Long-Term Outcomes for Arthroscopic Thermal Treatment for Scapholunate Ligament Injuries

Matthew B. Burn, MD¹ Eric J. Sarkissian, MD¹ Jeffrey Yao, MD¹

¹Department of Orthopaedic Surgery, Stanford University Medical Center, Redwood City, California

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Address for correspondence Jeffrey Yao, MD, Department of Orthopaedic Surgery, Stanford University Medical Center, 450 Broadway Street, MC 6342, Redwood City, CA 94063 (e-mail: jyao@stanford.edu).

Abstract

Background Arthroscopic electrothermal treatment of low-grade Geissler's scapholunate interosseous ligament (SLIL) tears has shown clinical benefit at short-term follow-up.

Questions/Purpose This study aims to evaluate the long-term functional outcomes in patients undergoing this treatment.

Patients and Methods A retrospective review of all patients treated between 2005 and 2013 was performed. Patients were excluded with less than 5 years of follow-up, the presence of static SLIL injuries, prior wrist surgery, and concomitant denervation. Symptom resolution, return to activity, postoperative complications, range of motion, grip strength, and subsequent treatment were recorded. Each patient completed Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH), Modified Mayo Wrist (MMW), and Patient-Rated Wrist Evaluation (PRWE) questionnaires.

Results Nine patients underwent treatment for Geissler's grade I, II, and III SLIL injuries with a mean 7 years (range: 5–11 years) of follow-up. Mean grip strength was 99% of the nonsurgical extremity. Wrist motion was near symmetric with a mean of 76 (± 14), 74 (± 8), 21 (± 13), and 40 degrees (± 13) for wrist flexion, extension, radial deviation, and ulnar deviation. QuickDASH improved significantly by a mean 39 points (50 [preoperative]–11 [postoperative], $p = 0.009$). Postoperative MMW and PRWE scores were 83 and 14, respectively. Visual analog scale (VAS) score was 1.4. A total of 90% was returned to their preinjury level of function or higher.

Conclusions Arthroscopic electrothermal treatment of low-grade Geissler's SLIL tears demonstrates excellent objective and subjective outcomes at a minimum 5-year follow-up, providing evidence that this is an effective, safe, and, most importantly, durable-therapeutic modality.

Level of Evidence This is a Level IV, case series study.

Keywords

- capsulorrhaphy
- electrothermal
- shrinkage
- scapholunate
- wrist

Scapholunate interosseous ligament (SLIL) injuries often result from trauma and are a common cause of dorsal-central wrist pain.¹ Geissler described four grades based on the appearance of the scapholunate ligament and the level of diastasis or step-off upon arthroscopic manipulation.^{2,3} Low-grade Geissler's (I, II, and III) injuries often respond to nonoperative management, including activity modification,

oral nonsteroidal anti-inflammatory drugs (NSAIDs), functional splinting, immobilization, injections, and physiotherapeutic modalities including flexor carpi radialis (FCR) strengthening.⁴ However, some go on to persistent pain and disability.⁵ Surgical management of these partial injuries without evidence of significant instability may involve simple debridement, pinning, capsulodesis, or electrothermal

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treatment.^{1,5-7} Although debridement has shown satisfactory outcomes, the potential for creating further instability and the lack of appropriate target tissue in redundant or elongated, rather than torn, ligaments present potential issues.^{5,7,8}

Electrothermal therapy utilizes radiofrequency (RF) probes producing alternating current at a high frequency, which transfers electromagnetic energy to the surrounding tissue in the form of heat.⁹ This technique has been used in ophthalmologic and cardiac surgery since the 1960s.⁹ The primary target in musculoskeletal surgery is type 1 collagen within ligaments which has a triple helical peptide pattern connected by “heat-stable” intermolecular and “heat-labile” intramolecular bonds.¹⁰ When heated to the appropriate temperature (between 60 and 80°C), the heat-labile cross-links break and change from a highly organized crystalline structure into a gel-like state, while the heat-stable bonds remain intact.^{9,11} At temperatures below this, no biologic changes take place, while higher temperatures can produce tissue liquefaction and/or necrosis.⁹ Following electrothermal treatment, fibroblastic nuclear pyknosis occurs where fibroblasts begin to repair the ligament by producing collagen using these unwound collagen fibrils as scaffolding.⁹ This reparative process continues for at least 2 to 3 months after electrothermal treatment, but the exact time period required before reaching normal biomechanical strength is not known.^{10,12,13} In addition to “tightening” of the ligament, another suggested mechanism for the clinical efficacy of electrothermal treatment is denervation.¹⁴ Electrothermal collagen shrinkage was a popular therapy for glenohumeral joint instability and attenuated knee anterior cruciate ligaments in the early 2000s.¹⁵ The initial enthusiasm waned in the shoulder and knee after long-term follow-up showed recurrent instability.¹⁶ However, successful use of electrothermal capsulorrhaphy has been reported in the wrist with prior studies, showing good short-term outcomes (6 months–4 years) for the treatment of scapholunate ligament injuries.^{1,8,17-19} The fundamental difference between the use of this technology in the wrist, instead of other joints, is the ability to immobilize the wrist for a full 6 weeks in a cast postoperatively to allow for adequate maturation of the thermally treated collagen, whereas this would be impossible in the shoulder or knee.

