EDITOR'S CHOICE

Lateral Ulnar Collateral Ligament Repair With Suture-Tape Augmentation for Traumatic Elbow Instability

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Purpose Ligament repair with suture-tape augmentation has been used in the operative treatment of joint instability and may have advantages with respect to early motion and stability. The purpose of this investigation was to describe the clinical results of traumatic elbow instability treated with lateral ulnar collateral ligament repair with suture-tape augmentation.

Methods All cases of acute and chronic elbow instability treated surgically between 2018 and 2020 were included if they underwent ligament repair with suture-tape augmentation of the lateral ulnar collateral ligament as part of the procedure. Cases with <6 months of follow-up were excluded. A manual chart review was performed to record patient demographics as well as injury and surgery characteristics. Radiographic outcomes, range of motion, and patient-reported outcome measures, including the visual analog pain scale and Disabilities of the Arm, Shoulder, and Hand, were recorded. Range of motion measurements were recorded at the end of the clinical follow-up, as were surgical complications.

Results Eighteen cases were included with a mean follow-up of 20 months. Five (28%) cases involved a high-energy mechanism, and 11 (62%) cases involved terrible triad fracture dislocations. The mean Disabilities of the Arm, Shoulder, and Hand questionnaire and visual analog pain scale scores were 17 and 2, respectively. The mean flexion-extension arc was 124°, and 2 (11%) cases had <100° flexion-extension arc. There were 2 (11%) postoperative complications, and both cases had postoperative instability requiring reoperation. We observed no cases of capitellar erosion from the suture-tape material.

Conclusions For complex elbow instability, ligament repair with suture-tape augmentation of the lateral ulnar collateral ligament results in acceptable functional outcomes and a reoperation rate comparable with other joint stabilization procedures. *(J Hand Surg Am. 2023;48(2):117–125. Copyright © 2023 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Elbow dislocation, elbow instability, lateral ulnar collateral ligament, ligament reconstruction, ligament repair.

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Posterolateral rotatory instability (PLRI) was first described by O'Driscoll et al[1] as elbow instability caused by insufficiency of the lateral collateral ligament complex. With a torn or deficient lateral ulnar collateral ligament (LUCL), posterolateral subluxation of the radial head can occur relative to the capitellum. Posterolateral rotatory instability can result from simple elbow dislocations, which have an estimated incidence of 5.21 per 100,000 person-years in the United States.[2] Since the first description of PLRI, there has been debate over the relative contributions of bony and ligamentous stabilizers.[3–8] The goal of any treatment involving elbow instability is the maintenance of a stable and congruent elbow joint, such that an early range of motion (ROM) can be initiated to minimize long-term stiffness. For complex elbow instability, surgical intervention offers dramatic improvement relative to nonsurgical treatment.[9,10]

Despite substantial improvements in surgical treatment, complications, including persistent and recurrent PLRI, can occur.[1,6,8–9] Ideally, a terrible triad injury is treated with surgical fixation or the replacement of the radial head and ligament repair. Coronoid fixation is sometimes performed; however, there is evidence that small fragments do not always require fixation to achieve stable articulation.[11,12] Despite these interventions, there are cases of persistent instability when the elbow is tested through a full arc of motion, particularly in extension and supination. Multiple techniques have been described to stabilize the persistently unstable elbow joint. Temporary transfixation or cross-pinning of the ulnohumeral joint has been used in the persistently unstable elbow; however, it requires violation of the articular surfaces and does not allow for early ROM.[13] Multiple methods of ligament reconstruction have been described that can aid in elbow stability but require autograft harvest or allograft use and may require supplemental stabilization as the graft incorporates.[14] Dynamic external fixation has been used as well, often in the setting of severe soft tissue trauma. Dynamic external fixation remains a technically challenging operation, particularly with respect to obtaining congruency throughout ROM.[13,15,16] The internal joint stabilizer (IJS) has been developed to enhance stability. It allows motion via a plate on the ulna rigidly linked to a pin transversely oriented across the distal humerus at its isometric point.[17,18] In addition to concerns regarding implant cost, it is recommended that this implant be routinely removed due to the possibility of implant failure, which requires a second operation.[17–19]

