



# Treatment of scapholunate ligament injury: current concepts

Jonny K. Andersson

- Injuries to the scapholunate joint are the most common cause of carpal instability.
- An isolated injury to the scapholunate ligament may progress to abnormal joint mechanics and degenerative cartilage changes.
- Treatment for scapholunate instability is aimed at arresting the degenerative process by restoring ligament continuity and normalising carpal kinematics.
- Early arthroscopic diagnosis of scapholunate injury is mandatory for establishing the prognosis of the injury, as a proper ligament repair is recommended within four to six weeks after trauma.
- In this review, anatomy, diagnosis and treatment of scapholunate ligament injury and carpal instability are discussed. Recommendations for treatment based on the stage and classification of injury and the degree of instability and arthritic changes are proposed.

**Keywords:** wrist; wrist arthroscopy; scapholunate ligament; carpal instability

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## Anatomy

The scapholunate (SL) ligament (SLL) is the most commonly injured carpal ligament.<sup>1</sup> The SLL is C-shaped and has three structurally distinct parts: volar; membranous; and dorsal (Fig. 1).<sup>2</sup> The dorsal part of the SLL is the strongest and the primary stabiliser of the SL joint and can resist forces of up to 260 N.<sup>3</sup> The avascular proximal membranous portion does not provide any significant laxity restraint (63 N), while the volar part of the SLL (118 N) plays an important role in terms of rotational stability.<sup>4,5</sup> The dorsal part of the SLL measures 2 mm to 3 mm in thickness and is in the range of 2 mm to 5 mm in length. The vascular supply to the scaphoid and SLL is delicate. The main vascular contribution comes from the radial artery. Extra-osseous vessels enter the dorsal ridge of the

scaphoid and supply two-thirds of the bone. It also appears that the radio-scapholunate (RSL) ligament provides a vascular supply directed at the SLL complex.

### *Types of injury and classification*

There is a gradient of SL injury severity, when it occurs. It ranges from occult, dynamic SL dissociation (gap), followed by carpal collapse, finally ending up in disabling arthritis (scapholunate advanced collapse (SLAC)) wrist.<sup>1</sup> It often takes three to 12 months after trauma before dynamic instability develops and SL dissociation is noted radiologically (SL angle > 60° and SL gap > 3 mm on clenched-fist or ulnar-deviation radiographs). For this development and progression to occur, an additional tear or gradual, continuous elongation of the secondary ligament stabilisers of the SL ligament is needed.<sup>6</sup>

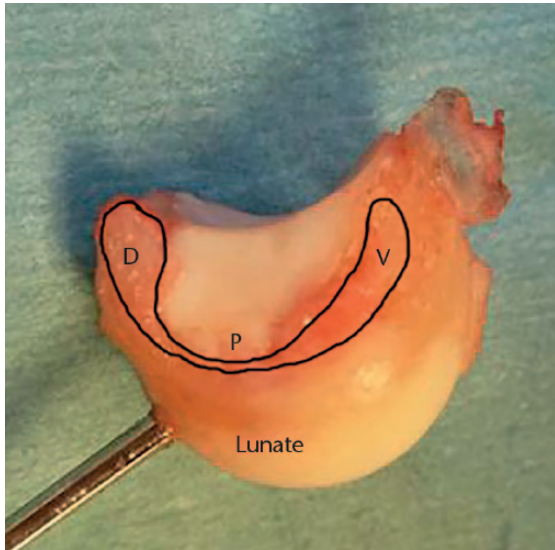
Approximately 5% of all wrist sprains have an associated SL tear.<sup>7,8</sup> SLL injuries are often associated with distal radius fracture (40% of the cases on average), particularly fractures of the radial styloid, the so-called Chauffeur's fracture (Fig. 2).<sup>9,10</sup>

An SL injury can be classified as partial or total and the degree of instability is arthroscopically classified according to Geissler (Table 1).<sup>11</sup>

### *Carpal instability and symptoms*

Carpal instability (CI) is the end-result of a wrist ligament injury.<sup>12,13</sup> When CI results in a major malfunction of a joint between the bones in the same carpal row (intra-carpal ligaments: SL, lunotriquetral (LT)), the case is defined as CI dissociative. In mid-carpal instability, also known as CI non-dissociative, which is not further described in this review, there is no dissociation between SL or LT in the proximal row, but instead a dysfunction of both radiocarpal and mid-carpal joints, where the latter tends to predominate and is not often associated with general hyperlaxity of the joints.

The failure of the injured ligament and the step-by-step attenuation and elongation of its secondary constraints<sup>6</sup> produce abnormal carpal kinetics (altered stress with the inability to bear functional loads) and abnormal



**Fig. 1** The scapholunate ligament is C-shaped. Its dorsal (D) component is the strongest (P, proximal; V, volar).



**Fig. 2** Chauffeur's fracture with concomitant scapholunate dissociation.

**Table 1.** Geissler's classification<sup>11</sup>

| Grade     | Description  |
|-----------|--|
| Grade I   | Attenuation and/or haemorrhage of the interosseous ligament as observed from RC space. No incongruence of carpal alignment in MC space => treatment by immobilisation  |
| Grade II  | Attenuation and/or haemorrhage of the interosseous ligament as observed from RC space. Incongruence and/or step-off as observed from MC joint. A slight gap (less than the width of a probe, < 2 mm) between the carpal bones may be present => treatment by reduction and pinning                                 |
| Grade III | Incongruence and/or step-off of the carpal alignment are observed in both the RC and MC space. The probe may rotate and pass through the gap (> 2 mm) between the carpal bones => arthroscopic reduction or open reduction and pinning or repair   |
| Grade IV  | Incongruence and/or step-off of the carpal alignment are observed in both the RC and MC space. Gross instability with manipulation is noted. A 2.7-mm arthroscope may be passed through the gap between the carpal bones ('drive-through phenomena'). Total injury => open re-insertion or ligament reconstruction |