The goal of this study was to review the long-term clinical outcomes after the arthroscopic electrothermal treatment of scapholunate interosseous ligament injuries with Geissler's grades I, II, and III instability. Our primary hypothesis was that both subjective (functional questionnaires) and objective outcomes (grip strength and motion) would show durable long-term improvement. This study represents the longest follow-up, currently available within the literature, for this technique.

Patients and Methods

After obtaining institutional review board approval, the authors performed a retrospective review of all patients who underwent carpal ligament electrothermal capsulorrhaphy by one fellowship-trained hand surgeon at a large

tertiary referral center between 2005 and 2013. All patients, older than 18 years old, with SLIL injuries and without arthritic changes who had failed nonoperative management and went on to receive arthroscopic electrothermal treatment during this time period were included. Nonsurgical treatment included a minimum of 6 weeks of rest, activity modification, functional splinting, immobilization, nonsteroidal anti-inflammatory drugs, occupational therapy, and/or corticosteroid injections. At the time of arthroscopy, all included patients demonstrated Geissler's grades I, II, or III instability. Exclusion criteria included less than 5-year follow-up, physical examination or radiographs demonstrating complete SLIL injury (static instability) or subsequent scapholunate advanced collapse (SLAC) arthritis, any prior wrist surgery, a traumatic injury to both wrists (polytrauma), and concomitant posterior interosseous neurectomy, or other denervation during the index procedure.

All patients presented with a history of dorsal-central wrist pain aggravated by wrist extension. On examination, they had tenderness over the dorsal-central wrist with palpation. None of these patients demonstrated evidence of intercarpal instability by stress testing (although frequently these maneuvers aggravated their symptoms), including Watson's scaphoid shift test, midcarpal or radiocarpal ballottement, and scapholunate or lunotriquetral ballotment.⁵ Radiographs, both static and stress, were obtained to rule-out higher grade SLIL injuries that would not be amenable to electrothermal treatment. Finally, none of these patients had arthroscopic evidence of complete SLIL injuries (Geissler's grade IV) that would not be amenable to thermal treatment. Magnetic resonance imaging without contrast of the involved wrist was obtained for preoperative planning when nonoperative management failed.

Review of the patient's charts was undertaken by authors who were not involved in the index surgical procedures. Demographics, such as gender, age, hand dominance, and laterality of the injured wrist, were collected. Patients were contacted to see if they were willing to participate in the research study. If they were willing and able to attend clinic in person, the questionnaires and measurements of grip strength and range of motion (ROM) were obtained. If, due to geographic restrictions, they were unable to attend clinic, the questionnaires were obtained electronically.²⁰ All grip strength measurements were obtained by the same calibrated Jamar hydraulic hand dynamometer (NexGen Ergonomics Inc., Quebec, Canada) set on the 2nd setting. All ROM measurements were made using a goniometer. The majority of patients (seven of nine patients) had preoperative quick disabilities of the arm, shoulder, and hand (QuickDASH) available. Upon follow-up, each patient completed a questionnaire packet including three standardized outcome measures, QuickDASH, Patient-Rated Wrist Evaluation (PRWE), and Modified Mayo Wrist Score (MMWS). This packet also contained following questions regarding whether the patient: (1) had received any subsequent injections or surgery for their operative wrist; (2) would have elected to undergo the surgery again knowing their current functional state; and (3) was able to return to function at the same or

higher level than prior to their injury, in addition to asking the patient to mark, using a visual analog scale (VAS) on a 10-cm horizontal line anchored at the end as “no pain (score of 0)” and “worst imaginable pain (score of 100);” their (4) current pain level; and (5) their average pain level over the past 2 to 3 months.²¹ Collected data were reported using descriptive statistics (mean and range). Comparison of pre- and postoperative QuickDASH scores involved a paired *t*-test with statistical significance set at $p < 0.05$.

