Available online at ScienceDirect www.sciencedirect.com

Elsevier Masson France EM|consulte www.em-consulte.com

Hand Surgery & Rehabilitation

Hand Surgery and Rehabilitation 35 (2016) 341–347

Original article

Scapholunate interosseous ligament injury in professional volleyball players

Lésion du ligament scapho-lunaire interosseux chez les joueurs professionnels de volley-ball

R. Mugnai [a,*], N. Della Rosa [b], L. Tarallo [a]

[a] *Orthopedics and Traumatology Department, University Hospital Policlinico di Modena, Modena, Italy*
[b] *Department of Hand Surgery and Microsurgery, University Hospital Policlinico di Modena, Modena, Italy*

Received 18 February 2016; received in revised form 30 May 2016; accepted 21 July 2016
Available online 27 August 2016

Abstract

Injuries to the scapholunate interosseous ligament (SLIL) are the most common cause of carpal instability. A SLIL injury typically follows a fall on an outstretched hand, with the wrist in hyperextension, ulnar deviation and intercarpal supination. We hypothesize that repetitive axial loading on the wrist in hyperextension, during the reception and digging motions of volleyball, can lead to functional overloading of the SLIL.

To identify patients and to determine the clinical history and surgical treatment performed, we analyzed hospital records, X-rays, electronic databases containing all the operations performed, and image files (including before and after surgery and follow-up).

We identified three SLIL injury cases in national volleyball team players, also at the libero position, who were treated at our clinic between 2007 and 2013 for scapholunate instability. Open reduction and Berger capsulodesis was performed in all cases. At a mean follow-up of 3 years (range, 22–50 months), the mean pain level on VAS was 0.3 (range, 0–1) at rest and 1.7 (range 1–2) during sport activities. The mean DASH score was 4 (range 2–5). The mean wrist flexion was 60° (range 55–70°) and extension was 80° (range 75–85°).

Given the greater susceptibility of these players for developing a SLIL injury, a high index of suspicion is needed when managing athletes presenting with wrist pain or instability.

Keywords: Scapholunate interosseous ligament; SLIL; Carpal instability; Volleyball; Sport; Libero; Athletes

Résumé

Les lésions du ligament scapho-lunaire interosseux (LSLIO) sont la cause la plus fréquente d'instabilité du carpe. Une lésion du LSLIO succède classiquement à une chute sur la main étendue, avec le poignet en hyperextension, en inclinaison ulnaire et en supination intercarpienne. Nous avons émis l'hypothèse qu'une mise en charge axiale répétitive du poignet en hyperextension pendant la réception et l'interception pouvait être responsable d'une surcharge fonctionnelle du LSLIO.

Pour retrouver les patients et reconstituer l'histoire clinique et les traitements chirurgicaux réalisés, nous avons analysé les courriers hospitaliers, les radiographies, les données informatiques contenant les protocoles opératoires et les dossiers d'images (y compris pré et post opératoires et pendant le suivi).

Nous avons identifié trois cas de joueurs de volley-ball de niveau national, spécialement des libéros, traités dans notre établissement entre 2007 et 2013 pour une instabilité scapho-lunaire. Une réduction à ciel ouvert et une capsulodèse selon Berger ont été réalisées dans tous les cas. Au recul moyen de trois ans (22–50 mois), la douleur sur l'échelle visuelle analogique était à 0,3 (0–1) au repos et à 1,7 (1–2) pendant l'activité sportive. Le score DASH moyen était de 4 (2–5). La flexion moyenne de poignet était de 60° (55–70), l'extension moyenne de poignet était de 80° (75–85).

* Corresponding author.
E-mail address: raffaele.mugnai@gmail.com (R. Mugnai).

http://dx.doi.org/10.1016/j.hansur.2016.07.003

Etant donnée la grande susceptibilité de ses joueurs à développer ce type de lésion, nous conseillons un haut degré de suspicion d'une lésion du LSLIO quand de telles athlètes se présentent pour une douleur ou une instabilité du poignet.

Mots clés : Ligament scapho-lunaire interosseux ; LSLIO ; Instabilité du carpe ; Volley-ball ; Sport ; Libero ; Athlètes

1. Introduction

Injuries to the scapholunate interosseous ligament (SLIL) are the most common cause of carpal instability [1–3] and can be associated with other lesions such as secondary ligament ruptures and wrist or carpal bones fractures [4,5].

