieved in 28 patients. 29 resumed normal preinjury work. Acceptable range of movement was achieved (Mean Flexion 51°; mean extension 52°). Average grip strength was 65 % of contralateral side. Progression of carpal collapse was noted in two wrists.

Nienstedt published his 10 year results with a small series using a modified Brunelli procedure using a strip of FCR tendon as a ligament substitute for static SL instability [62], based on the technique originally described by Van Den Abbeele and colleagues [63]. The FCR tendon was passed through the scaphoid tunnel and fixed to the dorsal lunate with an anchor. The mean follow-up was 13.8 years in a cohort of 8 patients. The reduction of the SL gap from 5.1 mm preoperatively and obtained intraoperatively to 2.4 mm was maintained to 2.8 mm long term. Average DASH score was 9, and six out of eight patients were pain free. One case had occasional slight pain and the other had chronic pain. With small numbers valid conclusions are difficult but the follow-up interval is significant and maintaining radiographic parameters with only one case developing arthritis might suggest a successful procedure.

Scapholunate Axis Method (SLAM)

In 2012 Lee et al. described the SL axis method (SLAM), which involves drilling a tunnel between the scaphoid and lunate and anchoring a free tendon graft in the lunate with an

intraosseous bullet anchor and in the scaphoid with an interference screw [64]. This was compared to the modified Brunelli and Blatt capsulodesis in 12 cadavers and in this experimental data was deemed a more anatomical and less restrictive reconstruction.

Cable Augmented Quad Ligament Tenodesis

Bain et al. in 2013 described a small series using tensionable suture anchors and an FCR tendon graft combination [65]. The technique was adapted from the modified Brunelli and has the theoretical advantage of maintaining SL reduction with a cable during the healing phase. Initial clinical results were promising but longer-term follow-up is needed.

Scapho-Luno-Triquetral Tenodesis (SLT)

The open reconstruction technique favored by Ross, Couzens, and colleagues has been developed for the treatment of dynamic or intraoperatively reducible static SL instability where other forms of SL reconstruction may previously have been considered [66]. It may also offer an augmentation for acute and semi-acute repairs of the SL ligament. It has also been successfully used in acute reconstruction/repair following perilunate dislocations where both the SL ligament and LT ligaments are damaged. Since development of this technique in 2009, Ross and colleagues have performed this operation on over 60 patients with grade three or four SL ligament injuries [66]. They have reported preliminary results on the first 11 consecutive patients who received this technique and were prospectively reviewed over a 12–24 month period [66]. At an average follow-up of 14 months (12–24 months) post operation they reported good early radiological and clinical outcomes. When comparing preoperative clinical results with their most recent follow-up, the cohort demonstrated pain relief with normal activities, improved Patient Rated Wrist Evaluation, QuickDASH, range of movement and grip strength scores. Radiological outcomes (SL angle and SL gap) were improved.

The technique involves passage of a distally based partial FCR graft across the volar STT joint and through a scaphoid tunnel. The graft exits the scaphoid between the scaphoid and lunate and is then passed through a second tunnel in the lunate and triquetrum (Fig. 10.9). It is tensioned and anchored with an interference screw in the ulnar aspect of the triquetrum then passed back across the midcarpal joint to reinforce the dorsal intercarpal ligament. It can also be used to augment acute and semi-acute repairs of the SL ligament. By reconstructing the SL ligament and LT ligaments it is also suitable for treatment of perilunate dislocations. This technique may be suitable for adaption to arthroscopic, or arthroscopic-assisted techniques, particularly with the development of procedure-specific targeting jigs and instruments. The authors are undertaking this development currently.

This technique is contraindicated in SL Advanced Collapse (SLAC) or irreducible static instability intraopera-

