SCIENTIFIC ARTICLE

Comparing Patient-Reported Outcomes on Three-Ligament Tenodesis between Partial and Complete Scapholunate Ligament Injuries: A Cohort Study

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Purpose Multiple studies report outcomes after 3-ligament tenodesis (3-LT) in treating traumatic scapholunate interosseous ligament injury (SLIL). However, investigators do not differentiate between patients with partial or complete SLIL injury. The relation between the extent of SLIL disruption and surgical outcomes and if this should be considered when treating a patient with SLIL injury remains unknown. We aimed to evaluate differences in patient-rated wrist evaluation (PRWE) scores, satisfaction and return to work between patients with partial or complete chronic traumatic SLIL injury treated with 3 ligament tenodesis at 12 months after surgery.

Methods All patients with chronic SLIL injury (partial and complete) who were treated with 3-LT at our clinic and received the same postoperative management between December 2011 and December 2019 were studied. Only patients who had completed the PRWE and return to work questionnaires preoperatively and 12 months after surgery were included. Patients were allocated to the partial (classified as Geissler 2 or 3) or complete SLIL injury group (classified as Geissler 4) by retrospectively assessing wrist arthroscopy reports.

Results Thirty-nine patients with partial and 90 with complete SLIL injuries were included. At 1-year follow-up, PRWE scores had significantly improved in both groups. When adjusting for clinical baseline characteristics, there was no statistically significant difference between patients with partial or complete SLIL injury. Patients with complete SLIL injury had a 70% higher return to work within the first 12 months after 3-LT; however, satisfaction with the treatment result was similar for both study groups 1 year after surgery.

Conclusions Patients with complete and partial traumatic SLIL injury report better PRWE total scores at 12 months after 3-LT, but there was no statistically significant difference between the groups in PRWE scores or satisfaction with the treatment result. *(J Hand Surg Am. 2022; ■(■):1.e1-e9. Copyright © 2022 by the American Society for Surgery of the Hand. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).)*

Type of study/level of evidence Therapeutic IV.

Key words Arthroscopy, patient-reported outcomes, scapholunate ligament injury, three-ligament tenodesis.

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Traumatic injury to the wrist can rupture the scapholunate interosseous ligament (SLIL).[1] A disrupted SLIL may cause scapholunate instability, leading to pain and disability.[2,3] The severity of the instability results from damage to surrounding supporting structures and the type of damage to the ligament itself.[3–5] Determining the extent of damage to the ligament remains difficult because physical examination and imaging techniques often are insufficient. Therefore, diagnostic wrist arthroscopy has an essential role in the diagnostic workup of SLIL injury. Geissler et al[6] were the first to classify these injuries using arthroscopy. They classified damage to the ligament into 4 types: a minor sprain, a stretch injury, a partial ligament tear, and a complete tear. Although the classification has moderate intra- and interobserver reliability and does not identify lesions to the secondary stabilizers of the wrist, it remains the gold standard.[7,8] It generally is accepted that the difference between a Geisler type 2 or 3, a stretched ligament, or a partial tear of the ligament, which can be a normal physiologic situation, and a type 4 where there is a complete tear of the scapholunate (SL) ligament and instability of the secondary stabilizers, can be made during arthroscopy.[9,10]

If the SLIL ligament is not repaired shortly after trauma (within a 4 to 6 weeks from injury), this repair is no longer possible and a reconstruction of the SLIL ligament must be performed.[11] A widely recognized reconstructive technique is the 3-ligament tenodesis (3-LT), described by Garcia-Elias et al[12] as a modification of the technique of Brunelli and Brunelli.[13] In general, 3-LT is performed when SLIL injury is chronic (>6 weeks) and the ligament is disrupted, carpal malalignment is still reducible and the articular cartilage is intact.[12] Studies on 3-LT outcomes report a significant improvement in patient-reported function and pain relief, and most patients (79%) declare to be satisfied with the postoperative result. Overall, low rates of postoperative complications (3%) and secondary surgeries (6%) are reported and 87% of the patients returned to work at 3-year follow-up.[4,14–17]

