INJURIES TO THE SCAPHOLUNATE LIGAMENT OF THE WRIST

INTRODUCTION
Scapholunate ligament (SLL) injury of the wrist is common in young individuals and athletes and it is often the consequence of a fall forwards from a height, sport injuries or a motorcycle accident. Goalkeepers in football and handball players (Figures 1a, b) as well as ice hockey players are prone to get this injury. The trauma mechanism is almost the same as in scaphoid fractures and distal radius fracture, but the SL injury is often missed initially as it is not obvious on x-ray or even on Magnetic Resonance imaging (MRI). Wrist arthroscopy is the gold standard and the preferred diagnostic technique with sufficient conclusive properties when it comes to wrist ligament injuries. After subacute re-insertion of SLL or ligament-reconstruction there is a long healing- and rehabilitation time. An outfield football player can go back to training after approximately 6 weeks and match after 8 weeks, but a goalkeeper should wait until 3-4 months postoperative. If the injury is older than 3-4 months at presentation, I prefer to wait with ligament-reconstruction to in between the seasons, and even to after the career, especially if the player is more than 33-35 years old.

In summary:
- 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.

DESCRIPTION OF THE SCAPHOLUNATE LIGAMENT INJURY
Approximately 5% of all wrist sprains have an associated SL tear. 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 (Figure 2). The scapholunate (SL) ligament is the most commonly injured carpal ligament. The SLL is C-shaped and has three structurally distinct parts: volar; membranous; and dorsal (Figure 3a, b). The dorsal part of the SLL is the strongest and can resist forces of up to 260 Newton.

There is a gradient of SL injury severity, when it occurs. It ranges from occult, dynamic SL dissociation (gap), static...
instability, followed by carpal collapse, finally ending up in disabling arthritis (scapholunate advanced collapse (SLAC) wrist).

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 (other extrinsic ligaments in the wrist) of the SL ligament is needed.

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

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. 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 volar flexion, while the lunate, which is still fixed to the triquetrum, is forced, due to carpal kinematics, to follow the triquetrum into dorsal extension. This static instability is often referred to radiologically as dorsal intercalated segment instability (DISI), following an SLL injury (Figure 4).

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.

The end result of long-standing SLL injury with dissociation (SLD) is always DISI and a so-called SLAC wrist (Figure 5). SLAC is the most common pattern of degenerative arthritis 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 at start, but it is most often debilitating, with pain, limited and restricted ROM and loss of strength.
Table 1: Geissler's classification.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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<tr>
<td>Grade I</td>
<td>Attenuation and/or haemorrhage of the interosseous ligament as observed from RC space. No incongruence of carpal alignment in MC space =&gt; treatment by immobilisation.</td>
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<td>Grade II</td>
<td>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, &lt; 2 mm) between the carpal bones maybe present =&gt; treatment by reduction and pinning.</td>
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<td>Grade III</td>
<td>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 (&gt; 2 mm) between the carpal bones =&gt; arthroscopic reduction or open reduction and pinning or repair.</td>
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<tr>
<td>Grade IV</td>
<td>Incongruence and/or step-off of the carpal alignment are observed in both the RC and MC space. Cross 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 =&gt; open re-insertion or ligament reconstruction.</td>
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RC=radiocarpal joint. MC=mid-carpal joint

Table 1: Geissler's classification.

**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) (Figure 6) indicates a total SL injury. However, positive tests occur in approximately 20% of the normal population, which contributes to diagnostic difficulties. 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 counterpressure 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 scaphoid is unstable and can be subluxated dorsally AND the patient experiences pain at the dorsum of the wrist.

