ORIGINAL RESEARCH

Clinical Efficacy of Arthroscopic Transplantation of Palmaris Longus Tendon Combined with Early Accelerated Motion Rehabilitation After Scapholunate Ligament Reconstruction for Geissler Type IV Scapholunate Instability

Qiuwen Ying, BM; Li Ding, BM; Fengming Gu, MM; Jingyi Mi, MD

ABSTRACT

Objective • The aim of this study is to investigate the clinical efficacy of early accelerated motion rehabilitation in treating wrist joint instability with Geissler IV scapholunate instability (SLI) using arthroscopic palmaris longus tendon transplantation in conjunction with scapholunate ligament reconstruction.

Methods • From June 2019 to January 2022, seven patients with Geissler Type IV SLI underwent arthroscopic ligament reconstruction and repair surgery of the wrist joint, followed by early accelerated motion rehabilitation. Postoperative follow-up indicators included visual analogue scale (VAS) for pain assessment, DASH-CHINESE upper limb function score, Mayo wrist joint score, wrist joint range of motion, and grip strength. Surgical efficacy was evaluated based on these indicators.

Results • All patients were followed up postoperatively, with a follow-up duration ranging from 6 to 20 months (mean: 15.3 months). No postoperative complications occurred, and significant improvements were observed in all measured parameters. Postoperative MRI results at one year indicated restoration of the anatomical structure of the scapholunate joint with good healing. Both VAS and DASH-CHINESE scores significantly decreased, and the differences between pre- and postoperative scores were statistically significant ($P < .001$). The preoperative Mayo wrist joint score was (47.857±21.380) points, with 2 cases rated as fair and 5 cases as poor. At the latest follow-up, the score was (84.286±6.726) points, with 2 cases rated as excellent, 2 cases as good, and 3 cases as fair. Wrist joint flexion-extension range, rotation range, and grip strength all significantly improved compared to the preoperative values, with statistically significant differences ($P < .001$).

Conclusion • The combined approach of arthroscopic transplantation of the palmaris longus tendon and early accelerated motion rehabilitation shows satisfactory clinical outcomes in treating Geissler Type IV scapholunate instability of the wrist joint. This combined approach is of great significance in improving the patient's quality of life and wrist function and helps reduce pain symptoms. Furthermore, in future research, it is recommended to increase the sample size and prolong the observation period to further validate the efficacy. (*Altern Ther Health Med.* 2024;30(10):134-138).

Qiuwen Ying, BM, Attending doctor; **Fengming Gu, MM**, Resident doctor; **Jingyi Mi, MD**, Chief physician; Department of Sports Medicine, Wuxi Ninth People's Hospital Affiliated to Soochow University, Wuxi, China. **Li Ding, BM**, Attending doctor; Department of Rehabilitation Medicine, Wuxi Ninth People's Hospital Affiliated to Soochow University, Wuxi, China.

Corresponding author: Jingyi Mi, MD
E-mail: jy8586yz@163.com

INTRODUCTION

Scapholunate Instability (SLI) is the most common type of wrist instability seen clinically. Its cause is often traumatic, leading to wrist extension, ulnar deviation, and dorsal rotation, primarily characterized by volar tilt and dorsal and radial displacement of the scaphoid bone. The scapholunate interosseous ligament (SLIL) is a crucial structure maintaining the normal alignment and motion of the wrist joint.[1] The injury of SLIL affects the stability of scaphoid and lunate interosseous, leading to instability and dysfunction of wrist joint. In wrist arthroscopy, scapholunate ligament injuries are often classified using the Geissler classification. Geissler Type IV (G4) scapholunate instability refers to a complete tear of the scapholunate ligament visible under arthroscopy, with a significantly widened gap through which a 2.7 mm arthroscope can pass to the opposite side of the joint.[2] If left untreated, a completely torn scapholunate ligament can lead to persistent wrist pain, decreased muscle strength, restricted motion, and even joint changes such as scapholunate advanced collapse (SLAC wrist), which refers to a pattern of wrist malalignment that has been attributed to post-traumatic or spontaneous osteoarthritis of the wrist.