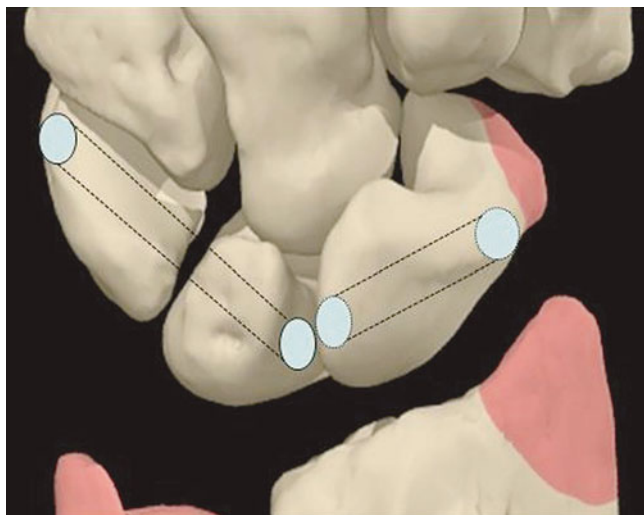


Fig. 10.9 Scapho-luno-triquetral tenodesis transosseous tunnel placement

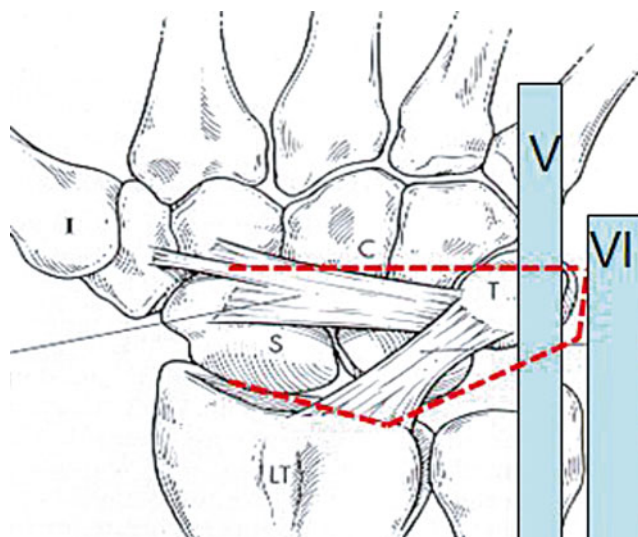


Fig. 10.10 Modified Berger flap exposure for the Scapho-luno-triquetral tenodesis technique

tively. The authors believe that this technique combines a large number of desirable features from previous procedures and addresses many of the potential facets of SL pathology to achieve a stable reconstruction of carpal stability. The features include:

1. In keeping with the initial intent of Brunelli's original description [60] the procedure provides a volar restraint to flexion of the distal pole of the scaphoid, and a reinforcement of the volar capsule of the STT joint.
2. There is no tethering of the dorsal carpus to the scaphoid. Therefore, there is no absolute restraint to radio carpal flexion.
3. The tunnels are positioned at, or close to, the isometric point of rotation between the scaphoid and the lunate. As a consequence, the potential for the normal sagittal plane rotation between the scaphoid and the lunate is not restricted. In addition, as the graft is tensioned, there is uniform apposition of the scaphoid and the lunate facets. This avoids excessive tensioning dorsally, with consequent opening on the volar aspect, or vice versa, as may occur with volar or dorsal reconstruction or capsulodesis techniques.
4. As the graft is tensioned, there is automatic reduction of the major aspects of pathology, including the rotary dorsal subluxation of the proximal scaphoid, and closure of the gap between the scaphoid and the lunate.
5. The transosseous passage of the graft avoids soft tissue bulk or formation of dorsal scar tissue, as occurs when a tendon graft is passed dorsally in the region of the dorsal band of the SL ligament, and anchored to the lunate dorsally.
6. The central positioning of the graft between the scaphoid and lunate does not compromise the possibility of repairing any residual native SLIL that may remain.

7. The triquetrum is ideally suited for anchoring of a tendon using an interference screw, and this anchoring in the triquetrum avoids excessive instrumentation or anchor placement in the lunate or scaphoid.
8. Passage of the graft across the LT interval allows additional stabilization of the LT interval. Many of these injuries are part of a spectrum of peri-lunate injury, and as a consequence, there may be subtle recognised or unrecognized pathology affecting the LT ligament. As a consequence, this reconstruction is particularly suitable for reconstruction of complete peri-lunate injuries.
9. The secondary passage of the tendon graft across the dorsal aspect of the mid carpal joint back to the scaphoid reinforces and reconstructs the dorsal intercarpal ligament, which may also be secondarily involved in these patterns of injury. This secondary reconstruction also provides an additional reinforcement to the relationships of the proximal row of the carpus in the coronal plane.

Scapho-Luno-Triquetral Tenodesis (SLT):

Surgical Technique

Exposure

A standard mid-line approach over the central dorsal aspect of the wrist is utilized.

