Surgical outcomes of chronic isolated scapholunate interosseous ligament injuries: a systematic review of 805 wrists

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Background: Management of chronic isolated scapholunate interosseous ligament (SLIL) injuries has generated a substantial volume of low-quality literature with descriptions of multiple new surgical techniques, and the impact of instability pattern and the optimal surgical technique remain unclear. The primary goal of this review was to compare clinical, radiographic and patient-rated outcomes between current surgical techniques.

Methods: We performed a systematic literature search using multiple databases. We analyzed clinical, radiographic and patient-reported outcomes. We used a fixed-effects model weighted by sample size with combined outcomes estimated via least squares means with 95% confidence intervals. We also performed a subgroup analysis of static versus dynamic instability.

Results: We assessed 805 procedures from 37 study groups, with 429 procedures used in subgroup analysis. There were no statistically significant differences in outcomes between surgical techniques or in subgroup analysis. Overall, postoperative wrist flexion and pain scores decreased, and grip strength and patient-rated outcomes improved.

Conclusion: Compared to overall preoperative values, modest improvements in pain score, grip strength and functional outcome scores were obtained from a range of reconstructive procedures performed for chronic isolated SLIL injuries. No significant differences could be ascertained between surgical techniques, potentially owing to the low quality of evidence and procedure heterogeneity. This study provides accurate preoperative reference values for future studies, highlights the controversial clinical impact of instability classification, and the need for higher-quality multicentre or collaborative trials to improve our understanding and management of this common injury.

Contexte : La prise en charge des blessures chroniques du ligament interosseux scapho-lunaire (LISL) a généré un volume substantiel d'articles de faible qualité où sont décrites plusieurs nouvelles techniques chirurgicales, mais l'impact du modèle d'instabilité et la technique chirurgicale optimale restent à clarifier. Le principal objectif de cette revue était de comparer les résultats cliniques, radiographiques et autodéclarés par les patients entre les diverses techniques chirurgicales actuelles.

Méthodes : Nous avons procédé à une interrogation systématique de la littérature dans plusieurs bases de données. Nous avons analysé les résultats cliniques, radiographiques et autodéclarés par les patients. Nous avons utilisé un modèle à effets fixes pondéré par la taille de l'échantillon, avec paramètres mixtes estimés par les moyennes des moindres carrés et des intervalles de confiance à 95 %. Nous avons aussi effectué une analyse de sous-groupes (instabilité radiographique dynamique c. statique).

Résultats : Nous avons évalué 805 interventions dans 37 groupes étudiés, et 429 interventions ont été utilisées dans les analyses de sous-groupes. On n'a noté aucune différence statistiquement significative pour ce qui est des résultats entre les techniques chirurgicales ni dans les analyses de sous-groupes. Globalement, la flexion du poignet et la douleur ont diminué, et la force préhensile et autres paramètres autodéclarés par les patients se sont améliorés.

Conclusion : Comparativement aux valeurs préopératoires globales, de modestes améliorations du score de douleur, de la force préhensile et des paramètres fonctionnels ont été obtenues au moyen de diverses interventions de reconstruction effectuées pour des blessures chroniques isolées du LISL. Aucune différence significative n'a pu être confirmée entre les techniques chirurgicales, probablement en raison de la faible qualité des données et de l'hétérogénéité des interventions. Cette étude fournit des valeurs de référence préopératoires précises pour de futures études et souligne l'impact clinique controversé de la classification de l'instabilité, ainsi que la nécessité de procéder à des essais multicentriques ou collaboratifs de meilleure qualité pour mieux comprendre et prendre en charge ce type fréquent de blessure.

A great deal of work has been done to better understand the biomechanics of the intercalated proximal carpal row and its reliance on both intrinsic and extrinsic ligaments for support. In particular, the scapholunate interosseous ligament (SLIL) has been the focus of investigation as an important balance between scaphoid flexion and triquetral extension within the proximal carpal row.[1–4] Cadaveric ligament-sectioning studies have identified a progressive degree of carpal instability evident with both SLIL injury and concomitant injury to the surrounding extrinsic ligamentous support.[4–7] Radiographically, this has been classified into predynamic, dynamic and static instability.[1,2] Predynamic instability is thought to correlate with a stretch or incomplete injury and does not show any anomalies on standard or stress radiographs. Dynamic instability correlates to isolated SLIL incompetence with intact secondary stabilizers. This allows maintenance of normal alignment in the resting wrist, but instability is exposed when the wrist is loaded during stress radiography. In contrast, patients with static instability display abnormal alignment and instability at all times. The resultant abnormal kinematics of a static instability pattern are thought to result in an abnormal wear pattern within both the proximal and the midcarpal rows, which may lead to a predictable pattern of arthritis known as scapholunate advanced collapse (SLAC) wrist.[2,4,7–9]

Although many studies have used the dynamic/static classification, it has been difficult to prospectively study the natural history, progression and prognosis of SLIL injuries in the general population. This is concerning, as SLIL tears have been reported in up to 35% of wrists in cadaveric specimens of older people[10,11] and observational studies with more than 10 years of follow-up have documented little radiographic progression of low-grade SLIL injuries toward development of SLAC wrist arthritis.[12,13] Despite these shortcomings, an instability pattern continues to be commonly cited as a determining factor in the choice of surgical procedure.[14,15]

Interpretation of the literature regarding treatment of SLIL injuries is further clouded by the difficulty of establishing a clinical diagnosis and the variability in the severity of the injuries studied. In the event that surgery is believed to be indicated, there is no consensus on the most appropriate technique, and a multitude of procedures and subsequent modifications have been described.[16–26] The primary goals of this study were to compare patient outcomes from current surgical techniques and perform subgroup analysis to assess whether a difference exists between outcomes in patients with static versus dynamic instability patterns. Secondary goals were to compile and report injury demographic characteristics and preoperative function.