Various reconstruction techniques have been reported for treating Geissler Type III and IV lesions, including different forms of capsulodesis, static or dynamic tendon fusions, tendon grafts, bone-ligament-bone reconstructions, and scaphoid and lunate fusion surgeries.[3-5] While these methods can correct instability and prevent scaphoid flexion, they often lack proper restoration of ligamentous function in the volar and dorsal directions, and they may reduce wrist joint range of motion due to the need for prolonged immobilization.[5] In a biomechanical study by Yi et al.[6], palmaris longus tendon grafts were used and introduced through drilling in the anterior and posterior planes of the scaphoid and lunate bones, effectively narrowing the SL gap to a normal state, and the anatomical SL reduction was significantly improved after reconstruction. In this case, functional exercise can be carried out early, which will be more conducive to speeding up the recovery of patients.

However, there is limited clinical application reported for such methods. There is still a lack of understanding about when and how to carry out rehabilitation exercises after surgery. Therefore, from June 2019 to November 2021, we performed arthroscopic scapholunate ligament reconstruction and repair combined with early accelerated motion rehabilitation in 7 patients with G4-type SLI, achieving satisfactory treatment outcomes. The results are as follows:

CLINICAL DATA

General Information

This study included 7 cases, consisting of 5 males and 2 females, with ages ranging from 27 to 60 years and an average age of 30.5 years. Among them, 1 case was on the left side, and 6 cases were on the right side. The duration of symptoms was (1.9±1.4) months. One case had a concomitant ulnar styloid fracture. Under arthroscopy, it can be observed that all patients have a complete tear of the scapholunate ligament, with a significantly widened gap.

Inclusion criteria

(1) Subacute phase with a clear history of trauma, limited motion, evident dorsal wrist swelling, and often accompanied by painful snapping; (2) Positive tenderness over the scapholunate gap; (3) Positive Watson scaphoid compression test; (4) Radiographic evidence showing a scapholunate gap greater than 3mm; (5) Wrist arthroscopy confirming complete tear of the SL ligament (Geissler Type IV) and inability to suture directly.

Exclusion criteria

(1) Degenerative joint disease; (2) Wrist X-ray showing scapholunate bone variations, fracture malunion, or congenital deformities; (3) History of wrist surgery.

Surgical Method

The surgical procedure involves arthroscopic repair of a complete tear of the scapholunate ligament, utilizing multiple portals and instruments for inflammatory tissue clearance and reconstruction, including the use of the palmaris longus tendon to create a box-shaped reconstruction. Scaphoid fixation and fracture management are performed as needed. The goal of the procedure is to restore stability and function to the scapholunate joint. The surgery was performed with the patient in a supine position under brachial plexus nerve block anesthesia. Intraoperatively, three to four portals, four to five portals, midcarpal ulnar (MCU), and midcarpal radial (MCR) portals were established. Under arthroscopy, the scapholunate joint was found to be lax with an increased gap, categorized as Geissler Grade IV. The articular cartilage on the wrist bone surfaces showed signs of softening, and there was hyperplasia of surrounding synovial and scar tissues. Alternating between the portals, arthroscopes and shavers were introduced to release and clear inflammatory synovial and scar tissues. A horizontal incision of about 3 cm was made on the dorsal aspect of the scapholunate joint, exposing the extensor tendon. The joint was held open, and the arthroscope was oriented towards the volar side, marking the location using the illuminated tip of the arthroscope. A horizontal incision of about 2 cm was made over the volar side of the wrist at the proximal palmar crease, exposing the palmaris longus tendon. The tendon was retrieved using a tendon harvester, with a length of approximately 12 cm. Continuing to expose the volar aspect of the scapholunate joint, the radioscapholunate ligament was carefully protected. A 1.2 mm Kirschner wire (K-wire) was inserted into the dorsal aspect of the scaphoid bone under mini C-arm fluoroscopy, followed by insertion of a 3.0 mm hollow drill, confirmed to exit on the volar side. Similarly, a 3.0 mm hollow drill was inserted into the dorsal aspect of the lunate bone, with proper positioning confirmed under mini C-arm fluoroscopy. Using a guided approach, the palmaris longus tendon was passed through the bone marrow canal created by the drills, forming a box shaped reconstruction of the scapholunate ligament. This involved implanting the palmaris longus tendon graft through the wrist capsule and the bone marrow canal formed by the scaphoid and lunate bones, connecting the two wrist bones in a box-like manner and securing the knot on the dorsal aspect of the scapholunate joint. The traction device was removed, and the knot was tied dorsally. A 1.5 mm K-wire was used for scaphoid fixation. After hemostasis, irrigation, and confirmation of proper instrument and accessory counts, the wounds were sutured. Additionally, in one case with a fracture of the ulnar styloid base, a locking compression hook-shaped steel plate was securely fixed.