Although there is a consensus on treating chronic, traumatic, complete SLIL lesions, treatment of partial lesions remains controversial. Several techniques, such as dorsal wrist capsulodesis or arthroscopic repair, have been proposed to treat partial traumatic SLIL injuries. However, the studies were based on small patient numbers and long-term results and comparative studies are lacking.[18–22] Some investigators prefer to treat only complete lesions with instability of the secondary stabilizers with 3-LT, whereas others do not seem to make a distinction between partial and complete lesions when treating a patient with 3-LT.[10,15,19,20,23]

Even though outcomes of 3-LT have been investigated previously, the current literature does not differentiate between patients with partial or complete SLIL tears when treating clinical instability. It remains unknown if there is a relation between the extent of SLIL disruption and 3-LT outcomes and if this should be considered when treating a patient with SLIL injury.

This study aimed to investigate if there is a difference in patient-reported pain, hand and wrist function, satisfaction and return to work (RTW) between patients with partial or complete chronic traumatic SLIL injury treated with 3-LT at 12 months after surgery.

METHODS

Patients

In this observational cohort study, patients with chronic traumatic SLIL injury treated with 3-LT between December 2011 and December 2019 and who completed all questionnaires at 1-year follow-up were eligible for inclusion. The SLIL injury was defined as traumatic when patients recalled a direct trauma to the hand or a fall on outstretched hands followed by complaints of a painful or unstable wrist. Arthroscopy was indicated when patients recalled a fall on outstretched hand injury followed by complaints of pain or instability at the SLIL region without improvement after nonoperative therapy. Symptoms were defined as chronic if they were present for ≥6 weeks. Exclusion criteria were patients treated with direct repair, nontraumatic SLIL injury, absent wrist arthroscopy reports, intact or unclear state of the SLIL, articular damage of the carpal bones or abnormal wrist anatomy due to other underlying pathology.

In our clinic, patients with partial or complete SLIL injury are treated with 3-LT. A distinction between the groups is not made preoperatively and both groups receive exactly the same surgical treatment and postoperative rehabilitation. Arthroscopic reports were evaluated and SLIL injury was classified according to the Geissler classification.[4] Two study groups were formed based on the extent of SLIL injury. Patients with SLIL injury classified as Geissler 4 were considered to have a complete SLIL injury. Patients with SLIL injury classified as either Geissler 2 or 3 were considered to have an incomplete SLIL injury, because these typically are difficult to distinguish from each other. Patients classified as having a

Geissler 1 injury are not treated with 3-LT in our clinic and, therefore, were not included in the study.

All patients were asked to participate in a routine outcome measurement system implemented at the clinic before the first consultation. The system consists of multiple electronically-based questionnaires to assess specific risk factors at baseline and patient-reported outcomes at baseline, and 3 and 12 months after surgery.[24] Patients received an invitation by email to fill out the digital questionnaire. Patients were asked for permission to use their data anonymously and had given written informed consent. The ethics committee approved our study protocol.

All surgeons performing wrist arthroscopy and 3-LT were experienced, highly-experienced or expert surgeons (level 3−5) according to the Tang classification.[25,26] All surgeons were fellowship trained and/or certified according to the Federation of European Societies for Surgery of the Hand.

Arthroscopic Evaluation

After brachial plexus anesthesia and tourniquet placement, the 1.9 mm arthroscope is introduced in the 3,4 portal with 3.5 kg traction. Additional midcarpal evaluation is performed through the radial and ulnar portal. Dry arthroscopy with careful inspection of the SLIL, radioscaphocapitate ligament, radioscapholunate ligament and LT ligament is performed, followed by examination of the cartilage of the scaphoid and lunate fossa and the scaphoid, lunate, triquetrum, capitate, hamate, and ulnar head. Parts of the procedure are recorded on video and all findings are documented systematically in the patient file directly after the procedure by the surgeon performing arthroscopy. The SLIL disruption is classified according to the classification of Geissler.

