Biomechanical Analysis of Three Different Reconstruction Techniques for Scapholunate Instability: A Cadaveric Study

Seungbum Chae, MD, Junho Nam, MD, Il-Jung Park, MD*, Steve S. Shin, MD†, Michelle H. McGarry, MS‡, Thay Q Lee, PhD‡

Background: This study aimed to compare the biomechanical strength of 360° scapholunate interosseous ligament (SLIL) reconstruction only using an artificial material (AM), double dorsal limb (DDL) SLIL reconstruction only using AM, and the modified Brunelli technique (MBT) with ligament.

Methods: Eight cadaver wrists were used for this study. The SL interval, SL angle, and radiolunate (RL) angle were recorded with MicroScribe. The SL distance was measured after dividing the volar and dorsal aspects. We utilized four different wrist postures (neutral, flexion, extension, and clenched fist) to compare five conditions: intact wrist, SLIL resection, 360° SLIL reconstruction using AM, DDL SLIL reconstruction using AM, and MBT SLIL reconstruction with ligament.

Results: The dorsal SL distance in the SLIL resection was widened in all wrist positions. The dorsal SL distance was restored with all three techniques and in all wrist positions. The volar SL distance in the wrist extension position was widened in the SLIL resection condition. The volar SL distance was restored in the extension position after 360° SLIL reconstruction using AM condition. There were no statistically significant differences in SL and RL angles among the conditions.

Conclusions: All three reconstruction techniques could restore the dorsal SL distance. However, only the 360° SLIL reconstruction using AM restored the volar SL distance in the wrist extension position. DDL SLIL reconstruction using AM tended to overcorrect, whereas 360° SLIL reconstruction using AM effectively stopped volar SL interval widening.

Keywords: Wrist, Ligaments, Scapholunate reconstruction

Scapholunate interosseous ligament (SLIL) rupture is known as one of the main causes of wrist instability. In most cases, the symptoms are mild, and the diagnosis is often delayed, making treatment difficult.¹⁻³ In the case of acute rupture, good results can be expected with simple sutures. In the case of chronic rupture, however, there are various treatment methods including dorsal capsulodesis, reduction and association of the SL joint using a screw, SL axis method, bone-ligament-bone grafting, and reconstruction of the SL ligament, which have not shown consistent results.¹⁻³,⁴⁻¹⁰ As the importance of dorsal SLIL was reported by Burger, reconstruction of the scaphoid interosseous ligament was developed with more focus on the dorsal region, but the results are reported to be unpredictable for a variety of reasons, including surgical technique, various tensions of the graft ligament, timing of
the surgery, weak stiffness of a graft tendon, and delayed rehabilitation.\textsuperscript{1,2,8,11-13}

We tried to study a method using an artificial material instead of a tendon graft to facilitate rapid rehabilitation by increasing the rigidity of the reconstruction site. The artificial material is a high-strength nonabsorbable tape-type thread that helps maintain rigidity of the reconstruction site, enabling rapid rehabilitation after surgery. The fiber-tape thread is currently used in various orthopedic reconstructions, such as anterior talofibular ligament reconstruction of the ankle, medial collateral ligament reconstruction of the knee, and ulnar collateral ligament reconstruction of the thumb.\textsuperscript{14,15}

We performed a comparative biomechanical study on two SLIL reconstruction methods that use an artificial material (AM) as a substitution for true ligaments (double dorsal limb [DDL] reconstruction) (Fig. 1A) and 360° SLIL reconstruction (Fig. 1B), as well as a conventional reconstruction method using a true ligament (the modified Brunelli technique [MBT]) (Fig. 1C). In DDL reconstruction, there are three fixation points, which are distal scaphoid, proximal scaphoid, and the center of the lunate to avoid invading the articular surface.