**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.

**Figure 3:** a) The different parts of the SL ligament - D=dorsal, the strongest and most important and strong part. P=palmar or mebranous part, V=volar. The SL ligament is C-shaped. b) arthroscopical findings of a total SL injury.
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, Figure 7) with an SL gap of > 3 mm and an SL angle of > 60°. The radiological definition (plain films) of DISI (Figure 4) 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’.
2. on the lateral view, a dorsal tilt of the lunate is typically shown: SL angle > 60° and capitolunate angle > 30° (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. In 2013, Ringler proposed an MRI strategy for the wrist ligaments to increase accuracy in diagnosing wrist ligament injuries:
1. Magnetic strength ≥ 1.5-T;
2. Dedicated wrist coils;
3. Field of view ≤ 10 cm;
4. Slice thickness ≤ 2 mm;
5. Matrix ≥ 384 × 256;
6. MRI sequences including T1-weighted, fat-saturated PD or T2-weight fast spin echo.

In my opinion, the most important thing, although, 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. showed in 2015 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

**Figure 4:** DISI, which tell us that we have a static instability.

**Figure 5:** The end result of long standing SL injury and static instability: SLAC wrist with degenerative arthritis.

**Figure 6:** Schematic figure of the Watson’s test.
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. 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.

MRI with intra-articular contrast can increase the sensitivity and specificity of wrist ligament diagnostics.

**Non-surgical treatment**

A combination of proprioceptive, neuromuscular training and physiotherapeutic treatment regimens appears to yield the greatest improvement in the sensorimotor control and stability of joints in terms of both rehabilitation and treatment strategies (flexor carpi ulnaris, FCU and flexor carpi radialis, FCR re-education). However, the more exact role of wrist proprioception and neuromuscular stability training after wrist ligament injuries and carpal instability needs to be further elucidated, 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 and athletes with high demands, can lead to the progressive deterioration of function, instability, pain, loss of grip strength and finally articular damage. Acute total SL 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 for partial injuries are arthroscopic debridement or thermal shrinkage, pinning or physiotherapy with the re-education of the FCR and FCU. 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, some with promising results and some with less promising results. It is clinically difficult to treat SL ruptures and the results are inconsistent. The injury is often missed because of difficulties in the clinical diagnosis and initial normal plain radiographs. Even if the SLL 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, although, 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 SL 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. 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. Early diagnosis and ligament-repair is still the benchmark and is strongly advocated. Capsulodesis (i.e. Blatt) 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 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 SL 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. 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. 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.

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. Radiographic degenerative changes in the long-term occur in < 30% of patients. Exact reduction and Kirschner-wire fixation without open suture 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 six-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. 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, 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. 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 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 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 (Figure 8) 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-trapeziotrapezoid (STT) ligaments), the dorsal SL is reconstructed and the ulnar translation of the lunate is reduced (which enhances the dorsal radiotriquetral (RTq) ligament). 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 SL. 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 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. 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/sport 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. 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., 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.

In symptomatic static irreducible SLD, the most commonly advocated treatment is partial fusion. The surgical management of the degenerative wrist due to SLAC is still a challenging choice among several different surgical options as salvage operations, such as proximal row carpectomy (PRC, where the surgeon remove the scaphoid, lunate and triquetre and let the capitate fall down to the lunate fossa at the radius), four-corner fusion (where the surgeon removes the scaphoid and makes a fusion between the lunate, capitate, triquetre and hamate – both techniques produce similar results with pain relief and a ROM of flexion 30° to 40°, extension 30° to 40° and 75%, maintained grip force). Total wrist fusion historically provides predictable pain relief at the cost of a complete loss of movement and shock absorption. 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.

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

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?

According to Andersson and Garcia-Elias in 2013, 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 (Figure 9) has both a descriptive and therapeutic value. By all accounts, different types of SL 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— and it should be performed within four to six weeks after the index trauma. 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. 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. 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. Bone-to-bone healing is preferable compared with ligament to bone.

The proposed classification is easy to adapt in the clinical setting. The Andersson-Garcia-Elias classification of SL 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, 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) and maybe also type 4 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 transosseous sutures or, most commonly, with anchor sutures, by open surgery. An arthroscopically assisted SL capsuloplasty and suture may as a matter of fact 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. Most patients will require ligament re-attachment techniques using transosseous 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 DSI.

The best treatment of choice in different grades of SL injury is, however, still a matter of discussion and debate. SL 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.

References
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