A ligament sparing Berger capsular flap [44] is developed further to the ulnar side than is usual, to gain access to the ulnar border of the triquetrum immediately radial to the ECU subsheath, which is not opened (Fig. 10.10). In addition to the usual elevation of the third and fourth compartments, division of the septum between fourth and fifth compartment and elevation of the extensor digiti minimi tendon is required (Fig. 10.11).

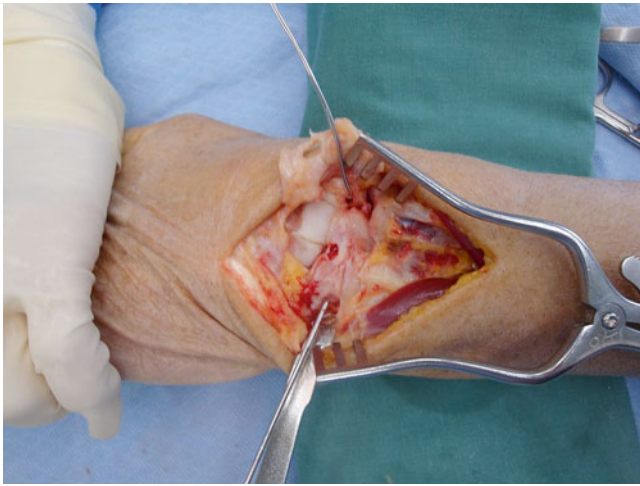


Fig. 10.11 Exposure for scapho-luno-triquetral tenodesis

Exposure of the ulnar aspect of the triquetrum, drilling the LT tunnel, and graft tensioning can be facilitated by placing a small Hohmann retractor in the vicinity of piso-triquetral joint. If there is a peri-lunate dissociation, the lunate and triquetrum should be reduced anatomically and pinned with a k-wire before drilling the LT tunnel. Elevate the flap, stopping over the dorsal ridge of the scaphoid. This preserves the capsular attachments to the dorsum of the scaphoid that carry the blood supply.

Alternate Exposure

Once a degree of familiarity is achieved with the technique using the large dorsal exposure described above, it may be possible to decrease the dorsal exposure by accessing the ulnar border of the triquetrum through a separate direct ulnar approach. This allows a limited dorsal exposure. The fifth compartment does not need to be elevated and the capsulotomy is more limited incorporating only a portion of the typical Berger flap, without the need to extend the flap past the triquetrum.

Expose the ulnar side of the triquetrum through a separate small direct ulnar incision approximately 2 cm long just volar to ECU. Care should be taken to protect dorsal branches of the ulnar nerve which have variable anatomy in this region. The LT tunnel can be drilled via this approach. Use of fluoroscopy to check cannulated drill guide wire positioning is recommended before drilling the definitive tunnel.

After it has been tensioned and secured with the interference screw through the ulnar incision the graft can be passed subperiosteally under the sixth and fifth compartments back toward the central dorsal exposure of the scaphoid and lunate, using a fine hemostat. Prior to this passage back to the dorsal incision, the graft may also be secondarily secured with sutures to the soft tissues over the ulnar triquetrum in the floor of the “ulnar snuff box”. The remainder of the

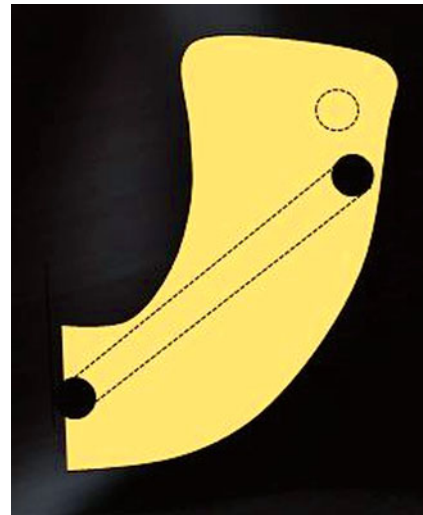


Fig. 10.12 Scaphoid tunnel placement for the scapho-luno-triquetral tenodesis technique

attachment of the graft to the dorsal scaphoid is the same as described with the more extensive dorsal exposure.

Harvesting the Graft and Preparation

Volar exposure of the scaphoid is similar to the volar approach for scaphoid fixation and grafting described by Russe [67]. Expose the tubercle and the distal half of the scaphoid. Minimize the division of the radio-scapho-capitate ligament at this point. Harvest approximately 40 % of FCR tendon using a technique allowing the tendon to be stripped from proximal to distal, leaving it attached distally. Tendon graft thickness should correspond to the transosseous tunnel diameter, which is usually 3 mm. Once the portion of tendon is harvested, mobilize it until it is distal to the ST joint.