**METHODS**

This Study was done with only cadavers. Eight fresh-frozen cadavers were used in this study (mean age, 61.3 years; range, 51–75 years; 5 men; 6 right-sided). The forearm specimens were transected at a distance of 12 cm from the tip of the radial styloid process. Midline dorsal and volar forearm incisions were made, and skin flaps were removed. We tried to reproduce the wrist motion using Pollack's method.\textsuperscript{16} On the volar side, the flexor carpi radialis, flexor carpi ulnaris, and flexor digitorum profundus tendon were dissected; on the dorsal side, the extensor carpi ulnaris, extensor carpi radialis longus, and extensor carpi radialis brevis tendon were dissected, and a weight was applied to implement wrist motion (Table 1). The wrist dorsal capsule was excised to confirm whether the SLIL was intact. MicroScribe (Gommeasure3D, Amherst, VA, USA) was used to measure the SL interval on the dorsal and volar sides. Using a pencil-shaped device of MicroScribe, the button on a pre-inserted marker (miniscREW) was pressed on the bone. MicroScribe displayed the location of the place in three-dimensional space using the X, Y, and Z axes (Fig. 2). As MicroScribe measured the SL interval, functions could be used to obtain the SL and radiolunate (RL) angles. The authors inserted two markers

| Wrist posture | Tendon          | Load (N) |
|---------------|-----------------|----------|
| Wrist flexion | FCR             | 10       |
|               | FCU             | 10       |
| Wrist extension | ECRL + ECRB    | 10       |
|               | ECU             | 10       |
| Ulnar deviation | FCU            | 10       |
|               | ECU             | 10       |
| Radial deviation | FCR            | 10       |
|               | ECRL + ECRB    | 10       |
| Clenched fist | FDP + FDS      | 10       |
|               | ECRL + ECRB    | 10       |
|               | ECU             | 10       |

FCR: flexor carpi radialis, FCU: flexor carpi ulnaris, ECRL: extensor carpi radialis longus, ECRB: extensor carpi radialis brevis, FDP: flexor digitorum profundus, FDS: flexor digitorum superficialis.

![Fig. 1. Methods of scapholunate interosseous ligament (SLIL) reconstruction. (A) Double dorsal limb SLIL reconstruction. (B) The 360° SLIL reconstruction. (C) The modified Brunelli technique.](image-url)
for the MicroScribe device in the metacarpal, two in the distal radius, one each in the volar and dorsal sides of the lunate, and two and one in the scaphoid volar and dorsal side, respectively (Fig. 3). The prepared specimen was fixed to a 6-cm-long PVC pipe using plaster (Fig. 4). The prepared specimen was hung on a custom wrist motion simulator system, and a weight was attached to the dissected ligament to make six wrist motions: neutral, flexion, extension, radial deviation, ulnar deviation, and clenched fist (CF). The experiment was conducted under the following cadaver conditions: (1) intact condition, (2) SLIL resection condition, (3) DDL SLIL reconstruction condition, (4) 360° SLIL reconstruction condition, and (5) MBT condition. The order of (3) and (4) was randomized. The dorsal and volar distances of the SL, SL angle, and RL angle were measured in the six wrist positions for each condition. We measured twice and if there was a difference within 1 mm in each axis, the data were accepted as consistent.

However, two problems were encountered in the pilot test. The first is that the soft-tissue condition was different for each specimen; thus, the deviation of the wrist joint motion was too large when reproducing the six wrist motions, and the data were inconsistent. Second, the markers in the volar region were hidden between carpal bones and radius in the flexion and extension positions, making it impossible to measure with MicroScribe. To solve this problem, a wrist motion was made at the same angle in all specimens with the same weight suspended on each muscle. A device that can achieve a constant angle was installed on the bottom of the hand zig, and a bar was attached to the third metacarpal and set to 0° in the neutral position, 60° in flexion and extension, and 0° in the CF position (Fig. 5) with a goniometer. Furthermore, the marker located on the volar side in wrist flexion and the one on the dorsal side in wrist extension were not measured because the strain loaded on the SLIL changes according to the wrist position. The strain increases on the volar side of SLIL when the wrist is extended. As in the pilot test, it was observed that the strain in the dorsal SLIL increased during flexion, the distance of the dorsal SL increased, and during extension, the strain in the volar SLIL increased and the volar SL interval increased (Fig. 6). Therefore, since the volar SL interval decreased in wrist flexion, it was judged that the influence of the SLIL reconstruction structure in the volar region would be limited, and thus measurement was not essential. Likewise, it was not necessary to measure the dorsal SL interval for the same reason during extension. Finally, eight cadavers made four wrist mo-
tions (neutral, flexion, extension, and CF positions) under five experimental conditions to observe the change of the SL joint (Table 2, Fig. 7). The repeated measures analysis of variance was used to determine statistical significance. All analyses were conducted using IBM SPSS version 21.0 (IBM Corp., Armonk, NY, USA) and presented as mean ± standard deviation. The p-values of 0.05 or less were considered statistically significant.

