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Original Research

Preliminary Outcomes of Scapholunate Ligament Augmentation with Internal Brace Technique

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Purpose: Injury to the scapholunate (SL) interosseous ligament (SLIL) is a common cause of carpal instability. Internal brace augmentation has been used in various ligament repair procedures; however, further investigation of its outcomes in hand surgery is needed. This study aimed to examine outcomes for patients who underwent SLIL repair with internal brace augmentation.
Methods: Patients who underwent SLIL repair with the internal brace technique and had at least 1 year of follow-up were contacted. Available patients returned for an in-person evaluation with new radiographs and physical examination. If patients could not be contacted but had x-rays and physical examinations performed at greater than 1 year after surgery, these data were collected from their medical records. Participating patients completed the *Quick*DASH and Patient-Rated Wrist Evaluation surveys and rated their satisfaction with the surgery. Outcomes assessed included wrist range of motion, grip strength, scaphoid shift test, SL gap, SL angle, and radiographic evidence of radiocarpal arthritis.
Results: We collected outcomes for 14 SLIL repairs among 13 patients (12 male). Mean length of the follow-up was 41 months ($n = 14$, 17–64). Mean *Quick*DASH and Patient-Rated Wrist Evaluation scores were 6.1 (0–43.2) and 9.6 (0–65), respectively. Radiographic measurements remained stable from immediate to latest follow-up, and no radiocarpal arthritic changes were noted. However, SL gap decreased from a mean of 5.33 mm (3.4–6.7) before surgery to 3.34 mm (2–4.6) at the latest follow-up, and SL angle decreased from a mean of 79.5° (67°–97°) before surgery to 67.3° (51°–85°) at the latest follow-up. All scaphoid shift tests were stable.
Conclusions: Therefore, SL internal brace augmentation has favorable short-term results with improvements in pain, function, satisfaction, and carpal alignment at greater than 1 year postoperatively. This technique can be an effective option for the management of SL instability in the short term.
Type of study/level of evidence: Therapeutic IV.

Injury to the scapholunate interosseous ligament (SLIL), diagnosed clinically or via magnetic resonance imaging, is one of the most common causes of carpal instability. It is well understood that chronic dissociation of the scaphoid and lunate bones, especially when injury to additional critical stabilizers of the proximal carpal row is involved,[1] can lead to dorsal intercalated segmental instability (DISI). This can further progress to degenerative arthritis, a condition referred to as scapholunate advanced collapse.[2] Therefore, early diagnosis and management of SLIL injury is critical.

The surgical management of SLIL injuries can involve direct repair of the native ligament, reconstruction of a new ligament, and/or other stabilization techniques for the scapholunate (SL) joint. Various procedures have been described in the literature including dorsal capsulodesis,[3] tenodesis,[4] and bone-ligament-bone autografts,[5] each with subsequent modifications such as the anatomical front and back repair and SL internal brace 360° tenodesis procedure.[6,7] Additional techniques include reduction-association with a screw through the SL joint[8] and the SL axis method.[9] However, there remains no consensus on the optimal technique for surgical management.[10]

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This study investigates SLIL repair with an "internal brace" constructed with suture tape and bone anchors (Arthrex). Primary ligament repair is typically performed using direct suture repair or suture anchor repair. Because of the inherent small and compromised nature of a torn SLIL, acute SLIL repairs are often augmented with K-wire stabilization and/or prolonged immobilization after surgery. When SLIL reconstruction is necessary, the Brunelli or modified Brunelli tenodesis technique is commonly used. This requires harvesting of a portion of the flexor carpi radialis tendon, which is passed through the scaphoid and lunate to stabilize the SL interval.[3] Internal brace augmentation has been offered as a method to strengthen the SLIL repair.[7,11] The suture tape can theoretically resist loads along multiple planes, potentially obviating the need for flexor carpi radialis harvesting or K-wire fixation and allowing for an earlier range of motion.[12]

The primary aim of this study was to investigate the outcomes of SLIL repair with internal brace augmentation at greater than 1 year after surgery using patient-reported outcome measures, functional outcome measures, physical examination, and radiographic findings. The results of this study will improve our understanding of this SLIL repair technique to help guide future management of SL instability.

Materials and Methods

Data collection

Upon institutional review board approval, a retrospective chart review of all patients at least 18 years of age who underwent SLIL repair with internal brace augmentation by one of three fellowship-trained orthopedic hand surgeons was performed. Data regarding patient demographics, date of surgery, laterality, operating surgeon, and preoperative diagnosis were collected. Patients who had greater than 1 year of follow-up since their surgery were contacted via telephone and invited to participate in the study.