The SLIL is part of a delicately balanced system of intrinsic and extrinsic ligaments, which ensure wrist stability and allow proper load transmission through the carpal joints [6–8]. The complexity of the secondary stabilizers explains why a SLIL lesion leads to a spectrum of instability [7,9], rather than a unique clinical manifestation, depending on bone congruency and, most importantly, additional ligament damage. Along with static scapholunate (SL) instability, which can be diagnosed based on plain radiographs, the term ''dynamic SL instability'' has been used to describe milder conditions, in which the integrity of secondary ligaments requires forceful maneuvers and stress radiographs for the instability to be detected [8,10]. Nevertheless, it is very important to recognize this lesion because a SLIL disruption alters wrist kinematics. If undiagnosed and untreated, it can cause progressive arthritic degeneration over time, leading to an end-stage condition known as scapholunate advanced collapse (SLAC) [11].

Many studies have shown that this injury is common in athletes prone to developing acute and chronic wrist injuries, like football players [12], baseball players [13], basketball players [14] and gymnasts [15]. Here, we report on three cases of national volleyball team players (from two different countries), all libero players, who were treated for scapholunate instability at our clinic between 2007 and 2013.

2. Patients and methods

To identify patients and to determine the clinical history and surgical treatment performed, we analyzed hospital records, X-rays, electronic databases containing all the operations performed, and image files (including before and after surgery and follow-up). All patients gave informed consent prior to being included in the study. This study was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki, as revised in 2000. The postoperative clinical evaluation was performed by one of the authors and included an analysis of passive range of motion (ROM), functional results based on the Disabilities of Arm, Shoulder and Hand (DASH) questionnaire, pain levels both at rest and during sport activities with a 10 cm visual analogue scale (VAS).

3. Cases description

3.1. Case 1

A 35-year-old right-hand dominant male libero player presented with a 4-week history of right wrist pain and popping, following a fall on his outstretched palm. He had misinterpreted the injury and treated it as a simple sprain. Examination revealed dorsal wrist swelling and tenderness over the scapholunate joint. Provocative ligament testing was hampered by the pain.

Anterior–posterior (AP) radiographs appeared normal, whereas lateral radiographs showed abnormal scaphoid palmar flexion, with a scapholunate angle greater than 70°. A high-resolution magnetic resonance imaging (MRI) exam showed a SLIL tear and an associated avulsion of the dorsal tubercle of the lunate (Fig. 1).

An open repair through a dorsal approach was performed. Capsulotomy with a radial-based triangular flap was performed according to Berger et al. [16]. Intraoperative shear test showed

Fig. 1. High-resolution MRI showing a SLIL tear and associated avulsion of the dorsal tubercle of the lunate.

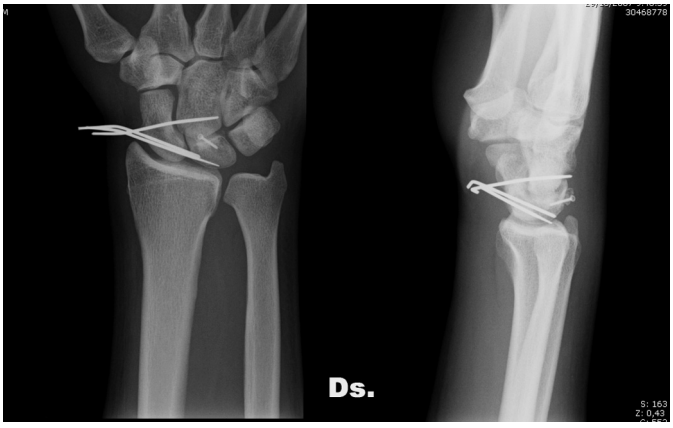

Fig. 2. Post-operative X-rays showing reduction and pinning of the scapholunate interval (two scapholunate K-wires and one scaphocapitate K-wire) and screw fixation of the avulsed lunate fragment.

dorsal dislocation of the capitate on the lunate (video available as a supplementary file). Surgical treatment consisted of reduction and pinning of the scapholunate interval (two scapholunate K-wires and one scaphocapitate K-wire) and screw fixation of the avulsed lunate fragment (Fig. 2).