Postoperative Care and Rehabilitation:

Postoperative Day 0. On the day of surgery, the surgeon immobilized the patient's elbow joint at 90° of flexion, forearm in a neutral position, and wrist joint in a neutral position using a plaster splint. This positioning is beneficial for the recovery of tendons and bones under appropriate tension. The limb was elevated and wrapped with self-

Figure 1. Intraoperative Procedures and Illustrations of Arthroscopic Ligament Reconstruction for Geissler Type IV Scapholunate Instability. (A) Superficial projection of the radiocarpal joint and design of surgical portals. (B) Geissler Type IV scapholunate instability, visible under the arthroscope, showing complete tear of the scapholunate ligament with a widened gap. A 2.7 mm arthroscope can be fully inserted into the scapholunate gap and pass through to the other side of the joint. (C) Removal of inflammatory synovium. (D) Passage of the palmaris longus tendon graft. (E) Implantation of the palmaris longus tendon graft through the bone marrow canal formed by the wrist capsule, scaphoid, and lunate bones, connecting the two wrist bones in a box-like manner and securing the knot on the dorsal aspect of the scapholunate joint.

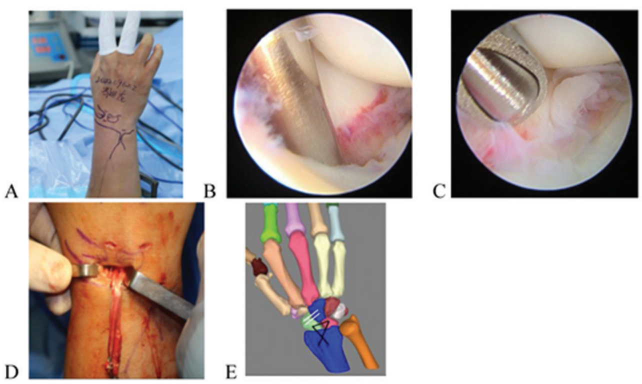

Figure 2. The patient is a 35-year-old male who sustained a fall from a height, resulting in Geissler IV scapholunate instability in the right wrist. A scapholunate ligament reconstruction and repair surgery were performed using arthroscopy. (A) Preoperative Range of Motion and Forearm Rotation of the Affected Wrist; (B) Preoperative MRI; (C) One-Year Postoperative Range of Motion and Forearm Rotation of the Affected Wrist; (D) One-Month Postoperative DR Image, Two-Month Postoperative MRI (Showing Bone Tunnel); (E) One-Year Postoperative MRI (Tendon-Bone Integration, Disappearance of Bone Tunnel)

adhesive bandages from the fingers to the wrist using a centripetal wrapping technique. The rehabilitation therapist instructed the patient to perform swelling reduction exercises using the muscle pump principle, including making a fist, gripping, and extending the fingers. Passive shoulder and elbow joint movements were also guided. Exercising 2-3 times a day, with each session lasting until the muscles feel fatigued, is recommended.