**RESULTS**

**SL Interval Distance**

A statistically significant difference in the dorsal SL interval in the neutral, flexion, and CF positions was found between the SLIL resection condition and the intact condition (neutral: \( p = 0.015 \); flexion: \( p = 0.003 \); CF: \( p = 0.003 \)). The dorsal SL interval was maintained in the neutral, wrist flexion, and CF positions after DDL SLIL reconstruction using AM (neutral: \( p = 0.007 \); flexion: \( p = 0.001 \); CF: \( p = 0.002 \)), 360° reconstruction using AM (neutral: \( p = 0.009 \); flexion: \( p = 0.001 \); CF: \( p = 0.002 \)), and MBT (neutral: \( p =

---

**Table 2.** Four Wrist Motions with Weights on the Tendons to Observe the Change of the Scapholunate Joint

| Wrist posture | Tendon | Load (N) | Angle (°) |
|---------------|--------|----------|-----------|
| Neutral       | FCR    | 10       | 0         |
|               | FCU    | 10       |           |
|               | ECRL + ECRB | 10      |           |
|               | ECU    | 10       |           |
| Flexion       | FCR    | 10       | 60        |
|               | FCU    | 10       |           |
|               | ECRL + ECRB | 10      |           |
|               | ECU    | 10       |           |
| Extension     | FCR    | 10       | 60        |
|               | FCU    | 10       |           |
|               | ECR + ECRB | 10      |           |
|               | ECU    | 10       |           |
| Clenched fist | FCR    | 10       | 0         |
|               | FCU    | 10       |           |
|               | ECR + ECRB | 10      |           |
|               | ECU    | 10       |           |
|               | FDP + FDS | 20      |           |

FCR: flexor carpi radialis, FCU: flexor carpi ulnaris, ECRL: extensor carpi radialis longus, ECRB: extensor carpi radialis brevis, FDP: flexor digitorum profundus, FDS: flexor digitorum superficialis.

---

**Fig. 5.** A custom wrist motion simulator system.

**Fig. 6.** The increased distance of the scapholunate joint. (A) Dorsal side during flexion. (B) Volar side during extension.

**Fig. 7.** Five experimental conditions to observe the change of the scapholunate joint. SLIL: scapholunate interosseous ligament.
0.016; flexion: \( p = 0.006 \); CF: \( p = 0.010 \)). However, in DDL SLIL reconstruction using AM, the dorsal SL interval was further decreased statistically significantly compared with that in the intact condition in all wrist motions (Fig. 8). After 360° SLIL reconstruction using AM, the volar SL interval in the wrist extension position was reduced significantly compared with that in the SLIL resection condition (\( p = 0.015 \)) (Fig. 9).

### SL Angle

The SL angle, the wrist neutral position, and CF showed a tendency to increase during SLIL resection compared with those in the intact condition, but it was not statistically significant (\( p > 0.05 \)). Additionally, there was a tendency for the SL angle to recover in 360° SLIL reconstruction using AM and MBT condition, but it was not statistically significant (\( p > 0.05 \)). In DDL SLIL reconstruction using AM, the SL angle tended to decrease compared with that
in the intact condition, but this was also not a statistically significant result \( (p > 0.05) \) (Fig. 10).

**RL Angle**

The SLIL resection condition in the neutral wrist and CF positions showed a tendency to increase the RL angle compared with that in the intact condition, but it was not statistically significant \( (p > 0.05) \). Additionally, DDL SLIL reconstruction using AM condition showed a statistically significant decrease in the RL angle compared with that in the SLIL resection and MBT conditions, and the decrease was greater than that in the intact condition. The 360° SLIL reconstruction using AM showed a statistically significant recovery of the RL angle compared with that in the SLIL resection in the CF position \( (p < 0.05) \) (Fig. 11).

**DISCUSSION**

The natural history of SL dissociation has yet to be revealed because of the complex anatomical structure of the carpal bone, its biomechanics, the difficulty of diagnosis, and the failure of treatment.\(^3,18\) According to biomechanical studies by Berger et al.,\(^19,20\) palmar SLIL and dorsal SLIL contribute to the stabilization of the SL joint. Particularly, it was reported that the breaking strength of dorsal SLIL was more than twice that of palmar SLIL. Because of this research, reconstruction using ligament has been focused on the reconstruction of the dorsal region.