The K wires were removed 6 weeks after surgery. Wrist physical therapy exercises were prescribed; the patient's symptoms improved and he was able to return to play after 4 months (Fig. 3).

3.2. Case 2

A 23-year-old right-hand dominant male libero player presented with painful clicking and loss of grip strength in his right wrist. He could not recall an injury event and was barely able to remember the onset of these symptoms, which he said was approximately 3 months prior. Local steroid injections were performed by the team doctor without substantial benefit. Physical examination revealed tenderness over the dorsal aspect of the wrist at the lunate fossa. The Watson scaphoid shift test [17] was positive, as a painful clunk was evoked when pressure was applied on the volar aspect of the scaphoid, into radial deviation of the wrist.

Fig. 3. Clinical evaluation 3 months after surgery showing nearly complete recovery of wrist extension, which is of primary importance for someone playing the libero position in volleyball.

On the X-rays, an increased radiolunate angle (greater than 15°) indicating a DISI pattern was visible, but neither abnormal scapholunate angle nor SL diastasis were found (Fig. 4). Imaging studies were completed with MRI, which confirmed the DISI deformity, suggestive of a SLIL lesion (Fig. 5).

Clinical suspicion of a SLIL injury was confirmed with an arthroscopic evaluation, which revealed the presence of a chronic Geissler grade III lesion. The scapholunate joint was stabilized through open reduction, pinning and Berger capsulodesis procedure [18].

Three months after the surgery, the patient was fully recovered and able to resume training.

3.3. Case 3

A 33-year-old right-hand dominant male libero player presented with a 4-month history of snapping sensations and pain of his right wrist. He could not recall falling on a hyperextended wrist. Local steroid injections were performed by the team doctor without substantial benefit. On examination, pain was elicited during palpation over the dorsal SL interval and the SL shift test was positive. Radiographs showed a DISI pattern, which was confirmed by an MRI. No other abnormalities were detected. A high index of suspicion for a SLIL lesion, based on clinical presentation, images, and

Fig. 4. Lateral X-rays showing a scapholunate angle of 53°. The arrow points to evidence of local steroid injections.

Fig. 5. High-resolution MRI confirmed the DISI deformity (radiolunate angle = 42°), but was not able to detect any apparent signs of SLIL disruption.

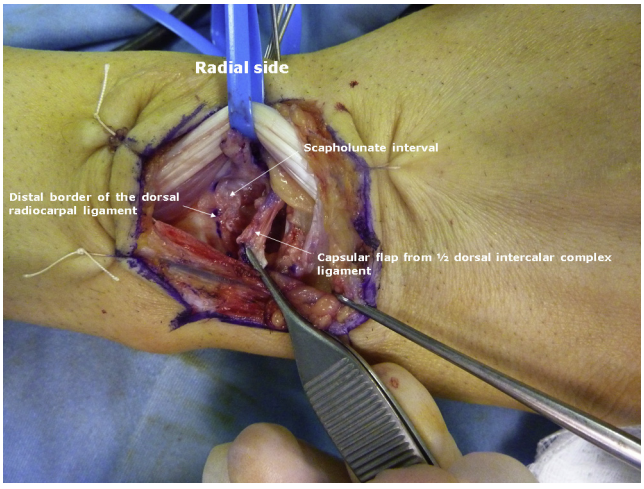

Fig. 6. Intraoperative view of the Berger capsulodesis procedure.

positive volar drawer test, led us to complete the evaluation with wrist arthroscopy.

Wrist arthroscopy showed a Geissler type III partial SLIL tear associated with rotational subluxation of the scaphoid. Scapholunate anatomic position was restored and stabilized with K-wire pinning. The repair was reinforced with a Berger capsulodesis (Fig. 6).

After three months of rehabilitation, the patient was able to return to play.

3.4. Clinical outcome

For these three athletes, at a mean follow-up of 3 years (range 22–50 months), the mean pain level on VAS was 0.3 (range 0–1) at rest and 1.7 (range 1–2) during sport activity. The mean DASH score was 4 (range 2–5). The mean wrist flexion was 60° (range 55–70°) and extension was 80° (range 75–85°).

4. Discussion

A SLIL injury typically follows a fall on an outstretched hand, with the wrist in hyperextension, ulnar deviation and intercarpal supination [19].