Methods

Literature search

Two reviewers (S.J.M., N.J.R.) independently performed a systematic literature search of MEDLINE, PubMed and Embase databases using the search terms “scapholunate” AND “treatment.mp” OR “therapeutics (MeSH heading)” (Appendix 1, available at canjsurg.ca/006918-a1). A priori inclusion and exclusion criteria (Table 1) were selected in accordance with PRISMA guidelines. Inclusion criteria were English-language paper, adult cohort, chronic injury (defined as a mean of at least 3 mo between injury and surgery) and a clear description of diagnostic methodology (accepted methods included diagnosis by wrist arthroscopy, magnetic resonance imaging, or a combination of examination findings and radiographic indicators). Physical examination findings were defined as dorsal wrist pain, swelling or a positive result of the Watson scaphoid shift test. Radiographic evidence involved increased scapholunate gap on standard or stress radiographs, or the presence of a dorsal intercalated segmental instability deformity, defined as a scapholunate angle of greater than 60° on a resting lateral radiograph. In addition, studies had to have a clear description of the surgical technique, a minimum of 1 year of follow-up and analysis using at least 1 of the following validated patient-reported outcome measures: visual analogue scale for pain, Patient-Rated Wrist Evaluation (PRWE), Mayo Wrist Score, Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire and QuickDASH questionnaire. We excluded articles that

Table 1. Inclusion criteria set a priori for study selection
Literature style
Original article
English language
Human subjects
Published in 1995–2015
Treatment options
Capsulodesis procedures
Intentional fibrous nonunion procedures such as reduction and association of scaphoid and lunate procedure
Tenodesis procedures
Bone–tissue–bone reconstruction
Study characteristics
Clinical study involving ≥ 5 patients
Chronic, isolated scapholunate injuries with mean time to surgery ≥ 3 mo
Follow-up period ≥ 1 yr
Diagnostic method described
Procedure described
Reporting of patient-centred outcome scores
Disabilities of the Arm, Shoulder and Hand (DASH) or QuickDASH questionnaire score
Mayo Wrist Score
Patient-Reported Wrist Evaluation score

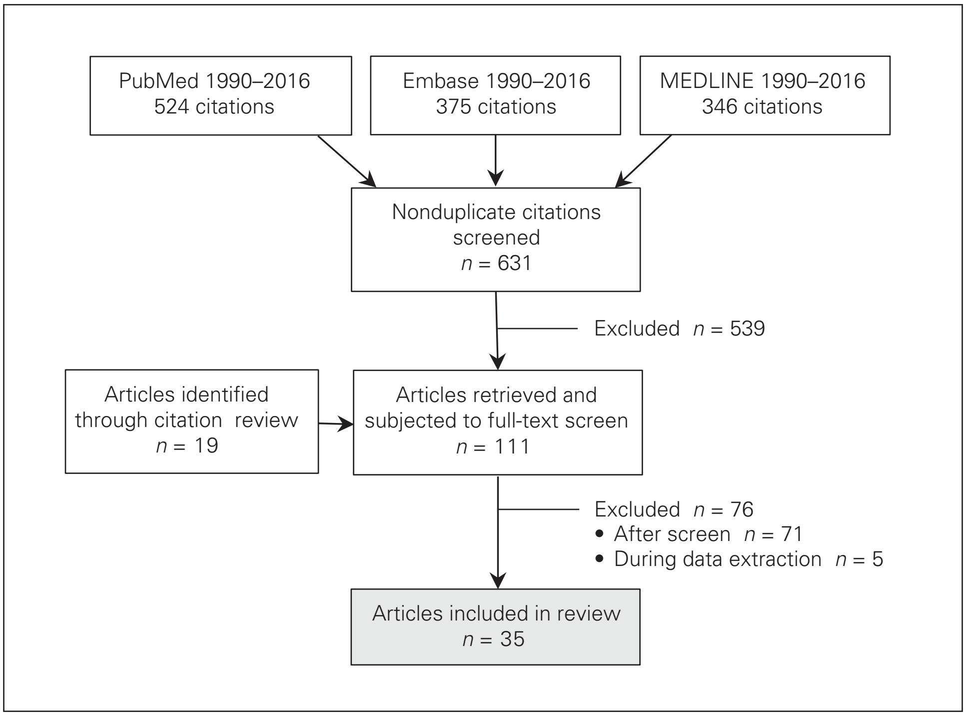

Fig. 1. Flow chart showing study selection.

Table 2. Procedures included under each surgical technique category

Capsulodesis	Tenodesis	Bone–tissue–bone reconstruction	Intentional fibrous nonunion procedure
Viegas	Brunelli tenodesis — Van Den Abbeele modification	Dorsal ligament graft	Arthroscopic RASL procedure with Herbert Whipple screw
Blatt	Tenodesis via dorsal/palmar FCR loop with fibre wire augmentation	Dorsal retinaculum graft	Arthroscopic débridement with pin fixation
Dorsal intercarpal ligament	Garcia-Elias 3-ligament tenodesis	Capitohamate ligament graft	Arthroscopic RASL procedure with Herbert Whipple/TriMed /HBS screws
Mayo	Scapholunotriquetral tenodesis	Trapezoid to second metacarpal graft	Open RASL procedure with HSC screw
Berger	Dynodesis (dynamic extension assist and volar tenodesis)		
Lavernia + primary repair			
Arthroscopic capsuloplasty			

RASL = reduction and association of the scaphoid and lunate.

were topic reviews, research on salvage procedures, strictly biomechanical or cadaveric studies, technique papers and studies that included patients with concomitant injuries that were not separable from the rest of the cohort (Fig. 1).