RC, radiocarpal joint; MC, mid-carpal joint

kinematics (abnormal carpal movement). The degree of carpal instability can vary from minor micro-movements, due to ligament attenuation and partial ruptures, to gross carpal displacement with abnormal radiographic carpal alignment.<sup>14</sup>

After a significant wrist trauma, a spectrum of wrist ligament injuries can develop. When the injury is a mild sprain, an occult pre-dynamic instability can be present. In more severe trauma, a dynamic instability (only possible to visualise in stress and load radiographs), characterised by the complete disruption of all parts of the ligament, can be present.<sup>15</sup> This dynamic instability is further characterised by the following: the ligament parts are still reparable, not yet retracted or necrotic, with good healing potential; the secondary constraints and stabilisers are still intact or attenuated to a minor degree and there is no carpal malalignment or cartilage damage. In static instability, an asymmetrically widened SL gap (> 3 mm) is present on neutral, static radiographs with a clear and typical history and distinct physical examination. Frequently, static instability is most often found months to years after the index trauma.

When the SLL is injured, the scaphoid tends to move into volarflexion, while the lunate, which is still fixed to the triquetrum, is forced, due to carpal kinematics, to follow the triquetrum into dorsal extension. The opposite happens with time when the LT ligament (LTL) is injured. This static instability is often referred to radiologically as dorsal intercalated segment instability (DISI), following an SLL injury (Fig. 3), and volar intercalated segment instability (VISI) following a LTL injury.

SL dissociation is the most common form of CI.

Patients with an SLL injury often present with a 'click' or 'pain' on the dorso-radial aspect of the wrist and there is often an episode of clear injury preceding the symptoms. Swelling and limited grip strength and range of movement (ROM) are also common symptoms.

#### *Complications after scapholunate ligament injury*

The end result of long-standing SLL injury with dissociation (SLD) is always DISI and a so-called SLAC wrist (Fig. 4).<sup>16,17</sup> SLAC is the most common pattern of degenerative arthritis of the wrist. It develops following SLD with



**Fig. 3** Dorsal intercalated segment instability (DISI) with a scapholunate angle of approximately 90° (S, scaphoid; L, lunate (red)).

rotary subluxation of the scaphoid. The degenerative changes first affect the radial styloid, then the radio-scaphoid joint, followed by parts of the mid-carpal joints. The head of the capitate, in particular, can erode fairly rapidly when it is subsequently dislocated into the gap between the lunate and the scaphoid. The radiolunate joint is not typically involved in SLAC arthritis, due to the spherical shape of the lunate and the congruity of the joint between the lunate and the lunate fossa of the radius.

The average time from the initial trauma to SLAC development is unknown and variable, depending, among other things, on the severity of the trauma, injured associated ligaments and secondary stabilisers, probably the initial step between the scaphoid and the lunate, and the individual configuration of the wrist. Empirically, SLAC wrist is most often found three to 15 years after the index injury. For the patient, SLAC wrist can sometimes be almost asymptomatic, but it is most often debilitating, with pain, limited and restricted ROM and loss of strength.<sup>17,18</sup>



**Fig. 4** Scapholunate (SL) advanced collapse after an SL injury, with subsequent arthritic changes at the radiocarpal and mid-carpal joints (SL advanced collapse - SLAC III). Also note the volarflexed scaphoid, appearing triangular distally with the so-called 'ring sign'.

#### Diagnosis of scapholunate ligament injury

SLL injury is common in young individuals and it is often the consequence of a fall forwards from a height, sport injuries or a motorcycle accident.

#### Clinical examination

A clinical examination of wrist ligament injuries consists mainly of palpation and laxity and provocation tests.

A positive Watson's test (scaphoid shift manoeuvre) (Fig. 5) indicates a total SL injury. However, positive tests occur in approximately 20% of the normal population, which contributes to diagnostic difficulties.<sup>3,19</sup> When performing the scaphoid shift manoeuvre, the examiner grasps the wrist from the radial side, placing the thumb on the palmar prominence of the scaphoid, while holding the fingers firmly around the distal radius. This enables the examiner's thumb to push on the scaphoid with counter-pressure provided by the fingers. The examiner's other hand grasps the patient's hand at the metacarpal level to control wrist position. Starting in ulnar deviation and slight extension, the wrist is moved radially with simultaneous slight flexion and with constant thumb pressure applied to the scaphoid. The Watson's test is positive if the



**Fig. 5** Watson's test – 'scaphoid shift' manoeuvre.

scaphoid is unstable and can be subluxated dorsally and the patient experiences pain at the dorsum of the wrist.<sup>3,19</sup> The SLL can also be examined with the so-called 'finger extension test' (maximum finger extension against resistance, during simultaneous volar flexion of the wrist), although this test can sometimes also be positive if the patient has dorsal synovitis or ganglia.