Patient-reported outcomes included Quick Disabilities of the Arm, Shoulder, and Hand questionnaire (*Quick*DASH), Patient-Rated Wrist Evaluation (PRWE), and a 5-point satisfaction scale (1 = very dissatisfied and 5 = very satisfied). Functional outcomes included grip strength measured as the mean of three consecutive attempts using a dynamometer (Jamar Hand Dynamometer; Sammons Preston Rolyan), passive range of motion (flexion, extension, radial deviation, and ulnar deviation), and the Watson scaphoid shift test for SL instability. Radiographic outcomes included SL gap (SLG) and SL angle (SLA), which were measured using the institution's imaging software. SLG was measured as the horizontal distance between the midportions of the scaphoid and lunate on a posteroanterior radiograph of the wrist. SLA was measured as the angle between the long axis of the scaphoid and short axis of the lunate on a lateral radiograph of the wrist. Data at preoperative and immediate postoperative follow-up visits were collected from patient charts when available. The same outcomes at minimum 1-year follow-up were collected from patients directly on return to the clinic for the study.

Statistical analysis

Descriptive statistics were performed for all outcomes of interest. Paired *t*-tests were used to compare pre- and postoperative radiographic measurements, immediate and latest postoperative radiographic measurements, physical examination results, and questionnaire scores when available. Statistical significance was set at $P < .05$.

Surgical technique

The procedure was performed similarly by all three surgeons (Fig. 1). A standard dorsal approach to the wrist was used. The joint was exposed with either a ligament-sparing capsulotomy as described by Berger et al[13] or an inverted T capsulotomy. A 1.6-mm K-wire was placed in both the scaphoid and the lunate, which was used as a joystick to correct the DISI deformity and compress the SL interval. Carpal reduction was secured with two 1.6-mm K wires, one through the SL joint and one through the scapho-capitate joint, percutaneously placed and cut a few millimeters below the skin. With the carpus reduced and pinned, the torn SLIL was repaired with multiple simple 2-0 nonabsorbable sutures and/or a suture secured in a 3.5-mm Arthrex Swivelock anchor used to perform the internal brace portion of the procedure. To augment the repair in one patient, a 2-mm strip of the extensor carpi radialis brevis tendon was harvested through the same exposure, and each end was whip-stitched with a 2-0 nonabsorbable suture.

Next, the internal brace augmentation was applied. Drill holes—3.5 mm if tendon graft was used, 3.2 mm if not—were made with a cannulated drill over guidewires into the proximal and distal poles of the scaphoid and the central portion of the lunate. A 3.5-mm SwiveLock anchor (Arthrex) was placed in the proximal scaphoid hole with suture tape, as well as a tendon graft and 2-0 nonabsorbable suture, if used. The suture tape ± tendon graft was tensioned and secured in the lunate docking site with a second 3.5 SwiveLock anchor. The 2-0 suture, if included, was used to repair the SLIL. Finally, the suture tape ± tendon graft was tensioned and secured at the distal scaphoid docking site with a third 3.5