Given the heterogeneity of procedures, they were organized into 4 categories (Table 2). The first category involved capsulodesis procedures, in which a portion of the wrist capsule or ligaments are partially transposed and reattached to the dorsal surface of the scaphoid to act as a tether against flexion. The tenodesis group included all procedures rerouting a portion of tendon near the scapholunate articulation through the carpus to restore and maintain alignment. Bone–tissue–bone procedures involved use of harvested tissues composed of 2 sections of bone connected by a soft tissue bridge and transplanted as an autograft to the scapholunate joint. The fourth category comprised procedures in which the scapholunate joint was débrided and stabilized with temporary or dynamic fixation. This was originally described as the reduction and association of the scaphoid and lunate procedure;[17] however, given the deviations from the original technique, we used the term "intentional fibrous nonunion" to categorize these procedures based on their pathophysiologic basis.

Citation review took place during the final full-text review process. Authors were contacted directly if the methodology of their paper was unclear or if they reported collection of necessary data that was not included or was reported in a manner that was incompatible with our analysis. We requested individual patient data to allow for subgroup analysis. In cases in which individual patient data were provided in the original research, we excluded data where appropriate to eliminate patients who did not fit our criteria, such as in cases of early surgical intervention, incomplete follow-up or presence of concomitant injury. If the study allowed identification of patients with static or dynamic instability patterns in the preoperative stage, we analyzed the data separately for each cohort for subgroup analysis in addition to the whole-cohort values used to compare surgical techniques.

We collected demographic characteristics and post-surgical complication data when reported. Clinical outcome data included range of motion, grip strength data and validated patient-centred outcome measures (pain visual analogue scale, DASH questionnaire, Mayo Wrist Score, PRWE). Radiographic outcomes included pre- and postoperative scapholunate angle and scapholunate gap.

Assessment of quality of selected studies

We assessed risk of bias and study quality using the Structured Effectiveness Quality Evaluation Scale (Appendix 1) combined with Sackett's levels of evidence (Appendix 1). The Structured Effectiveness Quality Evaluation Scale is a 24-question form with 0, 1 or 2 points awarded for each question. It evaluates study design, patient characteristics, intervention, analysis and recommendations. A score of 33 or higher indicates a high-quality study. Two reviewers (J.F.K., A.R.M.) applied the scale and provided a level of evidence for the studies included in the review.

Statistical analysis

We analyzed the data using a fixed-effects model weighted by sample size. We calculated the combined outcomes via least squares means, along with 95% confidence intervals (CIs). Least squares means are also referred to as "estimated population marginal means," which are within-group means appropriately adjusted for the weighted means in this model.[27] When we compared least squares means across multiple groups, we adjusted both the difference CIs and p values for multiple comparisons using the Bonferroni correction. The difference was deemed statistically significant when the 95% CI surrounding the least squares mean difference between groups did not contain 0. In comparisons involving only 2 groups, such as overall postoperative cohort to overall preoperative cohort, we performed Student's t test, with an α value of 0.05.

Results

The initial search strategy identified 631 articles, of which 111 underwent full-text evaluation and 35 were selected for inclusion in the final analysis. Of the 76 papers excluded, 43 did not report any patient-reported outcomes or data applicable to the comparison measures, or did not present new patient data, 7 involved concomitant injuries, 11 were off topic, 10 dealt with acute injuries, and 5 reviewed salvage operations for management of arthritis. For 1 cohort, preoperative data were presented in a short-term follow-up paper,[28] and the long-term results were subsequently presented in a separate publication.[29] We included both papers to provide a full data set for the cohort; however, we did not include the short-term outcome data in the analysis. We emailed 13 authors, of whom 6 responded: 3 responses indicated that individual patient data could not be provided for subgroup analysis,[30–32] 1 response caused exclusion of the study owing to inadequate follow-up,[33] 1 response allowed inclusion of the study after removal of data for 2 patients with concomitant injuries,[34] and 1 response provided individual patient metadata, allowing inclusion of patients into subgroup analysis.[35]

Data were collected on 805 procedures from a total of 35 papers[25,28–32,34–64] (Table 3). The review included 43 patients from 4 studies involving intentional fibrous nonunion type procedures,[32,41,48,61] 391 patients from 14 groups involving capsulodesis,[29–31,39,43,47,51,52,54,55,59,60,62,63] 319 patients from 12 groups involving tenodesis techniques[25,30,34,36,37,40,44–46,50,53,58] and 51 patients from 4 groups using bone–tissue–bone techniques.[35,42,57,64]

Overall, 68% of patients were male, and the patients' average age was 39 years (Table 4). In patients with identifiable traumatic events, the average time from injury to surgery was 19 months. The mechanism of injury was reported in 15 (43%) of included studies and was described for 313 patients (Table 5). The setting of the injury was reported for 287 patients (Table 5).

Preoperative clinical findings are summarized in Table 6. The average degree of flexion was 52° and of extension, 57°. Mean grip strength was 67% that of the contralateral side. The mean values for patient-reported outcomes were 4.86 for the pain visual analogue scale, 42.18 for the DASH questionnaire, 62.55 for the Mayo Wrist Score and 79.61 for the PRWE. We compiled preoperative and final postoperative values from surgical procedure categories (Table 6). Comparison between whole-cohort pre- and postoperative values identified statistically significant improvement in mean percentage of grip strength compared to the uninjured side (67.0% v. 82.6%), DASH questionnaire score (42.2 v. 18.5) and PRWE score (79.6 v. 32.1) and a statistically significant decrease in the pain visual analogue scale score (4.9 v. 3.0) and wrist flexion (52.3° v. 46.3°) ($p < 0.05$ for all).