Surgical technique

Patients receive an ultrasound-assisted regional anesthetic block by experienced anesthesiologists. The SLIL is approached dorsally through an incision through the fourth extensor compartment base and volarly through a small incision over the flexor carpi radialis (FCR) tendon at the level of the palmar wrist crease. A 2.7 or 3.0 mm drill hole is made through the scaphoid following its longitudinal axis. A strip of the FCR tendon is passed from the volar scaphoid tuberosity to the dorsal surface and fixated to the lunate with a bone anchor after correction of a dorsal intercalated segment instability deformity. The FCR tendon strip is passed through the radiotriquetral ligament and sutured back on itself under tension with the wrist placed in neutral position. During the surgical procedure, a neurectomy of the posterior interosseous nerve is conducted. We do not routinely use temporary K-wires for fixation of carpal bones.

Patients receive a cast after surgery for 1 week, followed by a splint and an extensive hand/wrist rehabilitation program. At 5−6 weeks after surgery, patients are instructed to wear the splint only at nighttime or during daytime as a protective measure. Between weeks 7−12 after surgery, patients are instructed to take off the splint as much as possible and the wrist rehabilitation program is continued with a focus on coordination, strength and stability. The wrist rehabilitation program is guided by a certified hand therapist at least 1 to 3 times a week.

Outcome measures

Primary endpoints were patient-reported pain and hand/wrist functionality measured using the Patient-Rated Wrist Evaluation (PRWE) and patient-reported satisfaction measured on a self-designed and validated questionnaire 12 months after surgery.[27] The PRWE evaluates pain and function with 15 questions on a scale ranging from 0 (no pain or dysfunction) to 10 (severe pain or dysfunction).[28] High PRWE scores consequently illustrate more pain or dysfunction than lower PRWE scores. Participants completed the first questionnaire between intake and surgery and subsequently at 3- and 12-months after surgery.

Satisfaction with the treatment result was assessed at 12-month follow-up and scored in 5 categories: poor, moderate, fair, good, and excellent. We classified patients with poor, moderate, or fair results as "unsatisfied" and good or excellent as "satisfied".

Secondary endpoints were RTW and complications. The RTW questionnaire was completed by participants 6 weeks, and 3, 6, and 12 months postoperatively. When patients return to work, subsequent questionnaires are canceled. The questionnaire uses 7 questions to evaluate if patients worked preoperatively, if patients were able to resume preoperative work activities, time after surgery until patients returned to work, difference in number of hours worked, difference in type of work, time until patients could resume normal work, and number of days away from work due to surgery.[29]

Basic patient characteristics, details on diagnostic workup and surgical procedure were collected. Complications were scored according to the International Consortium for Health Outcomes Measurement Complications in Hand and Wrist conditions tool, modified and derived from Dindo et al.[30,31]

Statistical Methods

A paired *t*-test was used for within-group comparison of 2 time points. For the bivariate analysis with a

TABLE 1. Demographic Details for Patients with Partial and Complete SLIL Injury

	Partial SLIL Injury	Complete SLIL Injury
No of patients (n)	39	90
Mean age (SD), y	42 (11)	47 (9)
Sex, male (%)	23 (59)	59 (66)
Body mass index, mean (SD), kg/m^2	26.1 (3)	26.9 (5)
Number of smoking patients, n (%)	10 (26)	9 (10)
Duration of symptoms, mean (SD), mo	28 (43)	27 (53)
Profession, n (%)		
Light physical work (eg office work)	13 (33)	31 (34)
Moderate physical work (eg working in a store)	12 (31)	32 (36)
Heavy physical work (eg construction work, road worker)	14 (36)	27 (30)
TFCC injury, n (%)		
Abnormal acute traumatic (Palmer I)	15 (39)	26 (29)
Abnormal degenerative (Palmer II)	2 (5)	5 (6)
Normal	22 (56)	59 (66)
Hand dominance, n (%)		
Left	4 (10)	9 (10)
Right	15 (39)	48 (53)
Ambidexterity	4 (10)	3 (3)
Unknown	16 (41)	30 (33)

TFCC, triangular fibrocartilage complex.

power of 0.8 and α of 0.05 the number of included patients supersedes the required 38 and 76 patients in each group. *Post hoc* power analysis showed that we did not have adequate power to evaluate for any significant differences in the complication rate.