#### *Radiological examination*

Although current non-invasive radiology may suggest several injury characteristics, the actual extent and nature of most ligament tears is not known precisely until the patient is assessed using an arthroscope or by open surgery.<sup>20</sup>

#### *Plain radiographs*

The initial diagnosis of SL injury can be difficult, as it often takes three to 12 months before dynamic instability is detected on plain radiographs (with clenched-fist films and ulnar deviation) with an SL gap of  $> 3$  mm and an SL angle of  $> 60^\circ$ . The radiological definition (plain films) of DISI (Fig. 3) is as follows:

- 1) on an anteroposterior view, signs of SLD, the normal trapezoidal configuration of the scaphoid, may be lost and it may appear triangular, sometimes with the so-called 'ring sign'<sup>21</sup> (Fig. 4);
- 2) on the lateral view, a dorsal tilt of the lunate is typically shown: SL angle  $> 60^\circ$  and capitolunate angle  $> 30^\circ$  (the capitate is displaced posteriorly compared with the distal radius).

#### *MRI and MR arthrography*

It has been generally accepted that appropriate parameter settings for MRI are very important for high accuracy.<sup>22</sup>

In 2013, Ringler<sup>22</sup> proposed an MRI strategy for the wrist ligaments to increase accuracy in diagnosing wrist ligament injuries:

- 1) magnetic strength  $\geq 1.5$ -T;
- 2) dedicated wrist coils;
- 3) field of view  $\leq 10$  cm;
- 4) slice thickness  $\leq 2$  mm;
- 5) matrix  $\geq 384 \times 256$ ;
- 6) MRI sequences including T1-weighted, fat-saturated PD or T2-weight fast spin echo.

In my opinion, the most important thing, however, is to have an experienced, dedicated radiologist working closely with the hand surgeon.

The SLL is C-shaped and thin (2 mm to 4 mm). The MRI diagnostics of injuries can therefore be challenging and difficult. Andersson et al<sup>23</sup> showed recently that a negative result from MRI is unable to rule out the possibility of a clinically relevant injury to the SLL or other ligaments of the wrist.

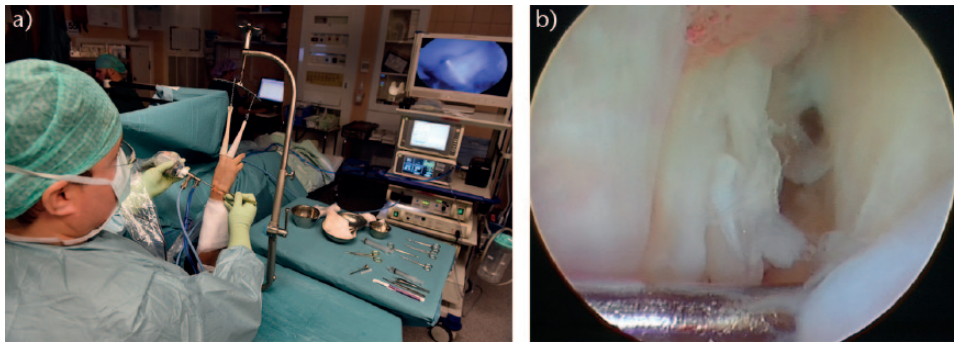
A complete tear of the SLL is diagnosed on MRI when there is a distinct area of discontinuity with increased signal intensity on fluid-sensitive sequences or a complete absence of the ligament. Other observations that may indicate an injury include severe distortion of ligament morphology, such as fraying, thinning or abnormal course. Secondary findings on MRI, such as the presence of excessive mid-carpal joint fluid and associated ganglia/synovitis, are sometimes important for an awareness of an existing ligament injury, but they are generally not helpful. The absence of SL diastasis or DISI deformity cannot exclude even a complete SLL tear.<sup>24</sup> A good knowledge of the MRI appearance of ligamentous anatomy, coupled with high-quality imaging and clinical history, is much more effective than MRI alone.<sup>22</sup>

#### *Wrist arthroscopy: indications*

The indications for wrist arthroscopy are wide and vary considerably, from performing a diagnostic procedure for chronic wrist pain to ligament reconstructive surgery and fracture reduction. Radiocarpal arthroscopy should always be accompanied by mid-carpal arthroscopy, which is essential when making the diagnosis of SL and LT instability. The cartilage, ligaments and joint capsule can be assessed and the injuries can be evaluated in terms of dynamic instability, degree of injury (partial, total), quality of the tissue, reparability and healing capacity. The grading scale reported by Geissler et al<sup>11</sup> (Table 1) provides a means of staging the degree of injury to the intrinsic ligaments and instability in order to choose the best type of treatment.

Injuries to the intrinsic carpal ligaments can be visualised from the radiocarpal joint - the SLL preferably from the portal between the third and fourth extensor tendon compartment (Fig. 6). It is important not only to assess the unimportant and insignificant proximal membranous portion of SLL but also to proceed all the way up to the distal,





**Fig. 6** a) Wrist arthroscopy technique. The 2 mm to 3 mm probe inserted through the 6R portal testing the scapholunate (SL) ligament (SLL) in a right wrist. b) Arthroscopic diagnosis of a total SL injury in a left wrist, a so-called Andersson-Garcia-Elias type 1a - ligament avulsion off the scaphoid, according to our new proposed classification (see Discussion and Fig. 9). This total SLL injury and instability with a 'drive-through phenomena' corresponds to Geissler grade IV injury (Table 1).

visualising the dorsal component of the SLL. Otherwise, it is easy to overestimate the degree and severity of the injury.

#### *Non-surgical treatment*

A combination of proprioceptive, neuromuscular training and physiotherapeutic treatment regimens appears to yield the greatest improvement in the sensorimotoric control and stability of joints in terms of both rehabilitation and treatment strategies.<sup>25</sup> However, the more exact role of wrist proprioception and neuromuscular stability training after wrist ligament injuries and carpal instability needs to be further elucidated,<sup>26</sup> although it has its role, especially in partial SLL injuries and pre-dynamic and dynamic instabilities.