Postoperative Day 3. The plaster splint was removed and replaced with a wrist joint neutral position orthosis. The rehabilitation therapist guided the patient to actively move the shoulder and elbow joints within the normal range of motion. Passive rotational movements of the wrist joint were performed within tolerable discomfort, followed by cold compresses after the training. Active and passive wrist flexion and extension were prohibited within 8 weeks after the surgery.

Postoperative Week 1. The rehabilitation therapist guided the patient to perform equal-length contractions of wrist flexion and extension in a neutral forearm position, along with mild active rotational movements. Low-intensity ultrasound therapy was administered to the scapholunate region of the wrist joint.

Postoperative Week 2. The surgeon removed the sutures and applied scar patches to the wound. The rehabilitation therapist guided the patient in performing passive rotational movements of the wrist joint to the maximum range of motion, using the uninjured side's activity as a reference. Grip strength training was introduced.

Postoperative Week 6. The rehabilitation therapist guided the patient in actively moving the wrist joint through its full range of rotation and performing wrist joint rotation resistance training using elastic bands.

Postoperative Week 8. The surgeon removed the Kirschner wire. The rehabilitation therapist guided the patient, under protection, to actively and passively flex and extend the wrist joint, with an angle not exceeding 30°. Paraffin therapy, medium-frequency, and other physical therapies were applied before training, followed by continued cold compresses after training.

Postoperative Week 12. The rehabilitation therapist increased the intensity of wrist flexion and extension training, aiming to achieve the maximum range of motion for the wrist joint. The orthosis protection was removed, and the patient was instructed in performing daily activities, such as writing, unscrewing bottle caps, opening doors, and unlocking locks. Furthermore, due to the prolonged recovery period of wrist joint function, patients might experience swelling within a short time after training, leading to rebound

Table 1. Comparison of various follow-up parameters of the affected Wrist Joint before surgery and at the last follow-up ($\bar{x} \pm s$, n = 7)

Follow-up Parameters	Before surgery	Last follow-up	*t*	*P* value
VAS scores	8.143±0.690	0.429±0.202	27.000	<.001
Mayo scores	47.857±21.380	84.286±6.726	-6.231	<.001
DASH-CHINESE scores	52.500±12.313	18.214±8.157	7.887	<.001
Flexion/extension range of motion	80.000±23.979	135.126±12.247	-6.301	<.001
Pronation/supination range of motion	122.143±6.061	162.857±9.063	4.649	.004
Grip strength (Kg)	11.714±4.751	26.713±7.088	-9.186	<.001

of movement angles. Therefore, timely psychological assessment and counseling were crucial, helping to alleviate negative psychological states such as anxiety, and encouraging patients to actively engage in frequent training.

Follow-up indicators and statistical analysis

Since patients generally experience significant recovery of wrist joint function around one year after surgery, we chose one year as the final follow-up time. Follow-up evaluations were conducted at 2 weeks, 1 month, 3 months, 6 months, and 1 year after the surgery. Subjective follow-up indicators included the Visual Analog Scale (VAS) for pain assessment, the Chinese version of the Disabilities of the Arm, Shoulder, and Hand (DASH-CHINESE) questionnaire for upper limb function assessment, and the modified Mayo Wrist Score. Objective follow-up indicators included wrist joint range of motion and grip strength. These subjective and objective indicators reflect the recovery of wrist joint function in patients after surgery. Statistical analysis was performed using SPSS 27.0 software. Paired rank-sum test was used for ordinal data, and paired *t* test was used for quantitative data. A significance level of $P < .05$ was considered statistically significant.

RESULTS

All patients were successfully followed up for a duration of 9 to 20 months, with an average of 15.3 months. No complications such as wound infections or iatrogenic fractures occurred. The MRI results at 1 year postoperatively indicated restoration of the anatomical structure of the scapholunate joint with good healing.