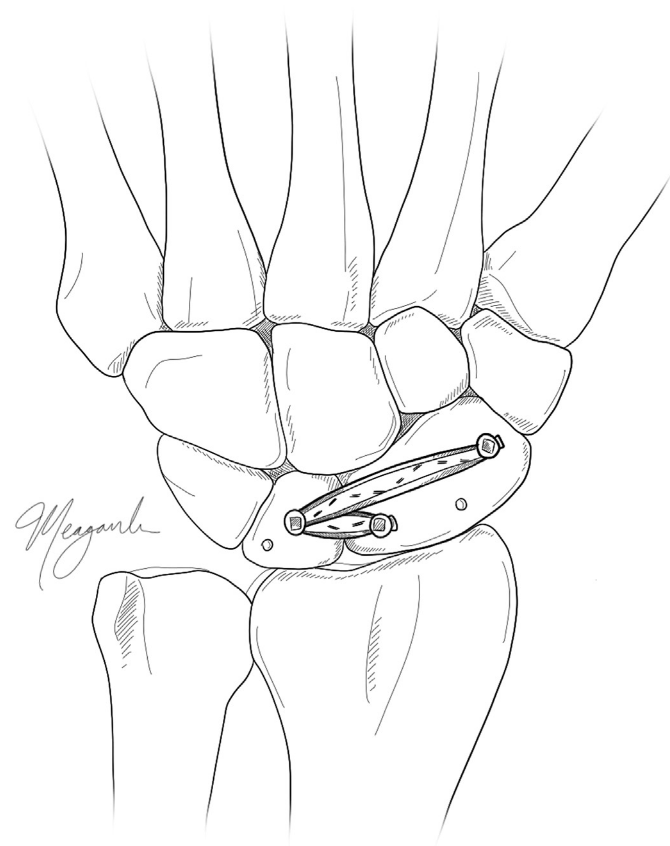

Figure 1. Schematic of the internal brace augmentation technique for scapholunate ligament repair, illustrating the suture tape ± tendon graft secured in the proximal and distal poles of the scaphoid and the central lunate.

SwiveLock anchor. After surgery, patients were placed in a volar plaster splint for 2 weeks and then transitioned to a short arm cast for an additional 2 to 3 months. Patients subsequently returned to the operating room for pin removal and to begin supervised hand therapy.

Results

A total of 102 patients who underwent SLIL surgery were identified via database search, of which 44 patients underwent internal brace augmentation. Thirty-five of these patients had greater than 1 year of follow-up since surgery. These 35 patients were contacted by phone, and 14 (32%) agreed to participate in the study. Ten patients were able to return to the clinic for new radiographs and physical examination, and the remaining four patients completed patient-reported outcome measures by phone interview but did not have radiographs at greater than 1 year after surgery. Ten patients had radiographs at greater than 1 year after surgery collected via chart review, and the remaining four patients could not be contacted to obtain patient-reported outcomes. Outcomes data were available for 14 SLIL reconstructions among 13 patients (12 male). K-wire placement and subsequent operative removal were required in 11 cases. The mean time from injury to surgery was 3.79 months ($n = 14$, 0.3–14.1), and the mean overall length of the latest follow-up was 41 months ($n = 14$, 17–64). The mean follow-up for patients with radiographic data was 39 months ($n = 10$, 17–64) and for patients completing outcome surveys was 43 months ($n = 10$, 22–63).

The mean calculated *Quick*DASH and PRWE scores at the latest follow-up were 6.1 (0–43.2) and 9.6 (0–65), respectively, indicating minimal to no pain or disability (Table 1). Mean preoperative *Quick*DASH score was 38.6 (13.6–72.7). No preoperative PRWE scores were available. The average difference in *Quick*DASH score between preoperative and postoperative time points was 32.5 ($P = .024$), representing a significant improvement in physical function and symptoms as the minimal clinically important difference for *Quick*DASH score can be considered 10.83 points.[14] Mean patient satisfaction with their surgery was 4.6 out of 5 (3.5–5). Only one patient did not feel that they returned to full functional status, although many noted minor loss of motion in their injured wrist.

Radiographic parameters remained improved after surgery compared to preoperatively (Table 2). SLG was 3.34 mm (2–4.6) at latest follow-up versus 3.26 mm (1.6–4.7) at immediate follow-up versus 5.33 mm (3.4-6.7) before surgery. SLA was 67.3° (51–85) at latest follow-up versus 70.0° (56–82) at immediate follow-up versus 79.5° (54–97) before surgery. Before surgery, seven (70%) wrists demonstrated a DISI deformity, as defined by an SLA greater than 70°; three (43%) of these seven wrists maintained correction of SLA to less than 70° at latest follow-up. Mean difference in SLG from before surgery to latest follow-up was 2.0 mm ($P = .0006$), and mean difference in SLA from before surgery to latest follow-up was 12.2° ($P = .060$; Tables 2 and 3). No radiocarpal joint space narrowing or other radiographic signs of joint degeneration was noted.

Physical examination findings at latest follow-up were compared between the injured wrist and uninjured contralateral wrist, excluding the one patient who underwent bilateral surgeries. Mean flexion and extension were 63° (45°–80°) and 61° (40°–80°) in the injured wrist compared with 83.3° (80°–90°) and 87.3° (85°–90°) contralaterally. Mean radial and ulnar deviation were 13.5° (10°–15°) and 18.3° (15°–20°) in the injured wrist compared with 14.5° (14°–15°) and 19° (18°–20°) contralaterally. Mean grip strength was 91.7 lb (81–104) in the injured wrist versus 93.5 lb (93.5) in the contralateral wrist after adjusting for right-hand versus left-hand dominance.[15] All scaphoid shift tests were stable. No major complications including reoperations, readmissions, or revision procedures were identified.