#### *Surgical treatment of acute-subacute scapholunate injury*

SL injury and deficiency and its treatment remain an unsolved problem in wrist surgery. Failure to diagnose and treat SL injuries, especially in the young adult with high demands, can lead to the progressive deterioration of function, instability, pain, loss of grip strength and finally articular damage.<sup>17</sup> Acute total SLL injuries need to be treated within four to six weeks after trauma with suture repair or re-insertion and pinning. Partial injuries are not best treated by open surgery. Instead, the treatment options are arthroscopic debridement or thermal shrinkage, pinning or physiotherapy with the re-education of the flexor carpi radialis (FCR). It is crucial to diagnose the SLL injury in the acute stage, as chronic SL instability is very difficult to treat because of its complexity. Many different methods have been suggested in the past,<sup>5,27-31</sup> some with promising results and some with less promising results. It is clinically difficult to treat SL ruptures and the results are inconsistent.<sup>32,33</sup> The injury is often missed because of difficulties in the clinical diagnosis and initial normal plain radiographs. Even if the SLL injury is diagnosed acutely, the ligament remnants are often short and

retracted, making it difficult to re-attach the ends. The SL complex is also exposed to great tension and torsion and must be able to sustain great loads. Because of these factors, it is not unusual for SL repairs to deteriorate with time. From all the available evidence, the best treatment for SLD is early surgical intervention performed directly when the diagnosis is made. This provides the best opportunity to restore the anatomy and prevents unfavourable attritional changes in the SLL and the secondary stabilisers of the wrist. The dorsal SLL plays a very important role in the stabilisation of the loaded carpus, but its importance should not be over-emphasised. In low-demand patients, good status of the secondary stabilisers with compensatory effects from the adjacent capsule-ligamentous structures and the dynamic strength of specific muscles may sometimes effectively ensure good carpal stability, at least for some years.<sup>34</sup> In general, however, if an SLL rupture has not healed, the risk of progressive joint deterioration and SLAC development is definite. The wrist should be better prepared to sustain loads if the SL is functional. Treatment options are based on the clinical stage at presentation and the time that has elapsed since injury. Acute injuries are arbitrarily defined as those presented within four weeks after the initial trauma, subacute injuries as those presented at four weeks to six months and chronic injuries as six months after the initial trauma. While the ideal time for acute repair has not yet been defined, all intrinsic carpal ligaments tend to undergo rapid degeneration in as short a time as two to six weeks, after which primary repair may be difficult or even impossible and ineffective.<sup>3</sup> Early diagnosis and open repair is still the benchmark and is strongly advocated. Capsulodesis is recommended for augmentation simultaneously with ligament repair but not as an isolated treatment. Direct open repair with ligament sutures, osteosutures, or bony fixation with bone anchors supplemented by Kirschner-wire fixation and/or capsulodesis<sup>35,36</sup> produce good results in

the short- and mid-term. Direct repair of the SLL is recommended for complete tears if there are no signs of arthritis and when the secondary wrist stabilisers remain normal.

During open surgery, it is possible to inspect directly the cartilage and look for concomitant ligament and chondral lesions. The most important dorsal component of the SLL is the one that can most often be directly repaired. There are no ideal open treatment options in the subacute setting for the volar part of the SL, as an open volar approach requires incision through the important secondary ligament stabilisers. A longitudinal dorsal incision centred over the SL interval is used. The dorsal retinaculum is divided along the third compartment and the fourth compartment is subperiosteally reflected ulnarly. The wrist joint is exposed through a longitudinal capsular incision or with a ligament-sparing technique according to Berger and Bishop.<sup>37</sup> The dorsal and proximal membranous portion of the SLL is evaluated. Once reduced anatomically, percutaneous pin fixation from the scaphoid into the lunate and from the scaphoid into the capitate is performed. This pinning technique has been shown to be the strongest method.<sup>38</sup> The ligament is then repaired using free needles, sutures, osteosutures and/or bone anchor sutures, depending on the type of injury. In some cases, it is easier to place the sutures into the ligament prior to the final reduction and then simply tie them all once the SL joint has been reduced and stabilised. A straight direct repair with sutures or suture anchors has remained a reliable technique in the acute setting, but the open technique is limited to the correction of the dorsal part of the SLL. Biomechanical research has previously indicated that only the dorsal SLL needs to be repaired to achieve relatively normal carpal kinematics in cadavers, but this has subsequently been the subject of debate in recent studies.<sup>1,28</sup>

The mid-term outcome after open subacute SL repair overall shows that > 70% of the patients will have a significant improvement in pain, grip strength will reach approximately 85% of the normal wrist and movement will become almost 80% of that of the normal side.<sup>35,36</sup> Radiographic degenerative changes in the long-term occur in < 30% of patients. Exact reduction and percutaneous Kirschner-wire fixation with or without augmentation with dorsal capsulodesis has also been recommended for acute partial and total tears. Exact reduction and Kirschner-wire fixation without open suture<sup>39</sup> has shown good to excellent results in patients with an acute or subacute presentation of SL rupture. Exact reduction, preferably under arthroscopic control in acute cases, is necessary when using this method of pinning alone. Pins should be left *in situ* for eight weeks.