At the last follow-up, significant improvements were observed in both pain symptoms and wrist joint function of the patients. The VAS score at the last follow-up was (0.429±0.202), significantly improved compared to preoperative scores, with a statistically significant difference ($t = 27.00$, $P < .001$). The DASH-CHINESE score at the last follow-up was (18.214±8.157), significantly lower than the preoperative score of (52.500±12.313), with a statistically significant difference ($t = 7.887$, $P < .001$). The preoperative Mayo Wrist Score was (47.857±21.380), with a rating of fair for 2 cases and poor for 5 cases. The score at the last follow-up was (84.286±6.726), with ratings of excellent for 2 cases, good for 2 cases, and fair for 3 cases, showing a statistically significant difference ($t = -6.231$, $P < .001$).

Regarding wrist joint range of motion, the preoperative flexion-extension range was (80.000±23.979) degrees, which improved to (135.126±12.247) degrees at the last follow-up. The preoperative rotational range was (122.143±6.061) degrees, increasing to (162.857±9.063) degrees at the last follow-up. Grip strength increased from (11.714±4.751) kg preoperatively to (26.713±7.088) kg at the last follow-up. All improvements in flexion-extension range, rotational range, and grip strength were statistically significant when compared to preoperative values ($t = -6.301$, $P < .001$; $t = -4.649$, $P < .001$; $t = -9.186$, $P < .001$). Refer to Table 1 for detailed information.

DISCUSSION

The SLIL is divided into three subregions: the dorsal side, the proximal side, and the volar side. When it's completely ruptured, the scaphoid bone can undergo a rotational subluxation, with the lack of stress opposition from the lunate and triquetral bones in the scaphoid flexion. This presents as instability in dorsiflexion of the proximal row of wrist bones, leading to compromised wrist functionality and further progression into wrist arthrosis.[7] Generally, a complete SLIL rupture requires surgical intervention to restore wrist stability. Repair might be feasible in the early stages, while reconstruction becomes necessary for delayed cases.[8] There are various treatment approaches for a complete SLIL rupture, including soft tissue and bony surgeries.[9] Despite advancements in these techniques, consensus on the optimal treatment approach has yet to be reached.[10]

Short et al.[11] demonstrated that in cases of scapholunate instability, the scaphoid bone undergoes flexion and pronation, resulting in conflict at the dorsal aspect of the radius. By threading a graft through the scaphoid tunnel from the dorsal side and tensioning it, the scaphoid bone is extended and corrected from its flexed position. Similarly, by threading the graft through the lunate tunnel from the volar side and tensioning it, the lunate bone is corrected from its volar rotation, avoiding friction at the dorsal edge of the radius. However, due to the anatomical structure of the scapholunate ligament resembling a C shape, the dorsal part is the thickest and most robust,[12] leading most reconstruction techniques[9,13,14] to focus on the dorsal part. Yet, pure dorsal reconstruction only produces a single point of connection between the scaphoid and lunate bones, therefore unable to prevent volar gapping and sagittal plane rotation.[15] Early cadaveric studies[6,16] affirmed the roles of both dorsal and volar ligaments in SL stability and the beneficial biomechanical outcomes of reconstructing both, though clinical evidence remains limited. Pak-cheong Ho[17] reported the volar and dorsal ligament united with tendon reconstruction approach to treat chronic scapholunate instability. Building upon this, we performed arthroscopically-assisted box type scapholunate ligament reconstruction, obviating the need for traditional open joint exposure. Through the implantation of a palmaris longus tendon graft within the joint capsule and the bone marrow space formed by the proximal scaphoid and lunate, the two wrist bones are connected in a box-like fashion and secured with knots on the dorsal side of the scapholunate joint. This effectively reduces joint separation, corrects adverse wrist bone rotation, and facilitates healing of the reconstructed scapholunate ligament. Follow-up results indicate significant improvement in wrist joint function among 29 patients. Postoperative MRI after one year demonstrates anatomical restoration and good healing of the scapholunate joint, with a 90.5% excellent outcome rate according to the Mayo score. We achieved outcomes similar to those of scholars like PC Ho, while arresting the trend towards SLAC wrist development.