Preparing the Scaphoid Tunnel

Drill a hole using a 3 mm cannulated drill bit, in a process similar to a traditional style Brunelli reconstruction [34, 60], except that the entry point dorsally is on the articular facet of the scaphoid for the lunate (not at the dorsal insertion of the SL ligament). The tunnel should be just dorsal to the center point of lunate facet of the scaphoid. The exit point on the volar side of the scaphoid is a few millimeters proximal and radial to the normal point that would be used for a traditional dorsal band reconstruction (Fig. 10.12). The position of the tunnel exit on the volar side needs to be accurate so that the tunnel can enter on the lunate facet of the scaphoid without violating the scapho-capitate joint. The point on the scaphoid facet should be just dorsal to the mid-point of the articular surface for the lunate. The reason for this is that if the corresponding point on the facet of the lunate is volar to the mid-point, the tendon graft will be traveling obliquely, from dorsal on the scaphoid, to volar on the lunate. This causes the

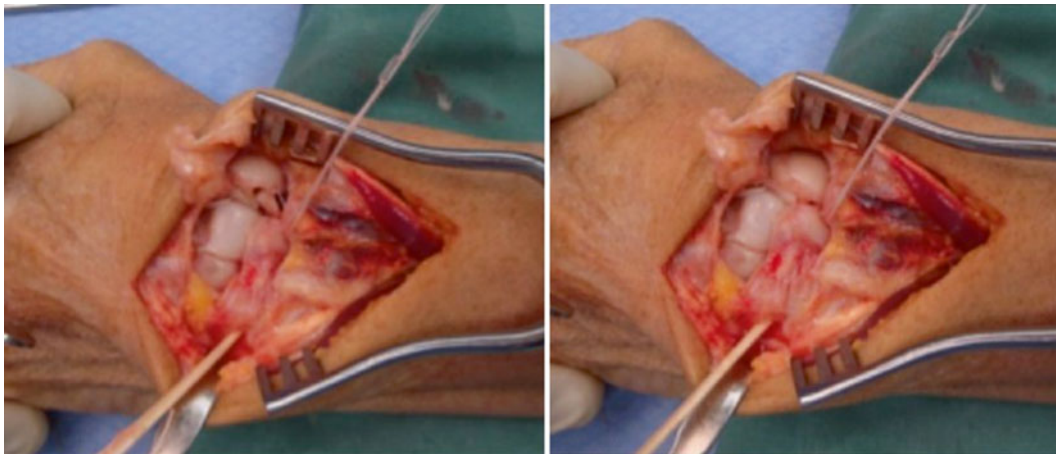


Fig. 10.13 Tensioning the tendon to reduce the SL interval for the Scapho-luno-triquetral tenodesis

graft to naturally reduce the rotary subluxation between the scaphoid and the lunate, and correct the dorsal subluxation of the proximal pole of the scaphoid, as it is tensioned.

Preparing the Luno-Triquetral Tunnel

The LT tunnel is drilled from the ulnar side of the triquetrum, across the LT joint to exit on the lunate just volar to the mid-point of the articular facet. Care is taken not to make the entry point on the ulnar aspect of the triquetrum too dorsal to avoid the risk of fracturing the tunnel when the interference screw is inserted. Care must also be taken not to enter too proximal on the triquetrum as the medial-lateral dimension of the triquetrum decreases significantly in its more proximal portion, and the tunnel needs to be long enough to accommodate the 8 mm length of the interference screw without it protruding across the LT joint.

Passing the Graft

The graft is then passed sequentially through the scaphoid from volar to dorsal then across the LT tunnel. The tendon needs to be approximately the same dimension as the tunnel so that the interference screw fit is tight. Ensure there is no slack in the graft between the FCR insertion and the volar entry to the tunnel before tensioning dorsally (Fig. 10.13).

Reducing the Joint

Pull on the tendon as it exits the triquetrum. The dorsal subluxation of the scaphoid will reduce and close the SL interval. Insert the interference screw (e.g. 3×8 mm PEEK screw, Arthrex Inc.) into the triquetrum volar to the tendon (Fig. 10.14). We have found that it is best to tension the graft with the wrist in ulnar deviation to ensure maximum tension. A similar bio-composite (e.g. TCP) screw would be preferable. We are reluctant to use a PLA screw due to probable cyst formation in small carpal bones.