If the appropriate conditions in terms of reducibility and healing are met, direct ligament repair and capsular

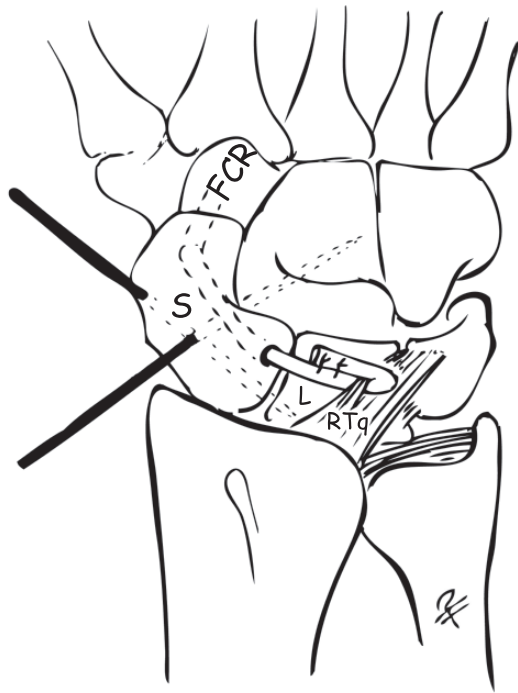
augmentation may be used in some cases, even if the injury is older than four to six weeks.<sup>35</sup> Direct repair and augmentation with a dorsal capsulodesis in chronic cases with dynamic SL instability also appears to be favourable in the short-term in some patients, according to Cohen and Taleisnik,<sup>35</sup> although the results appear to deteriorate both clinically and radiographically with time in patients who place high demands on their wrist.

Arthroscopic suture techniques of the SL and concomitant dorsal capsuloplasty have also recently been described.<sup>40</sup> Some of these studies should, however, be critically analysed, as most of the included patients appear to have had partial injuries.

#### *Surgical treatment for chronic scapholunate dissociation and scapholunate advance collapse wrist*

The choice of procedure for SL injury<sup>1,7</sup> in the absence of arthritis depends on the extent of the lesion, quality of the ligament remnants and reducibility of the joint. Older injuries with dynamic instability, which is still reducible, can be treated by some kind of ligament reconstruction.

Various tendon reconstruction techniques for the SL have been described in the past and the techniques have evolved considerably. In 1995, Brunelli and Brunelli<sup>27</sup> suggested the use of a strip of the FCR tendon to adjust both the distal and proximal parts of the scaphoid instability with rotatory subluxation. The strip of FCR is passed through a transverse hole drilled across the distal scaphoid to the dorsal part of the scaphoid neck and then anchored to the ulnar part of the distal radius. The three-ligament tenodesis (3LT) technique (Fig. 7) is a further developed and modified technique and appears to be an improvement. Using this technique, the FCR tendon is used to augment the palmar-distal connections of the scaphoid (which enhances and replicates the scapho-trapezio-trapezoid (STT) ligaments), the dorsal SLL is reconstructed and the ulnar translation of the lunate is reduced (which enhances the dorsal radiotriquetral (RTq) ligament).<sup>29</sup> A distally based strip of the FCR tendon, approximately 8 cm long and 3 mm wide, is harvested and passed through a drill tunnel from the palmar tuberosity of the scaphoid to the point of insertion of the dorsal SLL. The lunate should be easy to reduce, otherwise this technique is not recommended. A channel over the reduced dorsum of the lunate is carved with a rongeur and an anchor suture is placed in the cancellous bone. The FCR strip is then tightened through a slip in the RTq ligament and sutured once again to itself under tension. Kirschner-wire fixation between the scaphoid and lunate and scaphoid-capitate should remain in place for eight weeks. This 3LT technique has shown promising results, with significant improvements in pain and improved alignment but reduced movement and grip strength. In general, modified Brunelli ligament reconstruction and tenodesis using tendon grafts produce satisfactory results when it



**Fig. 7** The three-ligament tenodesis. A schematic drawing (S, scaphoid; L, lunate; RTq, dorsal radiotriquetral ligament; FCR, flexor carpi radialis).

comes to correcting reducible chronic SL instability in wrists without pre-operative notable osteoarthritis. This repair technique achieves a relatively pain-free wrist, with acceptable grip strength and normal SL distance, but with loss in the arc of movement and sometimes a loss of long-lasting correction of the SL angle. Garcia-Elias et al<sup>29</sup> reported a series of 3LT repairs involving 38 patients with a follow-up of approximately four years, in which they found that 75% of the patients returned to their normal occupational/vocational activities and experienced significant pain relief at rest. The patients regained approximately 75% of flexion and extension movement on average compared with the non-injured contralateral side. The average grip strength was 65% relative to the contralateral side. A recurrence of carpal collapse and DISI occurred in only 5% of the patients.

There are now also arthroscopically assisted ligament reconstruction methods that aim to reconstruct both the dorsal and volar part of the SLL, as described by Corella et al,<sup>28</sup> for example. With this approach, it is possible to reconstruct the dorsal SLL and the dorsal and volar secondary stabilisers while causing minimal damage to the soft tissues and avoiding injury to the volar secondary stabilisers, the posterior interosseous nerve and detachment of the dorsal intercarpal (DIC) ligament.