Surgical Technique

Using a standard wrist arthroscopy tower (Linvatec, Largo, FL), 10 to 15 lbs of distraction was applied to the index and middle fingers to distract the radiocarpal and midcarpal joints. The radiocarpal joint was insufflated with 3 to 10 mL of normal saline, while palpating the distal radioulnar joint and midcarpal joint for a fluid wave.²² Standard 3 to 4, 6R, midcarpal radial (MCR), and midcarpal ulnar (MCU) portals were created, and a complete diagnostic arthroscopy was performed. All scapholunate ligaments underwent arthroscopic stress testing and probe manipulation under direct visualization to define a Geissler's grade based on the level of instability (►Fig. 1). If deemed appropriate, the volar portion of the SLIL and radioscapophcapitate (RSC) ligament received electrothermal treatment from midcarpal joint, while the dorsal portion of the SLIL received treatment from both the radiocarpal and midcarpal joints. As has been previously described, electrothermal treatment was administered in small, nonablative pulses using a VULCAN RF arthroscopy system with a Micro TAC-S angled monopolar probe (Smith & Nephew, Andover, MA) to produce a visible color and texture change within the ligament.² ►Figures 2 and 3 demonstrate the SLIL pre- and postelectrothermal

Fig. 1 Image of the scapholunate interosseous ligament (SLIL) interval from the midcarpal joint prior to electrothermal treatment. The probe tip was able to be inserted into the interval.

Fig. 2 Image of the volar scapholunate interosseous ligament (SLIL) from the midcarpal joint prior to electrothermal treatment.

treatment viewed from the midcarpal joint. ►Fig. 4A, B and ►Fig. 5 demonstrate the SLIL pre- and postelectrothermal treatment viewed from the radiocarpal joint. Specific focus was paid to the dorsal portion of the SLIL as it is the most biomechanically important. The synovial fluid temperature was carefully monitored to avoid high temperatures that could lead to tissue injury and chondrolysis. ►Fig. 6 demonstrates a posttreatment examination for instability from the midcarpal joint. The wounds were closed with

Fig. 3 Image of the volar scapholunate interosseous ligament (SLIL) from the midcarpal joint after electrothermal treatment.

Fig. 4 (A and B) Images of the dorsal scapholunate interosseous ligament from the radiocarpal joint prior to electrothermal treatment.

nylon suture and the extremity was placed into a thumb spica splint extending to the proximal forearm for 2 weeks. At the first postoperative visit, the sutures were removed and the patient was placed into a thumb spica cast for an additional 4 weeks. Wrist ROM exercises began at 6 weeks postoperatively with use of a removable brace as dictated by comfort. Wrist strengthening exercises were begun at 8 weeks.

Results

During the study period, nine patients met all inclusion and exclusion criteria and were available for follow-up at a mean of 7-year (range: 5–11 years) follow-up. Fifty-six percent were men and the mean age was 40 years old (range: 26–55 years). All patients reported at least 6 months of symptoms and were treated nonoperatively for at least 3 months

prior to consideration for surgery. Based on diagnostic wrist arthroscopy, these injuries were classified as Geissler's grade 1 (three patients), grade 2 (four patients), and grade 3 (two patients). In the two cases of higher grade pathology (Geissler's grade 3), a small radial wrist incision was made to allow placement of two buried K-wires (scapholunate and scapho-capitate), while reducing the risk of iatrogenic damage to crossing branches of the superficial radial nerve. These patients required a second staged procedure at 8 weeks for pin removal. Concomitant procedures, in addition to electrothermal treatment of the SLIL, performed at the time of index arthroscopy, are listed in **Table 1**. Due to geographic restrictions, ROM and grip strength were unobtainable from two and three patients, respectively.

Fig. 5 Image of the dorsal scapholunate interosseous ligament from the radiocarpal joint after electrothermal treatment.

Fig. 6 Image of the scapholunate interosseous ligament (SLIL) following electrothermal treatment. During instability testing through the midcarpal joint, the probe tip was unable to be inserted into the SLIL interval.