A multivariable linear regression model was used to determine differences between the partial and complete SLIL injury groups, independent of clinical characteristics. Multivariable regression analysis had a power of 0.8 with an α of 0.05 to show an effect size of 0.15 using 9 predictors. Univariable survival analysis was performed with the Kaplan-Meier method to assess the time to RTW. In the survival analysis, patients were censored when they reached retirement age or were lost to follow-up. A Cox proportional hazard model was used to adjust for baseline variables in the RTW analysis. The confidence interval was set at 95% and $P < .05$ was considered statistically significant.

RESULTS

A total of 381 patients were treated with 3-LT during the study period. We excluded 138 patients because of an absence of trauma in the medical history or an unknown Geissler stage. Another 114 patients were excluded because of incomplete questionnaires, articular damage of the carpal bones (diagnosed preoperatively by x-ray, computed tomography, magnetic resonance imaging, arthroscopy or observed preoperatively), abnormal wrist anatomy due to other underlying pathology (Kienböck disease or symptomatic ulnocarpal abutment syndrome treated with ulna shortening osteotomy) or unavailable 12-month data. This resulted in the inclusion of 129 patients with partial and complete traumatic SLIL injury treated with 3-LT (Table 1).

Additional ligamentous injuries were observed in 63 patients. Forty-eight patients had additional triangular fibrocartilage complex injury simultaneously treated with arthroscopic debridement and synovectomy (Table 1). Since these were all peripheral tears, triangular fibrocartilage complex reinsertions were not performed. Two patients with partial SLIL injury and concomitant LT ligament injury were treated with an extended 3-LT (FCR strip extension to include the triquetrum).

We performed 3-LT either directly after arthroscopy (8%) or later (92%). This mainly depended on the surgeon's or patient's preference.