To ensure the firmness of the reconstructed scapholunate ligament, postoperatively, surgeons often require patients to wear braces for an extended period. However, this can result in prolonged swelling and stiffness of the wrist joint. Therefore, this study employed a series of early rehabilitation measures. On the day of surgery, patients were instructed to perform active finger grasping and apply cold compression. Applying moderate pressure to the soft tissue can close the generated small lymphatic vessels, blocking lymph fluid formation and reducing exudate production. Cold therapy induces vasoconstriction in small blood vessels, reducing bleeding. The combination of these techniques effectively mitigates wrist joint swelling and prevents stiffness. It's noteworthy that in the early stages, patients' wrist flexion and extension were strictly restricted. Simultaneously, patients were engaged in active and passive rotational movements of the wrist joint, training the rotational muscle strength of the wrist joint. Low-frequency ultrasound was used to facilitate the fusion of the reconstructed scapholunate ligament with the palmaris longus tendon and the scaphoid-lunate bones.[18] After 8 weeks post-surgery, following the removal of Kirschner wires for internal fixation, patients were immediately guided to initiate wrist flexion and extension activities as well as related muscle strength training. The early rehabilitation protocol implemented in this study ensures stability of the reconstructed scapholunate ligament while preventing wrist joint swelling and stiffness. These measures are believed to contribute to improved daily joint functionality and quality of life.

This study had limitations, including its retrospective research design. Moreover, although significant treatment results were observed in this study, the sample size was relatively small, which may affect the reliability of the research findings. Additionally, the observation period of this study was short, therefore, the long-term treatment effects could not be assessed. Besides, it was a retrospective study, which carries the risk of recall bias and incomplete information. Thus, in future research, it is recommended to increase the sample size and prolong the observation period to further validate the efficacy.

In summary, arthroscopic transplantation of the palmaris longus tendon for ligament reconstruction combined with early accelerated motion rehabilitation proves to be an effective treatment for Grade 4 wrist scapholunate instability. This approach offers multiple benefits in treating wrist joint instability. It alleviates patient symptoms, restores the anatomy of the scapholunate joint, and improves wrist joint mobility. Additionally, it prevents the recurrence of scapholunate instability, reduces potential costs of secondary surgeries, and minimizes the risk of functional deficits related to joint and muscle disuse. This method greatly preserves the original functionality of the wrist joint, shortens the patient's recovery time, and lessens the economic burden. It stands as an effective therapeutic approach.

ETHICAL COMPLIANCE

This study was approved by the ethics committee of Wuxi Ninth People's Hospital Affiliated to Soochow University. Signed written informed consents were obtained from the patients and/or guardians.

CONFLICT OF INTEREST

All authors declared no conflicts of interest.

AUTHOR CONTRIBUTIONS

Qiu-wen Ying participated in data collection, drafted the article; Li Ding participated in data collection, provided work support; Feng-ming Gu reviewed the article, provided work support; Jing-yi Mi reviewed the article, provided work support. Qiu-wen Ying and Li Ding contributed equally to this work.

FUNDING

This work was supported by 1.Wuxi Taihu Talent Plan" High-level Talents in Medical and Health (2020); 2.Major scientific research project of Wuxi Municipal Health Commission (Z202108); 3. Shanghai Key Laboratory of Peripheral Nerve and Microsurgery (20DZ2270200). NHC Key Laboratory of Hand Reconstruction (Fudan University)