The libero position was first introduced by the International Federation of Volleyball (FIVB) in 1996 [20]. In 1998, it was internationally recognized and in 2002, the National Collegiate Athletic Association (NCAA) rules were changed to include this new role. The libero is a player specialized in serve reception and defensive tasks. Reception and digging actions are performed by the libero to save the ball. Digging is the ability to prevent the ball from touching one's court after a spike, particularly a ball that is nearly touching the ground. A player sometimes performs a "dive", *i.e.*, throw his or her body in the air with a forward movement in an attempt to save the ball, and land on his or her chest. We hypothesize that the repetitive axial loading on the wrist in hyperextension, required by these activities to get up fast or push the body forward on the ground, can cause functional overloading of the SLIL (Figs. 7 and 8). Since the libero role has been introduced relatively recently in volleyball, there are no other reported cases in the scientific literature, but we believe that more will be in the coming years.

Diagnosing a SLIL tear can be very challenging. In the acute setting, pain and swelling are common, but a less severe clinical presentation than the one experienced with fractures and particularly non-traumatic lesions frequently mislead the patients to underestimate the injury and to seek medical assistance weeks to months later, because the pain has not gone away [6,10].

The classic manifestations of sub-acute or chronic injuries comprise weakness during gripping movements, catching, popping and pain in the wrist [2,8]. Steps must be taken to diagnose a SLIL lesion even with the mildest symptoms. The best approach includes physical examination, which should aim

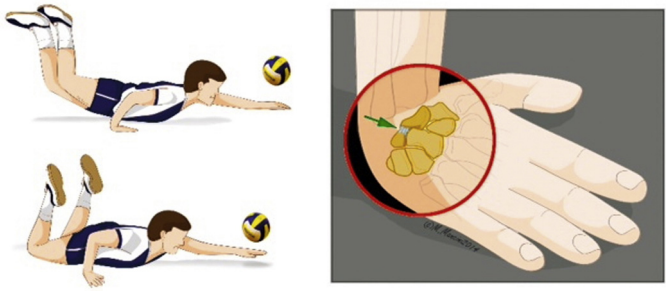

Fig. 7. Axial loading on the wrist in hyperextension, during serve reception and digging, causing functional overloading of the SLIL.

Fig. 8. Photo of a libero player showing how the hyperextended wrist is undergoing axial loading.

to exclude the presence of generalized ligamentous laxity [2], carrying out provocative maneuvers (*i.e.* Watson scaphoid shift test) [17] and an accurate radiological assessment.

On the X-rays, scapholunate diastasis (>3 mm), the ring sign (flexion of the scaphoid) and a scapholunate angle greater than 60° are all criteria indicative of static scapholunate instability. However normal X-rays are not sufficient to exclude a SLIL injury [2]. Lack of integrity of the secondary ligaments can give rise to dynamic instability, which can be uncovered only on stress X-ray views. MRI adds more information to the plain X-rays studies, as it provides better sensitivity and specificity in recognizing ligament and other soft tissues tears [21].

A cadaveric study was performed to compare the sensitivity, specificity and accuracy of CT arthrography, conventional 3-T MRI, and MR arthrography in detecting SLIL, lunotriquetral ligament, and triangular fibrocartilage complex tears [22]. The accuracy of CT arthrography and MR arthrography was about 90–100%, while that of conventional MRI accuracy was 70–90%. In particular the sensitivity, specificity and accuracy were 66%, 86%, and 80%, respectively, for conventional 3-T MR; 100%, 86%, and 90% for MR arthrography; and 100% using CT arthrography in detecting SLIL tears. Overall, injected exams, and in particular CT arthrography, are a better method to identify SLIL tears than conventional MRI [22].

However, arthroscopy is currently considered the gold standard for evaluating a scapholunate lesion, as it provides direct visualization of the injured structures [6]. In the current study, we used the classification proposed by Geissler [23], which did not correlate the degree of SL joint laxity to the specific tissue injury site. Several cadaveric studies have focused on the role of extrinsic ligaments in maintaining carpal stability [24]. This finding led to the development of new arthroscopic classification systems that include an *in vivo* assessment of the extrinsic ligaments of the wrist [25].