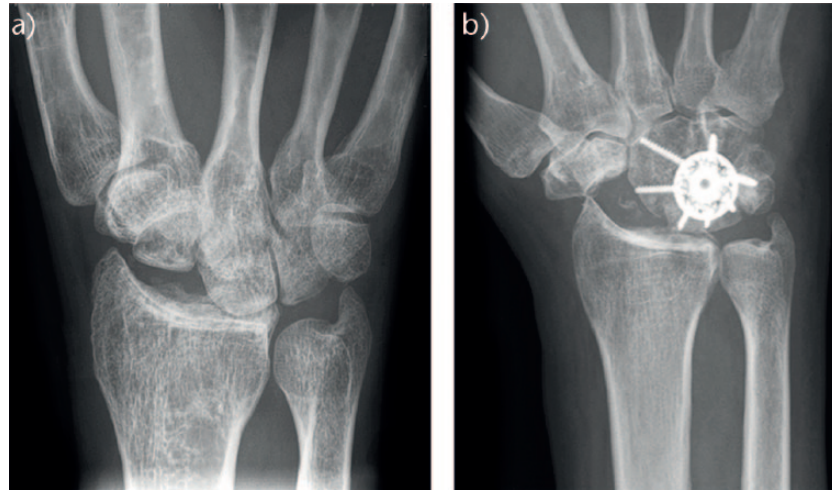
Dorsal capsulodesis was first described by Blatt.<sup>41</sup> He used a proximally based strip of the dorsal wrist capsule to

create a dorsal tether to the distal scaphoid for stabilisation and to prevent the tendency towards volar flexion and rotatory subluxation of the scaphoid. Alternatives are the method described by Linscheid and Dobyns,<sup>32</sup> who used a strip of the DIC ligament, and Herbert's method with a distally based capsular flap. However, the use of a dorsal capsulodesis alone for the treatment of chronic static SL instability is not enough. In a recent study in 2012, Megerle et al<sup>42</sup> followed the mid-term (mean eight years) results for 50 patients who underwent dorsal capsulodesis with a strip of the DIC ligament. After significant improvement directly post-operatively, the mean SL and radiolunate angles deteriorated to pre-operative values at final follow-up and the authors showed that capsulodesis alone was unable to maintain carpal reduction over time. They also found some evidence of early degeneration. Dorsal capsulodesis alone is not a recommended technique nowadays.

In cadaveric and clinical studies, the strength of bone-ligament-bone grafts<sup>43</sup> has been shown to be similar to that of the normal ligament. More commonly used grafts are bone-retinaculum-bone, second or third metacarpal-carpal-bone or hamate-capitate grafts, with or without screw augmentation. There is some lack of long-term results for this type of surgery, which makes it difficult for hand surgeons to determine its appropriate use. Early results have indicated that this method could play a role in the treatment of SL dissociation in the future,<sup>43</sup> but the consolidation of the graft in this compromised area is difficult and this technique still needs further research. Van Kampen et al<sup>44</sup> state that they have abandoned the technique of bone-ligament-bone graft for SL injury for other less technically demanding procedures.<sup>44</sup>

A new method, the SL axis method (SLAM) for SLL reconstruction, has also shown promising results in a cadaveric study. The SLAM appears to achieve an improved and closer SL interval and better SL-angle correction compared with conventional techniques of SLL reconstruction, according to Lee et al.<sup>31</sup> The method provides compression centrally and thereby improves the strength of both the dorsal and volar parts of the SL joint. No clinical results related to this method have so far been reported.

In symptomatic static irreducible SLD, the most commonly advocated treatment is partial fusion. SL fusion is probably the least reliable option, with small areas of bone contact and a high separating force in the SL interval by the capitate. Nonunion has been reported in approximately 50% using this method. STT fusion is a more difficult but more reliable option, with an average rate of nonunion in all reported series of 14%.<sup>3,16</sup> The goal is to re-align the proximal pole of the scaphoid with the scaphoid fossa of the radius. It is important to maintain the external proportions of the bones and to achieve correct alignment of the scaphoid with a radioscapoid angle of



**Fig. 8** Plain radiographs (anteroposterior view - right wrist) of proximal row carpectomy (a) and four-corner fusion (b).

between 40° and 60°. Over-reduction must be avoided because of restricted movement and impingement. Under-reduction with a preserved SL gap can also be a problem. Most daily activities involve the dart-throwing movement (extension-radial deviation to flexion-ulnar deviation)<sup>45</sup> and this movement occurs in the mid-carpal joint. RSL fusion and distal scaphoidectomy could therefore be a good choice, especially if there are degenerative cartilage changes in the radiocarpal joint and the mid-carpal joint is normal. The early results of this fusion published so far are promising.

The surgical management of the degenerative wrist due to SLAC is still a challenging choice among several different surgical options. Total wrist fusion historically provides predictable pain relief at the cost of a complete loss of movement and shock absorption. The complication rate in total wrist fusion is also relatively high (approximately 15%). In the event of a SLAC wrist (SLAC I to IV is explained in Table 2), only some kind of salvage operation can be recommended. Wrist denervation can only be used selectively. In SLAC I, a radial styloidectomy may relieve the pain and postpone further surgery. In SLAC II, the most used options are proximal row carpectomy (PRC) or four-corner fusion (4CF) (Fig. 8). In the short-term, these two operations produce similar results with pain relief and a ROM of flexion 30° to 40°, extension 30° to 40° and 75% maintained grip force.<sup>46</sup> In SLAC III (mid-carpal arthritis), the only alternative is 4CF or perhaps PRC plus resurfacing of the proximal part of the capitate with resurfacing capitate pyrocarbon implant. In older patients, with a low ROM pre-operatively and a round and blunt-shaped capitate, PRC can be recommended. In patients younger than 35 years or with a pointed, peaked and narrow capitate, 4CF can be recommended. Some scepticism is, however, in order in terms

of the long-term viability of a joint with a completely mismatched articular surface between the capitate and the lunate fossa of the radius. Long-term radio-capitate degeneration after more than ten years of follow-up is, however, often asymptomatic and generally only present in about 10% to 20% of patients after PRC. However, several other studies have reported a significantly larger number of patients with secondary arthritic changes after PRC, although most are symptom-free. There is a lack of well-conducted studies, but Mulford et al<sup>46</sup> reported and confirmed in a systematic review that both 4CF and PRC produce a clear improvement in pain and subjective outcome measurements for patients with symptomatic SLAC wrists. PRC can perhaps provide a better post-operative ROM, with less risk of the potential complications specific to 4CF (10% more complications occurring; such as non-union, hardware problems and dorsal impingement). This systematic review reported that the risk of subsequent osteoarthritis, albeit most often asymptomatic, is significantly higher after PRC. Subjective outcomes and quality of life, pain relief, ROM and grip strength appear to be similar in both groups.