Preoperative scapholunate gap measurements were reported in 26 studies, with a mean value of 3.1 mm. Preoperative scapholunate angle measurements were provided in 27 studies, with a mean value of 62.0°. Intraoperative or immediate postoperative scapholunate gap and scapholunate

Table 3 (part 1 of 2). Study characteristics and quality assessment*

Study	Procedure	Procedure category	Instability subgroup	Study design	No. of patients	No. of procedures	SEQES score
Caloia et al.,[32] 2012	Arthroscopic RASL with Herbert Whipple screw	Intentional fibrous nonunion	Static	Prospective cohort	8	9	21
Camus et al.,[39] 2013	Viegas capsulodesis	Capsulodesis	Mixed	Prospective cohort	24	25	23
Chabas et al.,[40] 2008	Brunelli tenodesis — Van Den Abbeele modification	Tenodesis	Mixed	Retrospective case series	19	19	18
Darlis et al.,[41] 2006	Arthroscopic chondral débridement with Kirschner wire fixation	Intentional fibrous nonunion	Dynamic	Retrospective case series	11	8	18
De Carli et al.,[38] 2011	Combined extensor carpi radialis longus tenodesis + Walsh dorsal intercarpal ligament capsulodesis	Excluded	Static	Retrospective case series	8	8	12
Dellarosa et al.,[42] 2016	Bone–tissue–bone (trapezoid to second metacarpal ligament)	Bone–tissue–bone	Mixed	Retrospective case series	11	11	25
Deshmukh et al.,[43] 1999	Blatt capsulodesis	Capsulodesis	NA	Prospective cohort	52	44	27
Elgammal et al.,[44] 2015	Garcia-Elias 3-ligament tenodesis	Tenodesis	Mixed	Retrospective case series	20	20	22
Ellanti et al.,[45] 2014	Brunelli tenodesis — Van Den Abbeele modification	Tenodesis	NA	Prospective cohort	13	13	21
Foo et al.,[46] 2014	Dorsal/palmar FCR loop + fibre wire	Tenodesis	Mixed	Prospective cohort	20	12	22
Gajendran et al.,[29] 2007	Dorsal intercarpal ligament capsulodesis	Capsulodesis	Static	Prospective cohort	21	16	24
Gray et al.,[35] 2015	Bone–tissue–bone (trapezoid to second metacarpal, capitate to trapezoid or second or third metacarpal ligaments)	Bone–tissue–bone	Mixed	Retrospective case series	26	21	21
Koehler et al.,[61] 2016	Arthroscopic RASL with Herbert Whipple screw/TriMed screw/HBS screw	Intentional fibrous nonunion	NA	Retrospective case series	18	18	22
Konduru et al.,[47] 2006	Blatt capsulodesis	Capsulodesis	NA	Prospective cohort	27	20	25
Larson et al.,[48] 2012	RASL with HCS screw	Intentional fibrous nonunion	NA	Retrospective case series	7	8	18
Links et al.,[50] 2008	Almquist 4-ligament weave	Tenodesis	Static	Retrospective case series	23	23	30
Links et al.,[50] 2008	Modified Brunelli tenodesis + RASL	Excluded	Static	Retrospective case series	21	21	30
Luchetti et al.,[59] 2010	Mayo capsulodesis	Capsulodesis	NA	Prospective cohort	18	18	24
Mathoulin et al.,[63] 2011	Arthroscopic capsuloplasty	Capsulodesis	NA	Prospective cohort	36	36	25
Megerle et al.,[51] 2012	Dorsal intercarpal ligament capsulodesis	Capsulodesis	Static	Retrospective case series	75	52	33
Misra et al.,[60] 2003	Blatt capsulodesis	Capsulodesis	NA	Retrospective case series	19	15	23
Moran et al.,[31] 2005	Blatt or Mayo capsulodesis	Capsulodesis	NA	Retrospective case series	31	31	28
Moran et al.,[30] 2006	Berger capsulodesis	Capsulodesis	NA	Retrospective case series	14	14	31
Moran et al.,[30] 2006	Brunelli tenodesis — Van Den Abbeele modification	Tenodesis	NA	Retrospective case series	15	15	31
Nienstedt,[34] 2013	Brunelli tenodesis — Van Den Abbeele modification	Tenodesis	Static	Retrospective case series	8	5	23
Papadogeorgou et al.,[52] 2010	Capsulodesis + extensor carpi radialis brevis ligamentoplasty	Capsulodesis	Static	Retrospective case series	32	32	21
Pauchard et al.,[53] 2013	Garcia-Elias 3-ligament tenodesis	Tenodesis	Mixed	Prospective cohort	20	19	33
Pomerance,[54] 2006	Lavernia capsulodesis + primary repair	Capsulodesis	Dynamic	Retrospective case series	17	17	30

Table 3 (part 2 of 2). Study characteristics and quality assessment*							
Study	Procedure	Proecdure category	Instability subgroup	Study design	No. of patients	No. of procedures	SEQES score
Ross et al.,[37] 2013	Scapholunotriquetral tenodesis	Tenodesis	NA	Prospective cohort	11	11	16
Seradge et al.,[25] 2004	Dynodesis (dynamic extension assist and volar tenodesis)	Tenodesis	NA	Prospective cohort	104	105	22
Shih et al.,[55] 2003	Blatt capsulodesis + ligamentoplasty	Capsulodesis	Dynamic	Prospective cohort	17	15	22
Soong et al.,[57] 2013	Bone–tissue–bone (dorsal retinaculum)	Bone–tissue–bone	Dynamic	Retrospective case series	14	6	21
Sousa et al.,[36] 2014	Brunelli tenodesis — Van Den Abbeele modification	Tenodesis	Dynamic	Retrospective case series	22	22	15
Szabo et al.,[28] 2002	Dorsal intercarpal ligament capsulodesis	Excluded	Static	Retrospective case series	21	22	27
Talwalkar et al.,[58] 2006	Brunelli tenodesis — Van Den Abbeele modification	Tenodesis	Mixed	Retrospective case series	117	55	19
van Kampen et al.,[64] 2015	Bone–tissue–bone (capitohamate ligament)	Bone–tissue–bone	Mixed	Retrospective case series	23	13	19
Wahegaonkar et al.,[62] 2013	Arthroscopic capsuloplasty	Capsulodesis	NA	Retrospective case series	57	57	32