A recent study examined the relationship between arthroscopic Geissler grades and specific anatomic lesions of the SL supporting ligaments. The authors demonstrated that sequential sectioning of the SL supporting ligaments caused a progressive increase in the Geissler grade, suggesting that the Geissler grade correlates with damage to distinct anatomical structures. In particular, Grade II was identified with lesions to the SLIL, particularly in the volar and membranous portions. Grade III followed sectioning of the dorsal SLIL and the volar extrinsic ligaments (radioscaphocapitate and long radiolunate ligaments). Sectioning of the dorsal extrinsic stabilizers was a key component in the progression from grade III to grade IV wrists [26].

The treatment strategy depends on several factors, such as the grade of the disruption, condition of secondary stabilizers, reducibility of the scapholunate joint and the patient's functional needs. When dealing with professional players, the aims of treatment are to relieve the symptoms, prevent progression to osteoarthritis and allow the athlete to resume training as soon as possible; as a consequence, a non-surgical approach may not be sufficient to achieve the patients' expectations in terms of recovery.

Early diagnosis is crucial as there is a significant difference between treatment strategies for acute or chronic lesions, and functional outcomes are improved when surgery is performed early on [27–29]. Numerous surgical procedures have been described to treat this condition.

Patients with acute partial tears (Geissler grades I, II, III) can be treated successfully with arthroscopic debridement and temporary K-wire stabilization of the SL and scaphocapitate joints [8,30]. Acute complete lesions (Geissler grade IV) are better addressed with open ligament repair, reinforced by dorsal capsulodesis [8,25–27,30–32].

Treatment of chronic lesions (more than 6 weeks old) is consistently influenced by the presence of secondary osteoarthritis. In chronic partial tears (Geissler grades I, II) arthroscopic debridement and pinning can still be attempted. However, an intense debate exists on how to best treat chronic lesions (especially Geissler grade III, IV), with many techniques proposed such as capsulodesis [18,30,32–34], arthroscopic-assisted techniques with dorsal capsulo-ligamentous repair [35] or bone-ligament-bone graft [36], tendon grafts [8], tenodesis [37,38], induced pseudoarthrosis (RASL procedure) [38], and new techniques including the scapholunate axis method (SLAM) [39] and the scapholunate intercarpal (SLIC) screw [40].

Chronic lesions complicated by arthritis require a different approach. The available options include: denervation and radial styloidectomy [41,42], proximal row carpectomy [43], arthrodesis and total wrist arthroplasty [8,42].

In our series, postoperative management consisted of a physical therapy program, and all the athletes were able to resume full training.

SLIL lesions are the most frequent cause of carpal instability. Besides acute injuries, very often the patient, and particularly the athlete, tends to misinterpret this condition as a simple sprain and only seeks medical advice weeks or months later, when the pain has not gone away. In addition, dynamic instabilities need imaging modalities beyond simple X-rays to be uncovered. If left untreated, these injuries can interfere with activities and progress to osteoarthritis, so it is very important to recognize and treat them appropriately. We would like to stress

the importance of early diagnosis. This allows the surgeon to perform less invasive techniques such as arthroscopy and pinning, and leads to better functional outcomes [28,29], which is particularly important when dealing with demanding professional athletes.

On the other hand, in chronic lesions (notably Geissler grade III and IV), the outcomes of all the available procedures tend to deteriorate over time, leading to variable grades of stiffness and residual pain, especially in those who place high demands on their wrists [44–46]. In such cases, it is very important to discuss the risk–benefit ratio with the athlete and possibly delay surgical treatment until the end of his professional career.

5. Conclusions

Given the greater susceptibility of volleyball players (especially the libero) to developing this kind of injury, we advise having a high index of suspicion for a SLIL lesion when managing athletes who present with complaints of wrist pain or instability. We have also treated some teenage volleyball players with partial tears in our clinic; we believe that education on how to correctly perform certain movements, from the very beginning of their training, may play an important role in preventing these injuries.

Disclosure of interest

The authors declare that they have no competing interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.hansur.2016.07.003.