Garcia-Elias et al.\(^1\) suggested three ligament tenodesis, which improved the Brunelli procedure. A total of 38 patients were studied, and as a result of a 46-month follow-up, 28 of the 38 patients reported that they were able to return to their original job without pain. However, it was reported that mild arthritis developed in 18% of the patients.

Therefore, the importance of the volar SLIL has recently reemerged, and several authors have introduced a reconstruction technique using volar plus dorsal SLIL.\(^21-23\) However, so far, long-term follow-up comparative reports are lacking on only dorsal SLIL reconstruction and volar and dorsal SLIL reconstruction. In the current biomechanical study, we investigated which of the two different reconstruction methods using AM instead of the true ligaments was more stable in the SL joint and compared with the biomechanical results of MBT.

We studied methods using an AM to increase the rigidity of the reconstruction site. Therefore, the influence of dorsal SLIL reconstruction using AM and 360° SLIL reconstruction using AM on the stability of the SL joint was investigated. Additionally, these two methods were compared with the MBT to determine if the procedure using AM was more stable. When compared with the intact condition during SLIL resection, it was expected that the SL interval would increase in both the volar and dorsal sides, but only the dorsal SL interval increased statistically significantly compared with the intact condition in the wrist neutral, wrist extension, and CF positions. The volar SL interval tended to increase in the wrist neutral, wrist extension, and CF positions, but it was not statistically significant \( (p > 0.05) \).

The dorsal SL interval showed effective recovery results in all three reconstruction methods \( (p < 0.05) \). However, there are no statistically significant differences between DDL SLIL reconstruction and 360° SLIL reconstruction. But in DDL SLIL reconstruction using AM, the dorsal SL interval decreased statistically in all wrist positions compared with that in the intact condition \( (p < 0.05) \), suggesting that there was an overcorrection. Compared with the MBT method, both DDL SLIL reconstruction and 360° SLIL reconstruction methods did not reduce the dorsal SL interval more significantly \( (p > 0.05) \). However, when comparing the average value and considering the characteristic of the material, the two are likely to be more...
robust methods than the conventional MBT method. Only in 360° SLIL reconstruction did the volar SL interval decrease significantly in the wrist extension position compared with that in the SLIL resection condition ($p < 0.05$).

The strain loaded on the SLIL changes according to the wrist position: when the wrist is extended, the strain on the SLIL in the palmar area increases. Therefore, the volar SL interval becomes the largest at wrist extension in the SLIL resection condition. At this time, it can be seen that the 360° SLIL reconstruction method effectively maintains the volar SL interval ($p < 0.05$). The SL angle was expected to increase in the SLIL resection condition compared with that in the intact condition, but there was no statistical significance ($p > 0.05$). Similarly, the degree of change based on the SL angle of the intact condition was not statistically significant.

The RL angle in the SLIL resection condition tended to increase compared with that in the intact condition in the same way as the SL angle, but the difference was not statistically significant ($p > 0.05$). However, in the DDL SLIL reconstruction using AM, the RL angle showed a significant decrease in the wrist neutral and CF positions compared with those of the other conditions. Additionally, the angle decreased more than the normal state, which is assumed to be more reduced compared with that of other experimental conditions, as the RL angle was overcorrected in the DDL SLIL reconstruction using AM. Additionally, in 360° SLIL reconstruction using AM, the RL angle showed a statistically significant recovery of the RL angle compared with that in the SLIL resection condition and MBT ($p < 0.05$). The 360° SLIL reconstruction using AM may be more stable in clinical settings. However, the need for a volar incision, the fact that the operation time can be longer, and the need for two more bone tunnels can be considered as obvious disadvantages; therefore, more research is needed.