NA = not available; RASL = reduction and association of the scaphoid and lunate; SEQES = Structured Effectiveness Quality Evaluation Scale.
*All studies were assessed as being level 4 evidence.

angle values were provided in 12 and 10 studies, respectively, with mean values of 2.2 mm and 56.2°, respectively. Final follow-up values were provided for scapholunate gap in 28 studies and for scapholunate angle in 30 studies at an average of 47 months postoperatively, with mean values of 2.7 mm and 57.9°, respectively. In comparison to preoperative values, the mean scapholunate gap decreased by 0.4 mm at final follow-up ($p = 0.05$), and the mean scapholunate angle decreased by 4.1° ($p < 0.05$).

Analyses of procedure type did not identify a statistically significant difference between any of the 4 procedure categories in any of the clinical or radiographic outcome measures. However, the intentional fibrous nonunion group had a significantly older patient population than the capsulodesis group, by an average of 12.1 years ($p < 0.05$), and the tenodesis group, by an average of 10.8 years ($p < 0.05$). The overall mean length of follow-up was 47 months, with the longest follow-up in the bone–tissue–bone group (89 mo). No other significant differences in patient demographic characteristics were noted.

In studies reporting radiographic instability, 147 procedures from 14 studies were identified to have been performed in patients with dynamic instability, and 282 procedures from 19 studies were performed in patients with static instability. Through scrutiny of individual patient metadata, we were able to exclude 66 predynamic injuries from the dynamic instability cohort in our analysis. Compared to the dynamic instability group, the static instability group had a larger mean preoperative scapholunate angle (71.4° v. 56.0° and a larger mean scapholunate gap (3.9 mm v. 2.5 mm) ($p < 0.05$ for both) (Fig. 2). There were no other statistically significant differences in any other radiographic or clinical outcome measure at any time point (Fig. 3).

Complications for each procedure category and for the overall cohort are presented in Table 7. We could not compare groups owing to the variability in reporting and follow-up duration. Reported complications included infection (1.9%), neuroma or scar tissue concerns (1.9%), complex regional pain syndrome (2.7%), failure of fixation or graft (4.3%) and conversion to salvage (5.4%). The overall rate of progression to SLAC wrist arthritis for the entire cohort was 8.4%. The highest rate of progression, 21.6%, was documented in the bone–tissue–bone group, and the lowest rate, 3.1%, in the tenodesis group.

Study quality

All studies were identified as level 4 evidence. Structured Effectiveness Quality Evaluation Scale scores ranged from 12 to 33 (mean 23.2). Two studies reached the benchmark score of 33 to be deemed high quality,[36,41] and 3 studies were found to have scores of 16 or less and were deemed to be of poor quality.[36–38]

Discussion

In this summary of the current literature on surgically managed chronic isolated SLIL tears, we evaluated data from 805 patient presentations. Just over two-thirds of patients were male, the average patient age was 39 years, and the mean delay to surgery from the time of injury was 19 months. This information confirms the generally accepted epidemiologic features of this population, which have previously been based on anecdotal expert opinion and small case series. Clinical data from the preoperative cohort provided a baseline

Table 4. Patient characteristics						
Procedure category; study	No. of procedures	% male	Mean age, yr	Mean time to surgery, mo	Mean length of follow-up, mo	Period of immobilization, wk
Bone–tissue–bone						
Dellarosa et al.[42]	11	73	38	9	29	8
Gray et al.[35]	21	90	46	9	93	8
Soong et al.[57]	6	71	37	9	143	8
van Kampen et al.[64]	13	92	49	17	108	4
Total	51	—	44	11	89	—
Capsulodesis						
Camus et al.[39]	25	50	38	12	26	8
Deshmukh et al.[43]	44	55	29	58	22	8
Gajendran et al.[29]	16	81	42	2	86	8
Konduru et al.[47]	20	35	37	24	41	8
Luchetti et al.[59]	18	50	35	10	45	4
Mathoulin et al.[63]	36	69	39	10	11	NS
Megerle et al.[51]	52	86	41	8	99	6
Misra et al.[60]	15	80	38	11	22	8
Moran et al.[31]	31	65	38	20	54	9
Moran et al.[30]	14	NS	41	20	38	9
Papadogeorgou et al.[52]	32	72	39	31	50	8
Pomerance[54]	17	71	36	6	66	10
Shih et al.[55]	15	87	29	18	25	6
Wahegaonkar et al.[62]	57	60	39	9	31	8
Total	392	—	37	19	45	—
Intentional fibrous nonunion						
Caloia et al.[32]	9	89	45	16	35	9
Darlis et al.[41]	8	73	37	7	35	10
Koehler et al.[61]	18	61	61	3	36	3
Larson et al.[48]	8	100	41	5	38	6
Total	43	—	49	7	36	—
Tenodesis						
Chabas et al.[40]	19	84	43	15	37	6
Elgammal et al.[44]	20	95	43	12	24	8
Ellanti et al.[45]	13	69	35	2	12	NS
Foo et al.[46]	12	50	40	13	28	6
Links et al.[50]	23	NS	29	11	29	8
Moran et al.[30]	15	NS	39	20	36	7
Nienstedt[34]	5	80	40	4	55	6
Pauchard et al.[53]	19	79	43	13	24	8
Ross et al.[37]	11	82	36	12	14	7
Seradge et al.[25]	105	NS	NS	29	63	6
Sousa et al.[36]	22	82	40	2	61	NS
Talwalkar et al.[58]	55	44	38	38	47	6
Total	319	—	39	21	45	—
Overall total ± SD	805	68 ± 6	39 ± 2	19 ± 5	47 ± 9	—

CI = confidence interval; NS = not specified; SD = standard deviation.

comparator in this study and could reliably be used as a more robust comparison for future studies.