References

[1] Boabighi A, Kuhlmann JN, Kenesi C. The distal ligamentous complex of the scaphoid and the scapho-lunate ligament. An anatomic, histological and biomechanical study. J Hand Surg Br 1993;18:65–9.
[2] Chennagiri RJ, Lindau TR. Assessment of scapholunate instability and review of evidence for management in the absence of arthritis. J Hand Surg Eur Vol 2013;38:727–38.
[3] Garcia-Elias M, Geissler WB. Carpal instability. In: Green DP, Hotchkiss RN, Pederson WC, Wolfe SW, editors. Green's operative hand surgery. 5th ed., Philadelphia: Churchill Livingstone; 2005. p. 535–604.
[4] Garcia-Elias M. The treatment of wrist instability. J Bone Joint Surg Br 1997;79:684–90.
[5] Richards RS, Bennett JD, Roth JH, Milne Jr K. Arthroscopic diagnosis of intra-articular soft tissue injuries associated with distal radial fractures. J Hand Surg Am 1997;22:772–6.
[6] Caggiano N, Matullo KS. Carpal instability of the wrist. Orthop Clin North Am 2014;45:129–40.
[7] Garcia-Elias M, Lluch AL, Stanley JK. Three-ligament tenodesis for the treatment of scapholunate dissociation: indications and surgical technique. J Hand Surg Am 2006;31:125–34.
[8] Kitay A, Wolfe SW. Scapholunate instability: current concepts in diagnosis and management. J Hand Surg Am 2012;37:2175–96.
[9] Watson H, Ottoni L, Pitts EC, Handal AG. Rotary subluxation of the scaphoid: a spectrum of instability. J Hand Surg Br 1993;18:62–4.
[10] Lewis DM, Osterman AL. Scapholunate instability in athletes. Clin Sports Med 2001;20:131–40. ix.
[11] Watson HK, Ballet FL. The SLAC wrist: scapholunate advanced collapse pattern of degenerative arthritis. J Hand Surg Am 1984;9:358–65.
[12] Brody GA. Commentary: scapholunate ligament injuries in professional football players. Hand Clin 2012;28:267–8.
[13] Graham TJ. Perspective on scapholunate ligament injuries in baseball players. Hand Clin 2012;28:261–4.
[14] Melone Jr CP, Polatsch DB, Flink G, Horak B, Beldner S. Scapholunate interosseous ligament disruption in professional basketball players: treatment by direct repair and dorsal ligamentoplasty. Hand Clin 2012;28:253–60. vii.
[15] Snider MG, Alsaleh KA, Mah JY. Scapholunate interosseous ligament tears in elite gymnasts. Can J Surg 2006;49:290–1.
[16] Berger RA, Bishop AT, Bettinger PC. New dorsal capsulotomy for the surgical exposure of the wrist. Ann Plast Surg 1995;35(1)54–9.
[17] Watson HK, Ashmead 4th D, Makhlouf MV. Examination of the scaphoid. J Hand Surg Am 1988;13:657–60.
[18] Moran SL, Cooney WP, Berger RA, Strickland J. Capsulodesis for the treatment of chronic scapholunate instability. J Hand Surg Am 2005;30:16–23.
[19] Mayfield JK, Johnson RP, Kilcoyne RK. Carpal dislocations: pathomechanics and progressive perilunar instability. J Hand Surg Am 1980;5:226–41.
[20] Web reference for Libero. http://www.fivb.org/en/volleyball/Basic_Rules.asp.
[21] Magee T. Comparison of 3-T MRI and arthroscopy of intrinsic wrist ligament and TFCC tears. AJR Am J Roentgenol 2009;192:80–5.
[22] Lee RK, Ng AW, Tong CS, Griffith JF, Tse WL, Wong C, et al. Intrinsic ligament and triangular fibrocartilage complex tears of the wrist: comparison of MDCT arthrography, conventional 3-T MRI, and MR arthrography. Skeletal Radiol 2013;42(9)1277–85.
[23] Geissler WB, Freeland AE, Savoie FH, McIntyre LW, Whipple TL. Intracarpal soft-tissue lesions associated with an intra-articular fracture of the distal end of the radius. J Bone Joint Surg Am 1996;78(3)357–65.
[24] Messina JC, Van Overstraeten L, Luchetti R, Fairplay T, Mathoulin CL, The EWAS. Classification of scapholunate tears: an anatomical arthroscopic study. J Wrist Surg 2013;2(2)105–9.
[25] Van Overstraeten L, Camus EJ. A systematic method of arthroscopic testing of extrinsic carpal ligaments: implication in carpal stability. Tech Hand Up Extrem Surg 2013;17(4)202–6.
[26] Lee SK, Model Z, Desai H, Hsu P, Paksima N, Dhaliwal G. Association of lesions of the scapholunate interval with arthroscopic grading of scapholunate instability via the Geissler classification. J Hand Surg Am 2015;40(6)1083–7.
[27] Bickert B, Sauerbier M, Germann G. Scapholunate ligament repair using the Mitek bone anchor. J Hand Surg Br 2000;25:188–92.
[28] Ruch DS, Poehling GG. Arthroscopic management of partial scapholunate and lunotriquetral injuries of the wrist. J Hand Surg Am 1996;21:412–7.
[29] Weiss AP, Sachar K, Glowacki KA. Arthroscopic debridement alone for intercarpal ligament tears. J Hand Surg Am 1997;22:344–9.
[30] Blatt G. Capsulodesis in reconstructive hand surgery. Dorsal capsulodesis for the unstable scaphoid and volar capsulodesis following excision of the distal ulna. Hand Clin 1987;3:81–102.
[31] Kuo CE, Wolfe SW. Scapholunate instability: current concepts in diagnosis and management. J Hand Surg Am 2008;33:998–1013.
[32] Slater Jr RR, Szabo RM, Bay BK, Laubach J. Dorsal intercarpal ligament capsulodesis for scapholunate dissociation: biomechanical analysis in a cadaver model. J Hand Surg Am 1999;24:232–9.
[33] Manuel J, Moran SL. The diagnosis and treatment of scapholunate instability. Orthop Clin North Am 2007;38:261–77. vii.
[34] Camus EJ, Van Overstraeten L. Dorsal scapholunate stabilization using Viegas' capsulodesis: 25 cases with 26 months-follow-up. Chir Main 2013;32(6)393–402.
[35] Wahegaonkar AL, Mathoulin CL. Arthroscopic dorsal capsulo-ligamentous repair in the treatment of chronic scapho-lunate ligament tears. J Wrist Surg 2013;2(2)141–8.
[36] Dellarosa N, Ozben H, Abate M, Russomando A, Petrella G, Landi A. An arthroscopic-assisted minimal invasive method for the reconstruction of