Fig. 10.14 Inserting the interference screw for the Scapho-luno-triquetral tenodesis

Once the graft is secured if there is any residual SL ligament tissue, it may be repaired using the surgeon's preferred technique. The graft is then passed across the dorsum of the mid-carpal joint. The goal is to augment (or reconstruct) the dorsal inter-carpal ligament. Place a small absorbable anchor with 2° suture in the waist of the scaphoid, being careful to avoid the tunnel containing the FCR graft. Suture the graft to the waist of the scaphoid. This is also the base of the Berger flap so use either an artery forceps (Hemostat) or tendon braiding forceps to pass the graft through the base of the Berger flap.

Closure

To protect the reconstruction, a single 1.1 mm wire is placed between the distal pole of the scaphoid and the capitate, or between the scaphoid and lunate, being careful not to perforate the graft. Surgeon preference may be to use two wires. The K-wire is left in situ for 6–8 weeks.

Rehabilitation

Post operatively the patient is allowed to mobilize the wrist to 30° of flexion and 30° of extension. If only one SL wire is used, oblique axis (dart throwing) motion can be commenced early with the wire in situ. Custom-made thermoplastic wrist splint is worn at all other times until the k-wire is removed (i.e. 6–8 weeks). After the wire is removed, wrist mobilization exercises are upgraded to include orthogonal flexion/extension exercises and oblique dart throwing type exercises which focus on the mid-carpal joint.

SLT Case Presentation

A 40-year-old male right-hand dominant cane farmer presents with an acute SL dissociation (with static deformity) and simultaneous distal radius fracture of his left wrist. Preoperative X-ray is depicted in Fig. 10.15. Surgery for internal fixation of distal radius and SL reconstruction using the scapho-lunato-triquetral tenodesis technique was performed at 10 days post injury. At 7 months post surgery, he had good radiological outcome (Fig. 10.16). He had

returned to normal work and function, and had achieved a good clinical outcome (Fig. 10.17).

Salvage

Wrist arthroscopy can be used to evaluate the degree and extent of articular cartilage degeneration in patients with SL ligament pathology. The status of the articular cartilage as determined arthroscopically helps to determine whether a reconstructive procedure, such as ligament reconstruction or capsulodesis versus a salvage procedure (e.g., a four-corner fusion or proximal row carpectomy), is indicated [68, 69]. Arthroscopic evaluation of the status of the articular cartilage of the head of the capitate is extremely useful in determining the indications for 4 corner fusion versus proximal row carpectomy. In selecting individuals with early SLAC wrist who desire only minimal arthroscopic intervention, debridement, and radial styloidectomy may be an option. This is further described in a later chapter.



Fig. 10.15 Preoperative X-ray depicting SL dissociation and undisplaced distal radius fracture



Fig. 10.16 Postoperative X-ray depicting ORIF distal radius fracture and SL ligament reconstruction using the authors technique



Fig. 10.17 Range of movement at 7 months post surgery

The hitherto unpredictable results of soft tissue reconstructions have led some authors to consider bony procedures preferentially [68, 69]. The chronicity of the injury and the difficulty in reducing the SL relationship will influence this decision.

Proximal Row Carpectomy

Proximal row carpectomy is a motion preserving salvage procedure not reliant on bony union. It allows earlier mobilization than four corner fusion and is technically less demanding [69].

Fusion

Partial Intercarpal Fusions

Limited carpal fusions may be a suitable salvage for some patients [70].

STT Joint Fusion

There is a paucity of recent literature on the use of STT joint fusion as a salvage technique since Kirk Watson and colleagues described this initially in 1991 [35].

Scapho-Capitate Fusion

The concern with scapho-capitate fusion is the alteration in carpal mechanics with loss of midcarpal oblique plane motion and increased contact stresses between the scaphoid and radius. Deletang et al. in 2011 reported on 31 scapho-capitate fusions for chronic scapholunate instability were followed for an average of 5 years [71]. The conclusion was that capsulodesis and ligament reconstruction provide the same functional results as SC fusion, but with slightly less stiffening.