Discussion

Various surgical techniques to restore carpal alignment after SLIL injury have been described in the literature,[10] including the recently developed internal brace augmentation technique.[7,12,16] The foundation of this technique is augmentation of the dorsal ligament repair with robust suture tape to provide immediate stability, likely enhancing ligament healing and longevity of the repair. It might also eliminate the need for K-wire fixation and permit earlier mobilization.[12] The internal brace concept has been clinically and/or biomechanically investigated in the context of various orthopedic procedures including repair of the knee medial collateral ligament,[17] knee anterior cruciate ligament,[18] patellar tendon,[19] anterior talofibular ligament,[20] elbow ulnar collateral ligament,[21] and thumb ulnar collateral ligament.[11] However, its clinical investigation is lacking for SLIL repair.

Several biomechanical studies published in the past 5 years have supported the greater strength of internal brace augmentation over primary repair alone for SL instability.[22–26] Park et al[24] tested the load to failure and linear stiffness in 21 fresh-frozen cadaver wrists and found that while it did not recreate biomechanical properties equivalent to native intact SLIL, SLIL repair with internal brace augmentation had significantly higher strength than repair alone. Using 12 wrists, Thompson et al[22] likewise demonstrated a higher maximum load to failure with internal brace augmentation compared to SLIL repair alone. Zeiderman et al[25] used computed tomography to analyze differences in alignment of the SL joint after dorsal intercarpal ligament capsulodesis alone, dorsal intercarpal ligament capsulodesis with internal brace, and tendon autograft with internal brace. The authors found that of the three methods, SLIL repair with internal brace augmentation maintained the best SLG reduction. Kakar et al[23] alternatively evaluated reconstruction with internal brace augmentation, and arrived at similar conclusions when demonstrating that internal brace augmentation had significantly higher breaking strength compared to tenodesis alone and thus better replicates native SL yield strength.

This preliminary series of 14 cases demonstrated that functional, patient-reported, and radiographic outcomes remained successful at a mean follow-up of 41 months. Few other clinical studies evaluating SLIL internal brace outcomes have been published, but similarly demonstrate favorable radiographic and functional

Table 1
Patient-Reported Outcomes at T0 and T2 Time Points ($n = 10$)

	T0 (Preoperative)	T2 (Latest Postoperative)	Change From T0 to T2
***Quick*DASH score**	38.6 (13.6–72.7)	6.1 (0–43.2)	−32.5 *$P = .0243$
PRWE score	—	9.6 (0–65)	—

DASH, Disabilities of the Arm, Shoulder, and Hand; PRWE, Patient-Rated Wrist Evaluation.
* $P < .05$ is statistically significant.

Table 2
Radiographic Outcomes at T0, T1, and T2 Time Points ($n = 10$)

	T0 (Preoperative)	T1 (First Postoperative)	T2 (Latest Postoperative)	Change From T0 to T2
Static SL gap (mm)	5.33 (3.4–6.7)	3.26 (1.6–4.7)	3.34 (2–4.6)	−2.0 *$P = .0006$
SL angle (°)	79.5 (54–97)	70.0 (56–82)	67.30 (51–85)	−12.2° $P = .0600$

SL, scapholunate.
* $P < .05$ is statistically significant.

outcomes. Kang et al[27] reported three cases of perilunate dissociation augmented with an internal brace after SLIL and lunotriquetral interosseous ligament repair. All three patients were pain-free, returned to all activities, and had good carpal alignment with no arthritic changes at a mean follow-up of 12.7 months.

Most other clinical studies, however, focus on reconstruction with a tendon graft rather than repair. Although their results cannot be directly compared to ours due to differences in surgical technique, these studies provide evidence of the functional benefits of internal brace augmentation as a reinforcement and highlight the scarcity of clinical data available. In their retrospective series of nine patients who underwent internal brace augmentation of SLIL reconstruction, Kakar et al[12] demonstrated favorable outcomes at a mean follow-up of 33.7 months, consistent with our findings at a longer follow-up. The authors demonstrated a significant reduction in SLG from 5.1 to 2.8 mm ($P < .05$) and SLA from 71° to 57° ($P < .05$). They also found improvement in *Quick*DASH score from 54 to 12 ($P < .001$) and PRWE score from 58 to 12 ($P < .001$). Most recently, Kemler et al[16] performed a nonrandomized trial demonstrating that patients who underwent SLIL reconstruction with internal brace and early mobilization had improved wrist flexion and extension, higher satisfaction, and earlier return to work compared to patients who underwent K-wire fixation and immobilization for 6 weeks alone. However, their outcomes relied on varying postoperative management. To our knowledge, no additional studies investigating SLIL repair or reconstruction augmented with an internal brace exist.