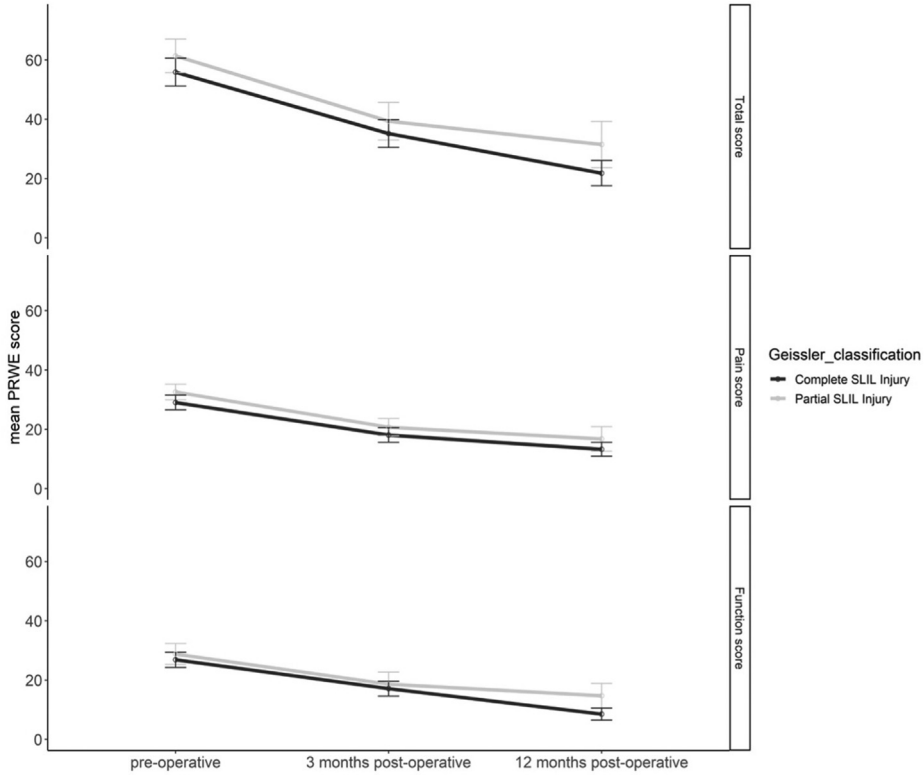

FIGURE 1: The mean patient-rated wrist evaluation total, pain, and function scores for patients with partial and complete SLIL injury preoperatively and at 3 and 12 months after surgery with 95% confidence interval error bars. The *greyscales* distinguish the partial and complete SLIL groups.

The percentage of simultaneous surgeries was distributed equally among both study groups, 17% in the partial and 18% in the complete SLIL injury group.

Patient-Rated Wrist Evaluation

The mean PRWE intake scores were 55.0 (SD = 22.8) for the complete group and 61.4 (SD = 18.1) for the partial group ($P = 0.15$). The PRWE total score, pain score, and function score significantly improved in both groups between intake and 3 months after surgery ($P < .05$) and 3 and 12 months after surgery ($P < .05$; Fig. 1).

When adjusting for clinical characteristics, PRWE total scores ($P = .94$), function scores ($P = .34$), and pain scores ($P = .31$) did not significantly differ at 12 months after surgery between the complete and the partial SLIL injury group.

Satisfaction

Fifty-two percent of patients with partial SLIL injury and 66% of patients with complete SLIL injury reported to be satisfied with the treatment result at 12 months postoperatively ($P = .44$; Fig. 2).

Return to work

The RTW rate at 12 months after surgery was 73% for patients with partial and 92% for patients with complete SLIL injury, with a mean RTW of 15 and 12 weeks, respectively. The curve shows that a few additional patients with a partial injury went back to work beyond 20 weeks whereas an upward trend is seen up until 26 weeks for patients with a complete injury (Fig. 3).

In a secondary analysis we adjusted for baseline characteristics and found a hazard ratio of 1.70 (95% confidence interval, 1.11−2.61; $P < .05$) for patients with complete SLIL injury. This implies the RTW within the first 12 months after surgery is 70% higher for patients with complete SLIL injury.

Complications

Twenty-five percent of all patients with chronic traumatic SLIL injury had grade 1, 12% grade 2 and 2% grade 3 complications (Table 2). The percentage of complications in the partial and complete groups was similar for all complication grades.