This study has limitations. First, it is a cadaver study, with a small sample size. Second, as a ligament reconstruction method, FiberTape (Arthrex, Naples, FL, USA) was used alone instead of a tendon graft. This is a disadvantage in that there is no healing potential of the reconstruction structure. However, when the tendon is used with FiberTape, the physical properties between the tendon and the FiberTape are different, so the fixation force is weakened, and the bone tunnel must be large, which leads avascular necrosis of the carpal bone. Additionally, the dorsal capsuloligamentous SL septum can be used as a healing potential instead of the tendon. However, clinically, more research is needed about reconstruction with AM for chronic SL dissociation. Third, ligaments failed by repeated strain during movement, not just 1–2 movement. This biomechanical study does not exactly represent the clinical situation. Fourth, when we reproduced the SLIL resection condition, there was no statistically significant difference in SL angle compared to the intact SLIL condition. This limitation of not being able to reproduce the dorsal intercalated segment instability (deformity that occurs during an actual SLIL tear) may be associated with the use of cadavers, which are different from the real human tissue. Fifth, there are second stabilizers of the SL joint: dorsal intercarpal ligament, scaphotrapezial ligament, and radioscapohamate ligament. They play an important role in the SL joint stabilization with SLIL, but we could not consider their effect in this study.

The main purpose of this study was as follows: reconstruction using ligaments inevitably delays the rehabilitation after surgery because the strength of the initial reconstruction site is weak. This can lead to limitation of the joint motion after surgery. Over time, the graft tendon is loosened. However, if reconstruction is performed using AM, these shortcomings can be overcome. The strength of reconstruction using AM was compared to the reconstruction using ligaments only. In addition, we compared the method of reconstruction only on the dorsal aspect of SLIL and the method of 360° reconstruction to figure out how the joint has higher stability. Of course, if reconstruction is performed only with AM, healing potential of the reconstruction site cannot be induced. Ligament reconstruction using synthetic material is not a recent but a traditional method. Anterior cruciate ligament reconstruction of the knee joint is a typical example. Various synthetic materials were attempted for reconstruction, but all long-term clinical results were considered failures.

In a prospective comparative analysis of ligament-only reconstruction and reconstruction using synthetic materials for chronic acromioclavicular dislocation in the upper extremity, reconstruction using synthetic materials was not as good as reconstruction using ligament. Of course, there are recent studies that report good results in ligament reconstruction using synthetic materials, but there are still few cases and no long-term results. Based on this, reconstruction using synthetic materials only should be applied with care in clinical settings. Therefore, more research is warranted, and at the same time, it should be accompanied by the development of biological synthetic materials. The strength of this study is that it is a biomechanical study comparing the DDL SLIL reconstruction method and the 360° SLIL reconstruction method, and for this purpose, the change in the SL joint was measured in detail on both the volar and dorsal sides with MicroScribe.
In conclusion, it seems that the reconstruction method using AM has a higher initial intensity than the reconstruction using only a ligament, enabling rapid rehabilitation. DDL SLIL reconstruction using AM and 360° SLIL reconstruction using AM showed the same effect on the dorsal SL interval. The volar SL interval showed better recovery in 360° SLIL reconstruction using AM, but more research is needed on the clinical significance of volar SL interval widening observed in dorsal SLIL reconstruction using AM. Additionally, the SL angle and RL angle results do not provide conclusive evidence that the 360° SLIL reconstruction using AM is significantly more stable than the dorsal SLIL reconstruction using AM.

CONFLICT OF INTEREST
No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGEMENTS
This study was supported by the Arthrex and Orthopedic Biomechanics Laboratory of the Congress Medical Foundation. This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (Ministry of Science and ICT) (No. 2020R1G1A110118511).

ORCID
Seungbum Chae https://orcid.org/0000-0003-3469-9289
Junho Nam https://orcid.org/0000-0003-1843-1645
Il-Jung Park https://orcid.org/0000-0001-8262-4287
Steve S. Shin https://orcid.org/0000-0003-4353-307X
Michelle H. McGarry https://orcid.org/0000-0003-2266-2622
Thay Q Lee https://orcid.org/0000-0002-1639-0280