Luegmair et al. in 2013 reported on scapho-capitate arthrodesis for SL instability in manual workers [72]. This high-demand group of 20 patients with an average follow-up of 10 years had a significant reduction in pain symptoms and maintained an average 87° flex-extension arc and 41° radio-ular deviation arc. Grip strength was 60 % of the opposite wrist. All patients united, 90 % of patients returned to work but 30 % had radiocarpal arthritis at last follow-up.

Four Corner Fusion ± Excision of Scaphoid

Four corner fusion and proximal row carpectomy are often compared and contrasted as salvage procedures. Cadaveric work by DeBottis et al. in 2013 showed a reduced range of motion compared to normal wrists with either procedure [73]. Wrist flexion was reduced similarly in both by 12–13°. Extension was decreased by 20° in the four corner fusion and 12° in the PRC.

Radio-Scapholunate Fusion

RSL arthrodesis is technically challenging although improved implants including memory staples and specific internal fixation implants have helped to improve union rates. It remains important to respect the three dimensional relationship of the scaphoid and lunate to preserve the shape of the articulation with the proximal capitate.

Bain et al. described RSL arthrodesis with distal pole of scaphoid excision and triquetral excision for isolated radiocarpal arthritis secondary to a variety of pathologies [74]. The midcarpal joint must be normal for this limited arthrodesis to be justified. Resection of the distal scaphoid and triquetrum was shown to increase range of motion in prior cadaveric studies [75].

Mühldorfer-Fodor et al. report on the results RSL arthrodesis for posttraumatic arthritis with or without distal pole of scaphoid excision [76]. The distal pole excision group had not only better radial deviation but better union rates too. Although this procedure is suitable for salvage in failed SL ligament reconstruction, in this cohort of 35 patients with follow-up, however, only two cases were due to SL pathology the majority of cases were arthritis secondary to intra-articular distal radial fractures.

Capitolunate Fusion

Wang et al. report on capitolunate and triquetrohamate fusions for scapholunate advanced collapse and scaphoid nonunion advanced collapse salvage [77]. In a consecutive series of 27 patients there was a 96 % union rate. Postoperative results showed a 21 % reduction in mean flexion-extension arc compared to preoperatively. There was no change in radio-ular deviation. The mean grip strength postoperatively increased by 27 %.

Total Wrist Fusion

Total wrist fusion is best reserved for salvage of pan carpal arthritis or failed limited carpal arthrodesis or other motion preserving procedures [78]. The overwhelming challenge of all treatments for SL pathology is avoidance of the need for total wrist fusion.

Summary of Treatment Options

Partial Tears

Acute partial tears may heal without treatment or may benefit from simple immobilization. There may also be a role for closed pinning, with or without arthroscopic assistance. Symptomatic chronic partial tears are less likely to be suitable for closed pinning; however, the residual ligament function may be too good for major reconstruction. In these cases capsulodesis (arthroscopic or open), or capsulorrhaphy (abrasion, thermal, suture) may be appropriate.

Complete Tears-Dynamic

In acute dynamic tears most authors would favor primary repair over reconstructive techniques. This still requires a pragmatic assessment of ligament quality intraoperatively

before proceeding to repair. In chronic dynamic tears the balance shifts toward reconstruction over repair. The challenge is in establishing the interval that defines a chronic tear.

Complete Tears: Static

When these tears are reducible at operation the preference may be for reconstruction or capsulodesis, although there are some authors who consider this pathology beyond the limit of soft tissue reconstruction to achieve stability and prefer partial fusion. Consideration may also be given to less invasive arthroscopic capsulodesis or capsulorrhaphy techniques.

In a static irreducible dissociation the only predictable options are partial or total fusion.

Conclusion

The management of SL ligament injury is continuing to evolve with both arthroscopic and more anatomical open reconstruction techniques being developed. The biggest dilemma facing the surgeon is when to apply repair versus reconstructive versus salvage techniques. This challenge is complicated by the difficulty in defining chronicity of the injury, the poor results of open primary repair in many series, and the lack of good natural history studies for both partial and complete ligament tears. In addition it remains difficult to make direct outcome comparisons with other techniques in the published literature. There is currently no standard for reporting preoperative and postoperative outcome data in relation to either clinical or radiographic results for SLIL pathology.

Acknowledgements We would like to acknowledge Dr Nick Daunt, Radiologist, QLD XRay for his assistance with the “Imaging” section of the chapter. We would also like to acknowledge Susan Peters, Senior Research Coordinator and Hand Therapist, Brisbane Hand and Upper Limb Research Institute for assistance with manuscript preparation.

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