Our outcomes can likewise be compared with reports of alternative methods for SLIL repair. A systematic review by Daly et al[28] investigated outcomes of tenodesis versus capsulodesis for chronic SLIL disruption. The authors identified 978 wrists from 40 studies at a mean follow-up of 39.1 months, and concluded that tenodesis had superior outcomes. They found an average reduction in SLA of 12.9° ($P = .001$) and SLG of 1.5 mm ($P < .001$) for tenodesis, and an average reduction in SLA of 1.1° ($P = .8$) and SLG of 0.3 mm ($P = .6$) for capsulodesis. In comparison, we found an average reduction in SLA of 12.2° ($P < .5$) and SLG of 2.0 mm ($P < .5$) at 39 months postoperatively, demonstrating similar results to tenodesis. Daly et al[28] also showed an improvement in the average DASH score of 27.3 ($P < .01$) for tenodesis and 20.2 ($P = .7$) for capsulodesis. Our SL internal brace results demonstrated a higher improvement in average *Quick*DASH score of 32.5 ($P < .05$). A more contemporary meta-analysis by Wu et al[10] of 1,172 patients from 42 studies found that bone-tissue-bone reconstruction may demonstrate better functional outcomes and reduced postoperative pain compared with capsulodesis and tenodesis. Specifically, DASH/*Quick*DASH score was best at 9.7 for bone-tissue-bone reconstruction, followed by 19.4 for tenodesis and 24.4 for capsulodesis ($P < .0001$) at a mean follow-up of 40.6 to 63 months. All scores were higher, indicating worse pain and/or disability, than our average *Quick*DASH score of 6.1. Future meta-analyses can aim to incorporate SL internal brace outcomes as the available data expands.

Of note, we found a further reduction in SLA from immediate to latest postoperative follow-up exists rather than the expected increase due to loosening of the repair over time. Possible reasons for this discrepancy include inherent measurement inaccuracies resulting from inconsistent, imperfect lateral x-ray views captured. Additionally, three patients had either greater than 1-year postoperative x-rays or immediate postoperative x-rays but not both, likely skewing the average values. It is also important to note that not all wrists experienced sufficient correction of SLA after surgery. Disruption to other ligament stabilizers, rather than isolated SLIL injury, may play an unrecognized role in the development of DISI deformity in our cohort. Several other limitations to this study exist, including insignificant variations in technique inherent to an individualized treatment approach. Most importantly, our relatively small cohort and large percentage of patients lost to follow-up pose a notable risk for selection bias. A strength of this study is that the temporal nature of data collection was hybrid. Although a portion of clinical and radiographic outcomes data was collected retrospectively, all patient-reported outcomes and a portion of clinical and radiographic outcomes data were

Table 3
Radiographic Measurements at T0, T1, and T2 Time Points ($n = 10$)

Demographics			T0 (Preoperative)		T1 (First Postoperative)		T2 (Latest Postoperative)	
Patient	Age at Surgery (y)	Laterality	SLG (mm)	SLA (°)	SLG (mm)	SLA (°)	SLG (mm)	SLA (°)
1	24.9	R	3.4	87	1.9	82	2	85
2	48.3	L	6	67	4.1	68	4.6	65
3	48.4	R	5.6	69	4.4	56	4.6	60
4	60.4	L	8.1	79	4.7	75	4.6	71
5	45.3	R	4.5	54	2.7	62	2.7	72
6	35.7	L	3.5	75	2.3	72	2.5	76
7	66.7	R	5.7	87	4.4	74	4.5	70
8	27.2	R	6.7	97	–	–	2.5	60
9	31.3	L	4.4	90	3.2	73	3.4	63
10	54.9	R	5.4	90	1.6	68	2.0	51
Mean	44.3	–	5.3	79.5	3.3	70	3.3	67.3
Range	24.9–66.7	–	3.4–6.7	54–97	1.6–4.7	56–82	2.0–4.6	51–85

L, left; R, right; SLA, scapholunate angle; SLG, scapholunate gap.

collected prospectively. Greater length of follow-up is necessary to assess the effectiveness of this procedure in the long term.

Overall, we found that the SL internal brace augmentation technique has favorable early results with consistent improvements in pain, function, and patient satisfaction. Although longer follow-up and a larger cohort are needed for more conclusive results regarding longevity of our outcomes, the procedure may be a reliable option for patients with SL instability.

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