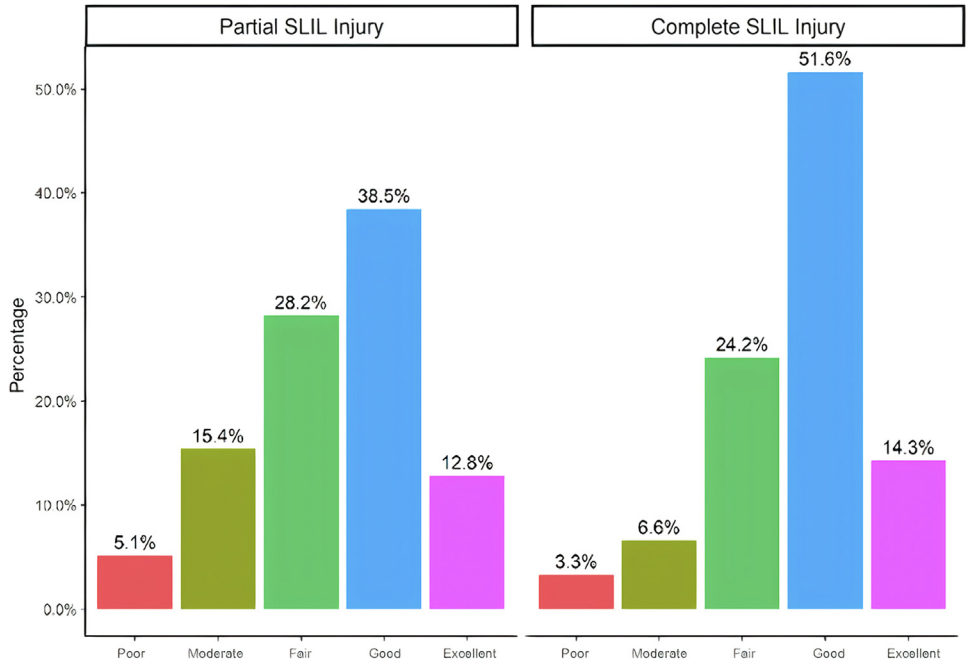

FIGURE 2: Satisfaction with the treatment result of patients with partial and complete SLIL injury at 12 months after surgery.

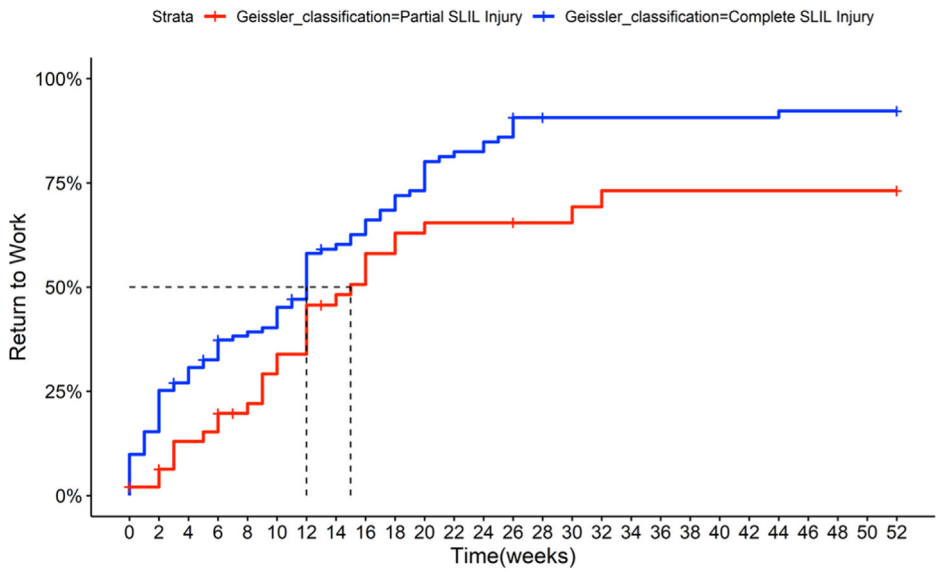

FIGURE 3: Kaplan-Meier plot of the return to work after surgery for patients with partial and complete SLIL injury.

DISCUSSION

This study aimed to investigate if there is a difference in patient-reported pain, hand and wrist function, satisfaction, and RTW between patients with partial or complete chronic traumatic SLIL injury treated with 3-LT at 12 months after surgery.

The mean PRWE total scores between the partial and complete SLIL injury groups at 1 year after surgery (32 vs 22 points) differed by 10 points, however this difference was not significant when correcting for baseline characteristics. Pauchard et al[15] reported a higher total PRWE score of 37 at a mean of 25 months after surgery; however, their sample contained patients with traumatic and nontraumatic SLIL injury and static and dynamic SLI. El Gammal et al[32] only included patients with Geissler 4 lesions in their study; however, they used different questionnaires to assess surgical outcomes (visual analog scale and Disability of

TABLE 2. Complications Within 12 Months Postoperative According to the International Consortium for Health Outcomes Measurement Complications in Hand and Wrist Conditions