REFERENCES

1. Carvalho VB, Ferreira CHV, Hoshino AR, Bernardo VA, Ruggiero GM, Aita MA. Dorsal capsulodesis associated with arthoscopy-assisted scapholunate ligament reconstruction using a palmaris longus tendon graft. *Rev Bras Ortop*. 2017;52(6):676-684. doi:10.1016/j.rboe.2016.11.010
2. 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):357-365. doi:10.2106/00004623-199603000-00006
3. Szabo RM, Slater RR Jr, Palumbo CF, Gerlach T. Dorsal intercarpal ligament capsulodesis for chronic, static scapholunate dissociation: clinical results. *J Hand Surg Am*. 2002;27(6):978-984. doi:10.1053/jhsu.2002.36523
4. Shih YC, Wu CC, Shih JT. Arthroscopic treatment of stable nonunion, unstable nonunion, or nonunion of the scaphoid with early degenerative radioscaphoid arthritis. *J Orthop Surg Res*. 2023;18(1):123. doi:10.1186/s13018-023-03609-8
5. 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. doi:10.1177/1753193414563012
6. Athlani L, Pauchard N, Dautel G. Outcomes of scapholunate intercarpal ligamentoplasty for chronic scapholunate dissociation: a prospective study in 26 patients. *J Hand Surg Eur Vol*. 2018;43(7):700-707. doi:10.1177/1753193418772801
7. Perevoshchikova N, Moerman KM, Akhbari B, et al. Finite element analysis of the performance of additively manufactured scaffolds for scapholunate ligament reconstruction. *PLoS One*. 2021;16(11):e0256528. doi:10.1371/journal.pone.0256528
8. Lee SK, Zlotolow DA, Sapienza A, Karia R, Yao J. Biomechanical comparison of 3 methods of scapholunate ligament reconstruction. *J Hand Surg Am*. 2014;39(4):643-650. doi:10.1016/j.jhsa.2013.12.033
9. Petersen W, Rothenberger J, Schaller HE, Rahmanian-Schwarz A, Held M. Experiences with Osteoligamentoplasty According to Weiss for the Treatment of Scapholunate Dissociation. *J Invest Surg*. 2018;31(4):313-320. doi:10.1080/08941939.2017.1330907
10. Andersson JK. Treatment of scapholunate ligament injury: current concepts. *EFORT Open Rev*. 2017;2(9):382-393. doi:10.1302/2058-5241.2.170016
11. Short WH, Werner FW, Green JK, Masaoka S. Biomechanical evaluation of ligamentous stabilizers of the scaphoid and lunate. *J Hand Surg Am*. 2002;27(6):991-1002. doi:10.1053/jhsu.2002.35878
12. Shahabpour M, Abid W, Van Overstraeten L, Van Royen K, De Maeseneer M. Extrinsic and Intrinsic Ligaments of the Wrist. *Semin Musculoskelet Radiol*. 2021;25(2):311-328. doi:10.1055/s-0041-1731653
13. Badida R, Akhbari B, Vutescu E, Moore DC, Wolfe SW, Crisco JJ. The role of scapholunate interosseous, dorsal intercarpal, and radiolunate ligaments in wrist biomechanics. *J Biomech*. 2021;125:110567. doi:10.1016/j.jbiomech.2021.110567
14. Nakamura T, Abe K, Iwamoto T, Ochi K, Sato K. Reconstruction of the Scapholunate Ligament Using Capitohamate Bone-Ligament-Bone. *J Wrist Surg*. 2015;4(4):264-268. doi:10.1055/s-0035-1566268
15. Corella F, Del Cerro M, Ocampos M, Larrainzar-Garijo R. Arthroscopic ligamentoplasty of the dorsal and volar portions of the scapholunate ligament. *J Hand Surg Am*. 2013;38(12):2466-2477. doi:10.1016/j.jhsa.2013.09.021
16. Zdero R, Olsen M, Elfatori S, et al. Linear and torsional mechanical characteristics of intact and reconstructed scapholunate ligaments. *J Biomech Eng*. 2009;131(4):041009. doi:10.1115/1.3005149
17. Ho PC, Wong CW, Tse WL. Arthroscopic-Assisted Combined Dorsal and Volar Scapholunate Ligament Reconstruction with Tendon Graft for Chronic SL Instability. *J Wrist Surg*. 2015;4(4):252-263. doi:10.1055/s-0035-1565927
18. Huegel J, Choi DS, Nuss CA, et al. Effects of pulsed electromagnetic field therapy at different frequencies and durations on rotator cuff tendon-to-bone healing in a rat model. *J Shoulder Elbow Surg*. 2018;27(3):553-560. doi:10.1016/j.jse.2017.09.024