REFERENCES
1. 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(1):125-34.
2. Schweizer A, Steiger R. Long-term results after repair and augmentation ligamentoplasty of rotatory subluxation of the scaphoid. J Hand Surg Am. 2002;27(4):674-84.
3. Walsh JJ, Berger RA, Cooney WP. Current status of scapholunate interosseous ligament injuries. J Am Acad Orthop Surg. 2002;10(1):32-42.
4. 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(1):81-102.
5. Darlis NA, Kaufmann RA, Giannoulis F, Sotereanos DG. Arthroscopic debridement and closed pinning for chronic dynamic scapholunate instability. J Hand Surg Am. 2006;31(3):418-24.
6. Koechler SM, Guerra SM, Kim JM, Sakamoto S, Lovy AJ, Hausman MR. Outcome of arthroscopic reduction association of the scapholunate joint. J Hand Surg Eur Vol. 2016;41(1):48-55.
7. Moran SL, Cooney WP, Berger RA, Strickland J. Capsulodesis for the treatment of chronic scapholunate instability. J Hand Surg Am. 2005;30(1):16-23.
8. 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(8):1380-6.
9. Van Den Abbeele KL, Loh YC, Stanley JK, Trail IA. Early results of a modified Brunelli procedure for scapholunate instability. J Hand Surg Br. 1998;23(2):258-61.
10. Yao J, Zlotolow DA, Lee SK. Scapholunate axis method. J Wrist Surg. 2016;5(1):59-66.
11. Brunelli GA, Brunelli GR. A new technique to correct carpal instability with scaphoid rotary subluxation: a preliminary report. J Hand Surg Am. 1995;20(3 Pt 2):S82-5.
12. De Carli P, Donndorff AG, Gallucci GL, Boretto JG, Alfie VA. Chronic scapholunate dissociation: ligament reconstruction combining a new extensor carpi radialis longus tenodesis and a dorsal intercarpal ligament capsulodesis. Tech Hand Up Extrem Surg. 2011;15(1):6-11.
13. De Carli P, Donndorff AG, Torres MT, Boretto JG, Gallucci GL. Combined tenodesis-capsulodesis for scapholunate instability: minimum 2-year follow-up. J Wrist Surg. 2017;6(1):11-21.
14. Gibbs DB, Shin SS. Return to play in athletes after thumb ulnar collateral ligament repair with suture tape augmentation. Orthop J Sports Med. 2020;8(7):2325967120935063.
15. Willegger M, Schuh R. Arthroscopically assisted tape augmentation for anterior talofibular ligament repair. Arthrosc Tech. 2020;9(6):e809-16.
16. Pollock PJ, Sieg RN, Baechler MF, Scher D, Zimmerman NB, Dubin NH. Radiographic evaluation of the modified
Brunelli technique versus the Blatt capsulodesis for scapholunate dissociation in a cadaver model. J Hand Surg Am. 2010;35(10):1589-98.

17. Lee SK, Park J, Baskies M, Forman R, Yildirim G, Walker P. Differential strain of the axially loaded scapholunate interosseous ligament. J Hand Surg Am. 2010;35(2):245-51.

18. Chae S, Roh YT, Park IJ. Scapholunate dissociation: current concepts of the treatments. Arch Hand Microsurg. 2020;25(2):77-89.

19. Berger RA. The gross and histologic anatomy of the scapholunate interosseous ligament. J Hand Surg Am. 1996;21(2):170-8.

20. Berger RA, Imeada T, Berglund L, An KN. Constraint and material properties of the subregions of the scapholunate interosseous ligament. J Hand Surg Am. 1999;24(3):953-62.

21. Chee KG, Chin AY, Chew EM, Garcia-Elias M. Antipronation spiral tenodesis: a surgical technique for the treatment of perilunate instability. J Hand Surg Am. 2012;37(12):2611-8.

22. Corella F, Del Cerro M, Ocampos M, Simon de Blas C, Larrainzar-Garijo R. Arthroscopic scapholunate ligament reconstruction, volar and dorsal reconstruction. Hand Clin. 2017;33(4):687-707.

23. Henry M. Reconstruction of both volar and dorsal limbs of the scapholunate interosseous ligament. J Hand Surg Am. 2013;38(8):1625-34.

24. Short WH, Werner FW, Green JK, Sutton LG, Brutus JP. Biomechanical evaluation of the ligamentous stabilizers of the scaphoid and lunate: part III. J Hand Surg Am. 2007;32(3):297-309.

25. Legnani C, Ventura A, Terzaghi C, Borgo E, Albisetti W. Anterior cruciate ligament reconstruction with synthetic grafts: a review of literature. Int Orthop. 2010;34(4):465-71.

26. Fauci F, Merolla G, Paladini P, Campi F, Porcellini G. Surgical treatment of chronic acromioclavicular dislocation with biologic graft vs synthetic ligament: a prospective randomized comparative study. J Orthop Traumatol. 2013;14(4):283-90.