Total wrist fusion is an option in SLAC IV, but total wrist arthroplasty has increased in number in the last few years, as the survival rate of the new generation of arthroplasties has increased markedly.<sup>47</sup>

The treatment of SLL injury in different stages is summarised in Table 2.

## Discussion

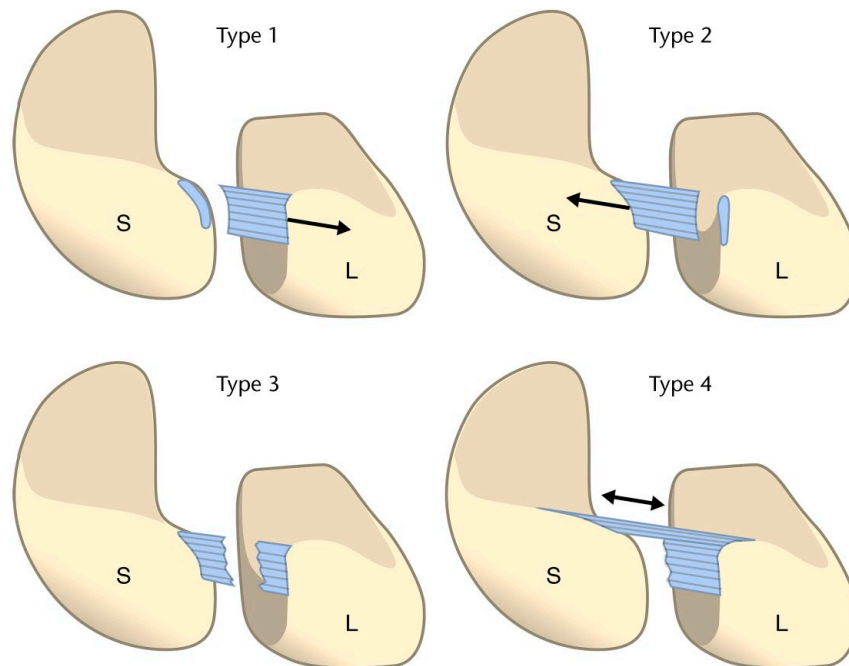
Many factors contribute to the choice of treatment for SL injuries. Garcia-Elias et al<sup>29</sup> developed a set of five questions that provide a useful framework for developing a stage-based treatment algorithm:



**Table 2.** Treatment of scapholunate (SL) ligament (SLL) injury in different stages

| SLL injury - different stages | Stage 1: pre-dynamic occult instability, partial tear   | Stage 2: dynamic instability   | Stage 3: static instability, no DISI and easily reducible  | Stage 4: DISI  | Stage 5: SLAC   |
|-------------------------------|---|--|--|--|---|
| Injured ligaments             | Partial SL injury (volar)<br>Dorsal SLL intact  | Incompetent dorsal SLL or<br>Total SLL complex injury + partial injury or attenuation of volar secondary stabilisers | Complete SL injury and injury or<br>Attenuation of volar or dorsal secondary stabilisers                 | Complete SL injury with secondary changes of all secondary stabilisers                     | As in stage 4   |
| Static radiographs            | Normal  | Usually normal   | SL gap $\geq$ 3 mm   | SL gap > 3 mm +<br>SL angle > 60° to 80°   | I Arthritis: radial styloid<br>II Arthritis: radioscaphoid<br>III Arthritis: midcarpal<br>IV Panarthrosis             |
| Stress radiographs            | Normal, but abnormal fluoroscopy  | Abnormal   | Grossly abnormal   | Unnecessary examination  | Unnecessary examination   |
| Choices of treatment          | Arthroscopic debridement or thermal shrinkage, pinning or capsulodesis or<br>Physiotherapy with re-education of FCR | Open SL repair or<br>Re-insertion with dorsal capsulodesis as an augmentation  | Open SL repair with capsulodesis or 3LT ligament reconstruction or other similar ligament reconstruction | Reducible: 3LT ligament reconstruction<br>Fixed: some kind of intercarpal fusion (SL, STT) | I Radial styloidectomy<br>II 4CF or PRC<br>III 4CF or PRC + RCPI<br>IV Total wrist fusion or total wrist arthroplasty |

DISI, dorsal intercalated segment instability; FCR, flexor carpi radialis; 4CF, four-corner fusion; PRC, proximal row carpectomy; RCPI, resurfacing capitate pyrocarbon implant; SLAC, scapholunate advanced collapse; 3LT, three-ligament tenodesis; STT, scapho-trapezio-trapezoid; I-IV, SLAC-wrist stages.



**Fig. 9** Classification of the dorsal scapholunate (SL) ligament injury, according to Andersson-Garcia-Elias. Type 1: lateral avulsion (42% of all SL injuries); type 2: medial avulsion (16%); type 3: mid-substance rupture (20%); type 4: partial rupture plus elongation (22%).