Table 1 Concomitant procedures performed during index wrist arthroscopy

Case	Triangular fibrocartilage complex (TFCC) debridement	Arthroscopic excision of dorsal ganglion cyst	Pinning (scaphocapitate and scapholunate ×8 weeks)
1	X		X
2	X		X
3	X	X	
4	X		
5	X	X	
6			
7	X		
8	X		
9		X	

Note: X indicates that the patient/case (represented by the number in the left-most column) received the treatment at the top of each column.

Questionnaires were obtained from all nine patients at the final follow-up. At final follow-up, 67% (six of nine) of patients had received no subsequent treatment. Of the remaining three patients, only one patient had received subsequent treatment for his scapholunate ligament involving a corticosteroid injection close to a decade postoperatively, leading to near-complete relief of his symptoms. The remaining two patients had sustained an ipsilateral triangular fibrocartilage complex tear or a contralateral distal radius fracture in subsequent falls that required treatment. Eight patients (89%) were able to return to their preinjury level of activity, while one patient was unable to return to yoga due to the wrist hyperextension and loading required. All nine

patients (100%) reported that they would choose to undergo the surgery again now as they know the outcome. Current VAS score was 1.4 (standard deviation [SD] = 2, range: 0–6), while VAS score averaged over the past 2 to 3 months was 1.2 (SD = 2, range: 0–6).

Overall, grip strength at final follow-up was a mean 99% of the contralateral hand (range: 86–109%). Mean wrist flexion, wrist extension, radial deviation, ulnar deviation, pronation, and supination were 76 (± 14) and 74 (± 8), 21 (± 13), 40 (± 13), 83 (± 7), and 86 (± 10) degrees, respectively. For all patients, the mean postoperative QuickDASH and PRWE scores were 14 (range: 0–59) and 14 (range: 0–56), respectively. Due to the grip strength requirement for calculation, MMWS was only available in six (67%) patients and mean postoperative scores were 83 (range: 75–100). For the seven (78%) patients with pre- and postoperative scores, QuickDASH improved significantly by 39 points, from 50 (range: 7–77) preoperatively to 11 (range: 0–59) postoperatively ($p = 0.009$). Individual Geissler's grades, grip strengths, ROM, QuickDASH scores, MMW scores, and PRWE scores are shown in ►Table 2.

Discussion

The authors aimed to examine the clinical subjective and objective outcomes of arthroscopic electrothermal capsulorrhaphy of the SLIL at long-term follow-up. This study demonstrates a clinically significant change in QuickDASH after electrothermal treatment of low-grade SLIL injuries, in addition to good-to-excellent MMWS and low-PRWE scores, which is maintained at long-term follow-up. Theoretical reasons for this success in the wrist (in comparison to the shoulder and knee) may be due to as follows: (1) the ability to adequately immobilize the wrist for a prolonged period of time (i.e., 6–8 weeks), allowing for consolidation and fibroblastic repair for increased stiffness; and/or (2) a smaller

Table 2 Patient demographic and outcome data

Case	Geissler's grade	Follow-up (y)	Pre Quick DASH	Post Quick DASH	Post Grip strength (%) ^a	Post Wrist flexion	Post Wrist extension	Post Pronation	Post Supination	Post MMWS	Post PRWE
1	III	6	48	0	109	85	85	75	90	100	0
2	III	6	34	11	86	50	75	80	75	85	25
3 ^b	I	11	–	34	–	–	–	–	–	–	56
4	I	10	68	0	–	–	–	–	–	–	0
5	II	6	70	0	95	65	60	90	90	80	0
6	II	5	7	5	99	80	80	80	90	75	3
7	II	5	45	5	–	90	70	80	95	–	5
8	II	7	77	59	106	85	70	80	70	80	27
9	I	11	–	11	98	75	80	95	95	75	15

Abbreviations: MMWS, modified Mayo wrist score; Post, postoperative; Pre, preoperative; PRWE, patient-rated wrist evaluation; QuickDASH, quick disabilities of the arm, shoulder, and hand.

^aGrip strength in operative hand, as a percentage, compared with contralateral wrist.