Surgical intervention for chronic isolated SLIL injuries resulted in a statistically significant improvement in grip strength and a significant decrease in pain at the expense of a clinically insignificant decrease in wrist flexion (6°). Statistically significant improvements were seen in DASH questionnaire and PRWE scores but not in the Mayo Wrist Score, although a trend toward improvement was seen. The improvements in both the DASH questionnaire and PRWE scores were above the minimally clinically important difference for their respective scores,[65] indicating moderate clinical improvement. This likely reflects the tendency of these 2 instruments to better capture decreases in pain and improvements in grip strength through focus on patient-reported disability, whereas the Mayo Wrist Score reports strictly on objective measures of function.

It was universally shown that the radiographic improvements in scapholunate gap and scapholunate angle through surgical reduction were lost over time. This was a consistent finding across all surgical procedure categories and instability types. Although no significant difference was seen within each instability subgroup, the radiographic pre- to postoperative improvement in the static instability subgroup was significantly better than that in the dynamic subgroup for both scapholunate gap and scapholunate angle. This likely reflects the more severe initial radiographic anomaly inherent with static instability.

We were unable to detect any statistically significant differences in outcomes between surgical procedure categories. This is consistent with the conclusions of a recent systematic review by Wang and colleagues,[66] who compared capsulodesis procedures to scapholunate ligament reconstructions. This is not to say no differences exist; however, given the heterogeneity of the diagnostic methods, surgical techniques, outcome measures and length of follow-up, it is not possible to determine the most appropriate approach to treatment at this stage. Capsulodesis and tenodesis procedures currently dominate the literature, accounting for 88.3% (711/805) of the procedures reviewed. In addition, all categories of surgical technique were substantially different in the theory behind repair, resulting in data that are challenging to compare directly. This highlights the need for well-designed prospective studies so that we may advance our knowledge in this area. The role for refinement and modifications of current techniques is unclear, and these studies add unnecessary heterogeneity to the current body of literature.

Analysis of complication data was limited by inconsistent reporting and discrepancies in follow-up. As development of patterns of SLAC wrist arthritis would be expected to increase with time, we felt that a comparison would be unfairly confounded because the length of

Table 5. Mechanism and setting of injuries

Variable	No. (%) of injuries
Mechanism of injury	
Unspecified trauma	151 (48.2)
Hyperextension	83 (26.5)
High-energy trauma	51 (16.3)
Other	28 (8.9)
Total	313 (100.0)
Setting of injury	
Workplace	110 (38.3)
Sport/recreation	103 (35.9)
Trauma	58 (20.2)
Other	16 (5.6)
Total	287 (100.0)

Table 6. Overall results

	Procedure category; mean value					
Outcome measure	Overall preoperative	Capsulodesis	Bone–tissue–bone	Intentional fibrous nonunion	Tenodesis	Overall postoperative
Scapholunate gap, mm	3.13 (*n* = 515)	2.93 (*n* = 201)	2.73 (*n* = 51)	3.05 (*n* = 43)	2.55 (*n* = 262)	2.74 (*n* = 557)
Scapholunate angle, °	62.00 (*n* = 608)	56.99 (*n* = 338)	70.35 (*n* = 51)	60.04 (*n* = 43)	56.16 (*n* = 262)	57.88 (*n* = 694)
Flexion, °	52.31 (*n* = 578)	46.52 (*n* = 331)	51.86 (*n* = 51)	44.16 (*n* = 43)	45.48 (*n* = 295)	46.34* (*n* = 720)
Extension, °	56.56 (*n* = 578)	53.49 (*n* = 331)	52.14 (*n* = 51)	52.62 (*n* = 43)	53.48 (*n* = 295)	53.34 (*n* = 720)
Ulnar deviation, °	29.58 (*n* = 498)	26.84 (*n* = 285)	33.74 (*n* = 34)	22.00 (*n* = 8)	28.17 (*n* = 295)	27.77 (*n* = 622)
Radial deviation, °	17.05 (*n* = 498)	16.02 (*n* = 285)	18.76 (*n* = 34)	14.00 (*n* = 8)	14.30 (*n* = 295)	15.37 (*n* = 622)
Grip strength, kgf	33.53 (*n* = 565)	34.31 (*n* = 356)	30.10 (*n* = 51)	27.00 (*n* = 18)	32.27 (*n* = 282)	33.00 (*n* = 707)
Grip strength, % contralateral side	67.01 (*n* = 179)	82.74 (*n* = 284)	82.88 (*n* = 21)	81.79 (*n* = 43)	82.58 (*n* = 186)	82.61* (*n* = 534)
Visual analogue scale for pain score	4.86 (*n* = 423)	3.12 (*n* = 250)	1.25 (*n* = 13)	2.17 (*n* = 27)	3.10 (n = 204)	3.01 (n = 494)
Patient-Rated Wrist Evaluation score†	79.61 (*n* = 86)	50.00 (*n* = 56)	17.94 (*n* = 45)	26.00 (*n* = 8)	28.22 (n = 19)	32.12* (*n* = 128)
Mayo Wrist Score‡	62.55 (*n* = 112)	72.64 (*n* = 163)	74.69 (*n* = 19)	81.25 (*n* = 8)	78.25 (*n* = 20)	73.69 (*n* = 210)
Disabilities of the Arm, Shoulder and Hand questionnaire score†	42.18 (*n* = 279)	16.48 (*n* = 239)	17.46 (*n* = 34)	13.20 (*n* = 35)	24.06 (*n* = 142)	18.50* (*n* = 450)

*$p < 0.05$ for difference between overall preoperative value and overall postoperative value.
†A lower value denotes improvement.
‡A higher value denotes improvement.