- 1) Is the dorsal SLL intact?
- 2) Does the dorsal SLL have sufficient tissue to be repaired?
- 3) Is the scaphoid posture normal?
- 4) Is any carpal malalignment reducible?
- 5) Is the cartilage on the radiocarpal and mid-carpal surfaces normal?

Kitay and Wolfe<sup>4</sup> added one more question: does the abnormal SL relationship involve two distinct planes of deformity (widening and rotatory)?

According to the thesis by Andersson in 2016<sup>48</sup> and Andersson and Garcia-Elias in 2013,<sup>49</sup> we still need to take another factor into account. None of the questions above mention the different types of ligament rupture as a factor

to consider. Any treatment algorithm that does not take account of whether the ligament has stretched out, ruptured or torn off the bone is incomplete. In fact, for the treatment to be successful, it needs to be based on a detailed evaluation of all the factors influencing the outcome. Certainly, the type of ligament rupture is an important one.

The new proposed classification of dorsal scapholunate ligament injury by Andersson and Garcia-Elias<sup>49</sup> (Fig. 9) has both a descriptive and therapeutic value. By all accounts, different types of SLL injury require different types of surgery. If the healing potential of a torn SLL is optimal, repairing the lesion, if easily reduced, in order to recover its original functional strength is the most reasonable approach. The thesis by Andersson<sup>48</sup> and other current opinions claim that repair should be performed within four to six weeks after the index trauma.<sup>1,4,7,20</sup> After that, the ligament ends undergo fibrotic changes, degenerates and ends up not being possible to suture. In SLL injuries, Andersson-Garcia-Elias types 1 and 2 with avulsion injuries, the time to repair could perhaps be extended beyond four to six weeks, due to better blood supply and ligamentous integrity to either the scaphoid or the lunate.<sup>2,6</sup> In particular, the 1b injury ought to be preferable from the point of view of healing, as it contains a bony fragment and is re-inserted to the dorsal ridge of the scaphoid, where the blood supply enters the scaphoid.<sup>2</sup> The healing potential of a torn SLL is probably more optimal in acute avulsion injuries with a bony fragment or in a mid-substance injury with fresh but not attenuated or retracted ligament ends. In these cases, an open repair with ligament re-attachment or suture repair and augmented pin fixation is the most reasonable approach.<sup>29,35,36,49</sup> Bone-to-bone healing is preferable compared with ligament to bone.<sup>50</sup>

The proposed classification is easy to adapt in the clinical setting. The Andersson-Garcia-Elias classification of SLL injuries can be used in both open and arthroscopic surgery and in acute, subacute and chronic injuries. It is also important to keep in mind that it is easy to overestimate the extent of SLL injury and the grade of laxity using only the Geissler classification,<sup>11</sup> particularly in patients with joint hypermobility. Different types of SLL injuries should probably be treated by different methods of surgery. While Andersson-Garcia-Elias type 3 mid-substance ruptures (only 20% of the cases) may allow a direct repair, also by arthroscopic technique, ensuring end-to-end contact of the two ligament stumps, type 1 or 2 ligament avulsions do not allow this. In fact, if the entire ligament has been pulled off the bone, the only feasible solution is to re-attach the avulsed ligament to the denuded bone with trans-osseous sutures or, most commonly, with anchor sutures, by open surgery. Type 4 injuries, involving the elongation of a subtotal ruptured SLL, can be treated by detaching the elongated fascicle and

advancing it to a more distal position over the dorsolateral ridge of the scaphoid, including the augmentation of the repair with some sort of capsulodesis or tenodesis. In some of the patients who have a type 4 injury, arthroscopic plication may also be an alternative. An arthroscopically assisted SL capsuloplasty and suture may not be possible in all patients, particularly not when the ligament has avulsed off the bone (60% of the cases; Andersson-Garcia-Elias types 1 and 2), leaving no ligament remnant on one side.<sup>49</sup> Most patients will require ligament re-attachment techniques using trans-osseous sutures, bone anchors or ligament reconstruction.

## Conclusions

A negative result from MRI is unable to rule out the possibility of a clinically relevant injury to the SLL. Clinical provocation wrist tests are of limited diagnostic value. The current gold standard, wrist arthroscopy, remains the preferred diagnostic technique with sufficient conclusive properties when it comes to wrist ligament injuries.

Four different types of SL injury exist, according to the new classification by Andersson-Garcia-Elias. The type of SL injury can probably be decisive for the choice of surgical approach and for the healing conditions.

According to the literature, the integrity and quality of the dorsal SLL, the posture of the scaphoid (widening and rotatory), carpal alignment and cartilage status contribute to the choice of treatment for SL injury. Early diagnosis is mandatory. Ligament-reconstruction techniques should only be performed when there is easily reducible DISI.

The best treatment of choice in different grades of SL injury is, however, still a matter of discussion and debate. SLL injuries remain a challenging problem, even to experienced hand and upper extremity surgeons. There is still a lack of consensus among hand surgeons as to the appropriate treatment of various stages.

### AUTHOR INFORMATION

Department of Hand Surgery, Sahlgrenska University Hospital, Göteborg, Sweden and Department of Orthopaedics, Institute of Clinical Sciences, The Sahlgrenska Academy, University of Gothenburg, Göteborg, Sweden.

Correspondence should be sent to: Jonny K. Andersson, MD, PhD, Department of Hand Surgery, Sahlgrenska University Hospital, SE-413 45 Göteborg, Sweden. E-mail: jonny\_a@telia.com

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