	Partial SLIL injury, n (%)	Complete SLIL injury, n (%)	Specification
None	22 (56)	56 (62)	None
Grade 1	12 (31)	20 (22)	Extra analgesics*, splinting or hand therapy†
Grade 2	4 (10)	12 (13)	Steroid injections or antibiotics‡
Grade 3A	0 (0)	0 (0)	None
Grade 3B	1 (3)	1 (1)	Proximal row carpectomy

*Additional nonsteroid anti-inflammatory drugs or opioids other than the standard postoperative protocol.
†When advised or performed after the standard postoperative immobilization and hand therapy protocol of 3 months.
‡Infection or inflammation directly related to the surgery.

Arm Shoulder and Hand) and did not report outcomes for patients with Geissler 2-3 injuries.

The partial and complete groups improved by ≥29 points in PRWE total scores at 12 months after surgery (29.9 and 33.2, respectively). This is considerably greater than the minimal clinically important difference of 14 presented by Sorenson et al,[33] 11.5 presented by Walenkamp et al,[34] and 22 presented by Hoogendam et al.[35] Even though we initially observed a difference of 10 points between the groups, this difference was not statistically significant and both groups have substantially exceeded the minimal clinically important difference.

Our results on satisfaction with the treatment results did not differ significantly between the groups, which further implies that differences in PRWE scores between groups are not clinically relevant when the minimal clinically important difference is greatly exceeded. Earlier studies reported a good or excellent satisfaction of 79% after 3-LT treatment for chronic SLIL injury.[16] However, separate results for patients with partial or complete lesions were not provided and the follow-up period was longer.

We observed a significant difference in median RTW between the study groups. Patients with complete SLIL injury returned to work earlier (12 vs 15 weeks) and the RTW was higher for patients with complete SLIL injury (92% vs 73%) at 12 months after surgery. The association between the Geissler classification and the RTW was significant (hazard ratio, 1.70). This is important to mention to patients when informing them about their surgery.

Complication rates were similar between the study groups. This corresponds to the results of Rohman et al,[23] who concluded that the occurrence of complications depends mainly on the duration of preoperative complaints and not on the extent of SLIL injury. Most complications were minor (25%) requiring extra analgesics, splinting, or additional hand therapy. Two percent of patients underwent minor or major reoperations, which is similar to 3% reported by Talwalker et al[16] and lower than 6% reported by Daly et al.[14]

A limitation of our study is the absence of measurement data on SL gaps, SL angles, and radiographic classification of static or dynamic SLI. Since this was a retrospective study, a study protocol was not in place when the patients were treated, and was the reason why there was no standardized workup and radiographic classification. Moreover, wrist arthroscopy was performed by multiple surgeons with varying arthroscopy expertise. Surgeons may debate the subjectivity of arthroscopic distinction between Geissler 2 and 3 tears,[7,8] whereas Geissler 4 tears generally are evident on arthroscopy.[36] Since we put Geissler 2 and 3 SLIL tears in the same study group, we do not expect this to have influenced the results. Additionally, co-interventions took place in both groups. Even though these were distributed equally in the 2 groups, additional procedures might have been more critical to the success of the intervention in one group than the other. This could have influenced the study results; however, we were unable to assess this in the current study. Finally, the lack of statistical power in the multivariable analysis is a limitation. With a sample of 135 patients, α of 0.05, power of 0.8, 5 clinical parameters, and 2 groups, we would only be able to find a "large" effect size of 0.44. The fact that after adjusting for clinical characteristics, the difference in PRWE is no longer significant means the differences are associated with clinical characteristics and probably not large.

This study provides evidence that patients with partial and complete SLIL injury significantly

improve in wrist function and pain score, and after adjusting for clinical characteristics we did not find a statistically significant difference between the groups. Therefore, we conclude that 3-LT effectively reduces pain and improves functionality in patients with chronic SLIL injury and clinical instability with varying extents of disruption. Accordingly, the extent of SL disruption should not be a consideration when counseling patients on 3-LT.

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