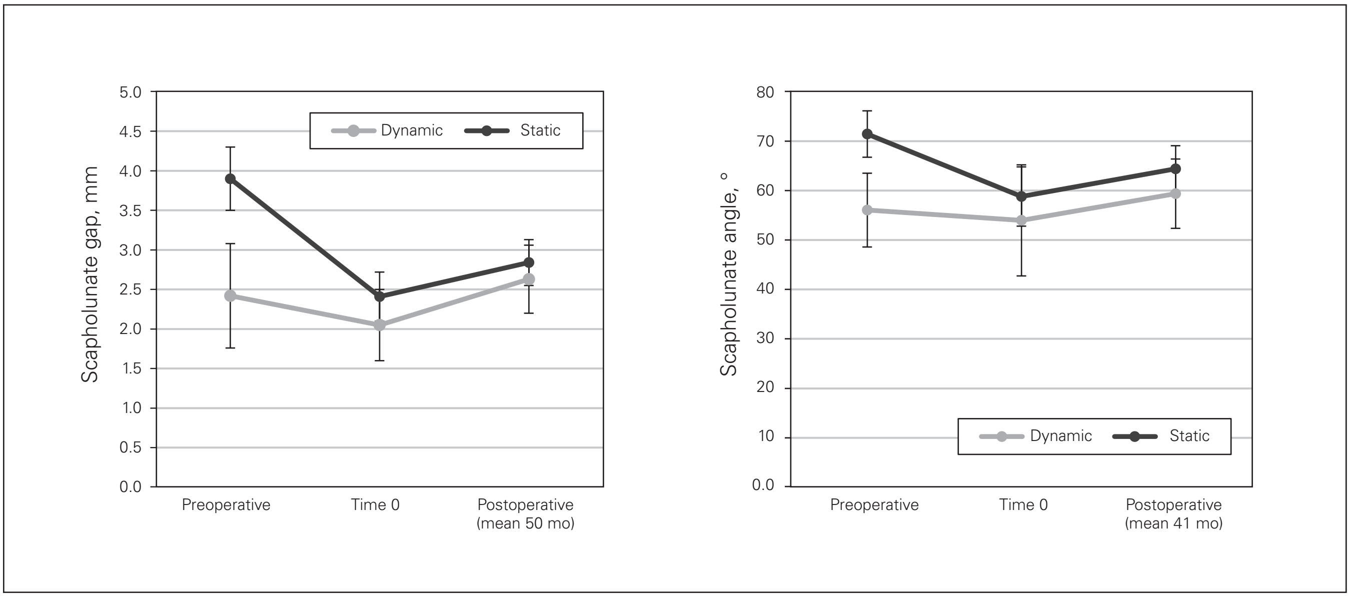

Fig. 2. Scapholunate gap (left) and angle (right) measurements for static and dynamic instability subgroups. Error bars represent 95% confidence intervals.

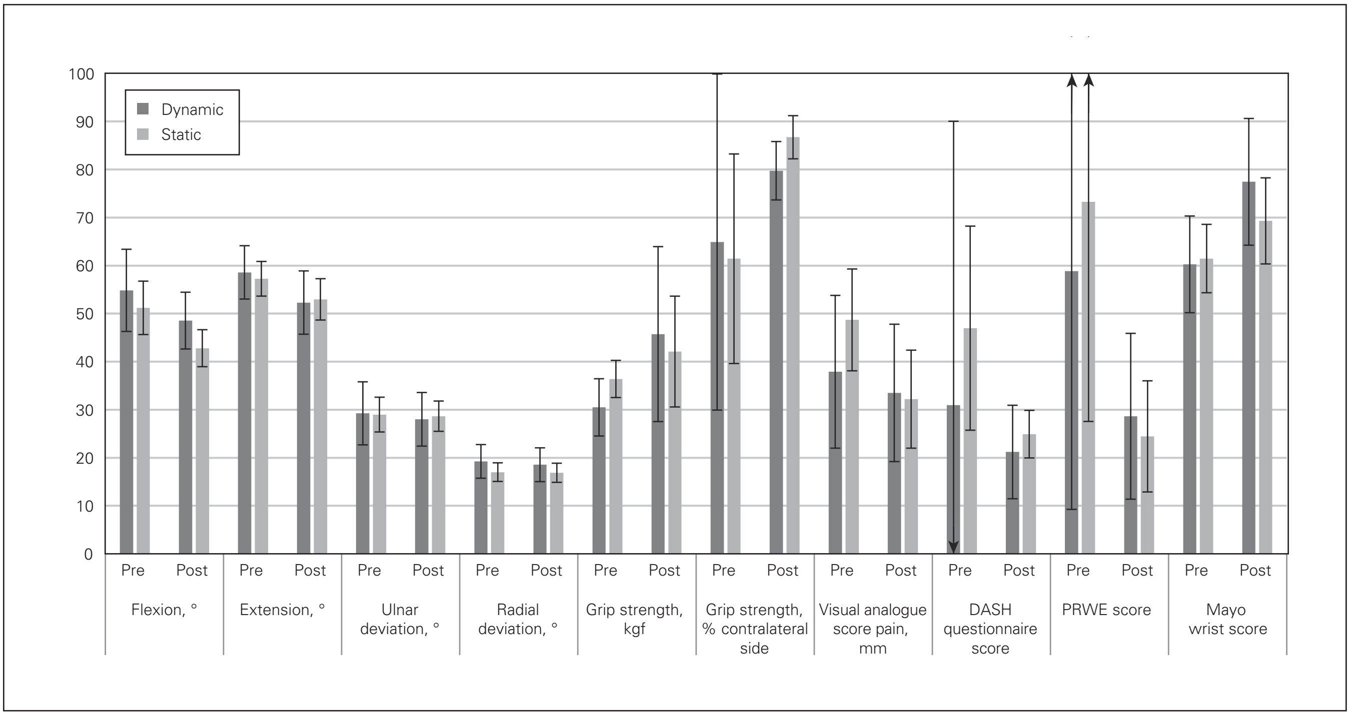

Fig. 3. Other radiographic and clinical measurements for static and dynamic instability subgroups. A higher value denotes improvement in the Mayo Wrist Score, whereas a lower value denotes improvement in the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire and Patient-Rated Wrist Evaluation (PRWE) scores. Error bars represent 95% confidence intervals. Pre = preoperative, post = postoperative.