the scapho-lunate ligament using a bone-ligament-bone graft. J Hand Surg Eur Vol 2016;41(1)64–71.
[37] Brunelli GA, Brunelli GR. A new technique to correct carpal instability with scaphoid rotary subluxation: a preliminary report. J Hand Surg Am 1995;20:S82–5.
[38] Talwalkar SC, Edwards AT, Hayton MJ, Stilwell JH, Trail IA, Stanley JK. Results of tri-ligament tenodesis: a modified Brunelli procedure in the management of scapholunate instability. J Hand Surg Br 2006;31:110–7.
[39] Yao J, Zlotolow DA, Lee SK. Scapholunate axis method. J Wrist Surg 2016;5(1)59–66.
[40] SystemAcumed® (2013): Sales Representative Guide to Biometals. GEN60-383 01-B. Effective.
[41] Rothe M, Rudolf KD, Partecke BD. [Long-term results following denervation of the wrist in patients with stages II and III SLAC-/SNAC-wrist]. Handchir Mikrochir Plast Chir 2006;38:261–6.
[42] Chantelot C. Post-traumatic carpal instability. Orthop Traumatol Surg Res 2014;100:S45–53.
[43] DiDonna ML, Kiefhaber TR, Stern PJ. Proximal row carpectomy: study with a minimum of ten years of follow-up. J Bone Joint Surg Am 2004;86:2359–65.
[44] Gajendran VK, Peterson B, Slater Jr RR, Szabo RM. Long-term outcomes of dorsal intercarpal ligament capsulodesis for chronic scapholunate dissociation. J Hand Surg Am 2007;32:1323–33.
[45] McAuliffe JA, Dell PC, Jaffe R. Complications of intracarpal arthrodesis. J Hand Surg Br 1993;18:1121–8.
[46] Pomerance J. Outcome after repair of the scapholunate interosseous ligament and dorsal capsulodesis for dynamic scapholunate instability due to trauma. J Hand Surg Am 2006;31:1380–6.