^bThis patient received subsequent treatment for his scapholunate ligament involving a corticosteroid injection close to a decade postoperatively, leading to near-complete relief of his symptoms.

cross-sectional area of treatment leading to more complete denervation.^{10,17} This denervation effect of electrothermal treatment has been demonstrated by Pirolo using immunofluorescent staining.^{14,23}

Prior studies have been published on the clinical results of electrothermal treatment for partial SLIL injuries with overall promising results. Danoff et al published their results as part of a clinical review paper with a mean of 4-month (range: 3–8 months) follow-up in eight patients (Geissler's grade 1, one patient; grade 2, seven patients) showing subjective "good pain relief" and "minimal loss of motion" in six patients, while one patient went on to wrist arthrodesis.¹⁹ Darlis et al published on 16 patients (Geissler's grade 1, two patients; grade 2, 14 patients) at a mean of 19-month (range: 9–34 months) follow-up.⁸ Of these, 50% of patients achieved "excellent" (defined by an MMWS score > 90) and 38% "good" (between 80 and 89) results, with a final grip strength of 78% compared with the uninjured hand.¹⁷ Although they reported a change in VAS pain from pre- to postoperatively, the preoperative values were collected postoperatively (based on patient memory) and are at high risk of recall bias. No patients required further procedures. Hirsh et al published on 10 patients (all Geissler grade 2) with a mean of 28-month (range: 12–44 months) follow-up.¹ Postoperatively, they found a mean QuickDASH of 20 and grip strength of 90%. While 90% of patients were asymptomatic, one patient required a revision wrist arthroscopy with debridement. Shih and Lee reported on 19 patients (predynamic, six patients; dynamic, 13 patients) with a mean of 28-month (range: 24–34 months) follow-up.¹⁸ Postoperatively, they found a mean MMWS of 89. Separate pre- and postoperative grip strength values were not reported, but they found a 15% improvement in grip strength after surgery. Although 15 patients were "fully satisfied" and "resumed preinjury activity," three patients went on to revision surgery with dorsal capsulodesis close to 1 year postoperatively. Lee et al published on six SLIL injuries (in addition to 10 lunotriquetral ligament injuries) at a mean of 52-month (minimum 3 years) follow-up.¹⁷ Outcomes were not reported for SL specifically but overall (for both SLIL and LTIL injuries) they showed a mean postoperative MMWS score of 95.

Due to differences in outcome, reporting between all of these studies, comparisons with the findings of our study are difficult. However, our study reports on the longest term follow-up of patients undergoing this treatment in the literature with a mean 7 years (minimum 5 year) of follow-up for nine patients. Only one patient had recurrent symptoms that required additional treatment which occurred 9 years after the index procedure and resolved after a corticosteroid injection. Most studies have shown an improvement in grip strength postoperatively; however, based on relative values found in prior reports, the recovery appears to continue to increase past 1 to 2 years postoperatively to near 100% after 5 years. In agreement with other studies, wrist motion (wrist flexion, wrist extension, radial deviation, ulnar deviation, and pronosupination) appears to recover to near full at long-term follow-up. While two studies reported change in MMWS pre- to postoperatively, none reported change in QuickDASH pre- to postoperatively.^{17,18}

There are limitations to the current study including the retrospective nature, the small sample size, and the lack of radiographic follow-up. However, the long-term follow-up is a major strength of this study. Although a larger sample size would be preferable, the authors had very strict inclusion and exclusion criteria and chose to exclude several patients based on inadequate minimum follow-up time, prior wrist surgery or polytrauma, concomitant thermal treatment of other intercarpal injuries, and concomitant posterior interosseous neurectomy or other denervation. Three of the included patients had concomitant arthroscopic dorsal ganglion cyst excisions, which have been commonly reported in association with other intra-articular pathology, most commonly scapholunate ligament injuries (often Geissler's grade II or III tears).²⁴ Due to the nature of wrist pathology and trauma, it is rare for scapholunate ligament injuries to occur in isolation. Prior studies on electrothermal treatment of scapholunate ligament injuries have also included concomitant procedures, such as debridement/repair of Triangular fibrocartilage complex (TFCC) injuries, and debridement of chondral injuries.^{1,8} Radiographic follow-up was not available, so we are unable to comment on chondrolysis or radiographic parameters for carpal alignment. However, Lee demonstrated no chondrolysis or progression of carpal malalignment at 4-year radiographic follow-up.¹⁷

Our study demonstrates excellent objective functional parameters and subjective outcome scores with no need for further procedures for Geissler's grades I, II, and III SLIL instability at a mean follow-up of 7 years (minimum 5 years). To our knowledge, this is the longest follow-up data for this procedure and our findings suggest that arthroscopic electrothermal treatment is an effective, safe, and, most importantly, durable therapeutic modality for treating these long-term injuries.

Ethical Review Committee Statement

This study was approved by the human subjects in medical research panel of the Stanford University institutional review board (eProtocol# 38220).

Note

The study was conducted at Stanford University Medical Center.

Conflict of Interest

None declared.

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