follow-up ranged from 36 months in the intentional fibrous nonunion group to 89 months in the bone–tissue–bone group. Dorsal intercalated segmental instability deformity at final follow-up was mentioned as a complication in several papers, but we did not include it as other studies made no mention of the deformity or loss of reduction but still had mean scapholunate angle values for their overall cohorts greater than 60°, which suggests that this metric is inconsistently reported and is inaccurate for analysis.

Table 7. Complications

Variable	Procedure category; no. (%) of cases*				
	Bone–tissue– bone *n* = 74	Capsulodesis *n* = 358	Intentional fibrous nonunion *n* = 43	Tenodesis *n* = 319	Overall *n* = 794
Mean length of follow-up, mo	89	45	36	45	47
Complication					
Scapholunate advanced collapse progression	16 (21.6)	37 (10.3)	4 (9.3)	10 (3.1)	67 (8.4)
Complex regional pain syndrome	1 (1.4)	13 (3.6)	0 (0.0)	7 (2.2)	21 (2.6)
Infection	1 (1.4)	10 (2.8)	2 (4.6)	2 (0.6)	15 (1.9)
Neuroma or symptomatic scar tissue	2 (2.7)	6 (1.7)	0 (0.0)	7 (2.2)	15 (1.9)
Fixation or graft failure	8 (10.8)	11 (3.1)	8 (18.6)	7 (2.2)	34 (4.3)
Conversion to salvage	9 (12.2)	16 (4.5)	5 (11.6)	13 (4.1)	43 (5.4)

*Except where noted otherwise.

There is a paucity of natural history data available on chronic isolated SLIL tears, and it is difficult to determine the true risk of development and progression of arthritis from nonoperative strategies. We believe clinical equipoise exists with regard to the benefit of surgical treatment, particularly in the setting of symptomatic low-grade SLIL injuries. O'Meeghan and colleagues[12] reported a single cohort of 12 wrists with arthroscopically confirmed Kozin grade 1 or 2 SLIL injuries that were monitored over an average of 11.5 years. The mean final clinical and radiographic outcomes in their cohort as well as their clinical improvement in pain visual analogue scale scores closely resemble the overall postoperative results in our study. Arthritis developed in a single patient, at the radial styloid. A second prospective observational study, by Mrkonjic and colleagues,[13] followed 10 SLIL injuries, 3 static and 7 dynamic, detected at the time of a distal radius fracture for a minimum of 13 years. Those authors found no evidence of radiographic progression to SLAC wrist arthritis. These reports involved low-grade injuries and therefore may not be directly comparable to the overall cohort in our analysis. Nevertheless, we believe it is reasonable to proceed with a nonreconstruction cohort in prospective randomized controlled trials for patients presenting with symptomatic SLIL instability, especially in the setting of low-grade injuries.

Future studies involving patients with symptomatic static SLIL instability could improve the overall body of knowledge by presenting randomized controlled trials with assessors blinded to treatment and providing individual patient metadata that include complications, patient-reported outcome scores and plans for long-term follow-up (> 10 yr). Consideration of new surgical techniques should be tempered, and these should be performed only with rigorous comparison to previous techniques and appropriate baseline data, as the increasing heterogeneity in treatment options is hindering progress in understanding this clinical entity.

Limitations

There are multiple limitations to a study of this design, many of which highlight deficiencies in the literature base. Most notable are the high variability in the available published data, the lack of natural history data, the heterogeneity in diagnostic methods and reported outcome measures, and the overall low quality of evidence. Only 2 papers (6%) reached the benchmark score of 33, indicating high-quality studies, on the Structured Effectiveness Quality Evaluation Scale. In addition, variations in surgical practice, such as posterior interosseous nerve neurectomy, could not be accounted for in the data and present an important confounding variable. It is important to note that other authors acknowledge the limitations within the current literature[67,68] and have attempted to improve on techniques that have been unsuccessful. In accordance with this, we have seen several popular surgical approaches or modifications subsequently abandoned or modified.[29,69] Even the most experienced surgeons continue to search for a reliable solution, yet the primarily retrospective nature of the data collected on this topic makes it difficult to interpret which literature is consistent with current practice. Finally, our study highlights modest postoperative improvements in grip strength, pain score, and DASH questionnaire and PRWE scores in all patients undergoing surgery. When combined with the recurrence of radiographic anomaly, these improvements are difficult to separate from a potential placebo effect. Subgrouping of patients based on radiographic instability did not provide clinical prognostic value and suffers from similar limitations.

Conclusion

Based on the current standard of literature, it will be difficult to advance our knowledge on chronic isolated SLIL tears. It is time to stop putting our energy into single-surgeon retrospective case series. Collaboration in the form of multicentre prospective randomized controlled trials and consistent reporting using common data elements offer an opportunity to truly understand the problem, learn about the natural history and potentially flesh out optimal treatment strategies. To achieve this, we recommend increased documentation of patients selected for nonoperative management, documentation of diagnostic method, stratification of patients by degree of injury, standardized outcome measures, including patient-reported outcomes, and long-term follow-up.

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