Ligament repair with suture-tape augmentation (LRSTA) has been developed and used successfully in other joints, including the knee, thumb metacarpophalangeal joint, and ankle. This augmented repair provides early enhanced construct strength, which may be beneficial in cases in which early mobilization and activity are a priority.[20,21] In overhead throwing athletes, LRSTA of the medial ulnar collateral ligament has recently gained popularity and may allow for an earlier return to activity compared with traditional ligament reconstruction techniques.[22–24] Similarly, LRSTA has been used to augment LUCL repair and has shown biomechanical advantages compared with repair alone.[25–27] There is a paucity of literature with respect to clinical outcomes for LUCL repair with suture-tape augmentation. Clinical series are limited by short-term follow-up and infrequent cases with high-energy, complex dislocations.[28]

The purpose of this investigation was to describe the outcomes and results of traumatic elbow instability treated with LUCL repair using suture-tape augmentation. We hypothesized that this technique, as part of the operative stabilization of these complex injuries, would result in acceptable functional outcomes and a complication rate compared with previously published results using other approaches.

MATERIALS AND METHODS

Geisinger Health System institutional review board approval was obtained for this retrospective investigation. All cases of acute and chronic elbow instability treated between January 2018 and December 2020 were identified within our institutional database. Acute instability was defined as patients presenting within 6 weeks of sustaining an elbow fracture dislocation. Patients were included for analysis if they were 18 years of age or older and underwent LUCL repair with suture-tape augmentation as part of their operative procedure. Cases with <6 months of follow-up were excluded from our analysis. All cases were surgically treated by a single fellowship-trained hand and upper-extremity surgeon (L.C.G.) within our hospital system, which is a rural, academic, level I trauma center in the northeastern United States.

A manual chart review was performed after all cases were identified. Recorded baseline characteristics included age, sex, body mass index, marital status, employment, hand dominance, tobacco usage, diabetic status, injury laterality, associated upper-extremity injuries, and medical comorbidities. Injury characteristics were recorded for each case.

FIGURE 1: Kocher approach was used for LUCL repair with internal-brace augmentation for a complex elbow fracture dislocation. A = anconeus, B = extensor carpi ulnaris

FIGURE 2: The lateral radiograph of the elbow depicts the clinical, intraoperative landmarks used for anchor placement at the LUCL origin. A pilot hole for the anchor is drilled at a point near the bisection of a line running parallel to the anterior cortex of the humerus and a line parallel to the radial neck.

We used the Broberg-Morrey modification of the Mason classification and the Regan and Morrey classification systems to describe radial head and coronoid fractures, respectively.[29,30]

We reviewed the intraoperative reports as well as preoperative and postoperative radiographs to record the details of the performed procedures. Additionally, patient-reported outcome measures (PROMs), including the visual analog scale (VAS) for pain and Disabilities of the Arm, Shoulder, and Hand questionnaire (*Quick*DASH), were recorded. Range of motion measurements were recorded at the final follow-up and were obtained by a hand therapist using a manual goniometer. We reviewed radiographs obtained at the final follow-up to quantify posttraumatic degenerative changes and heterotopic ossification (HO). For HO, we used the Hastings and Graham classification: radiographic HO without functional limitation (class I), limitation in flexion-extension (class IIA), limitation with pronosupination (class IIB), limitation with flexion-extension and pronosupination (class IIC), and ankylosis of the forearm or elbow (class III).[31] To quantify elbow degenerative changes postoperatively, we used the Broberg and Morrey classification system: slight joint space narrowing with minimal osteophyte formation (grade 1), moderate joint space narrowing with moderate osteophyte formation (grade 2), and severe degenerative change with gross destruction of the joint (grade 3)[30,32] We also looked for radiographic evidence of capitellar erosion (or notching on the lateral aspect of the capitellum on the anteroposterior

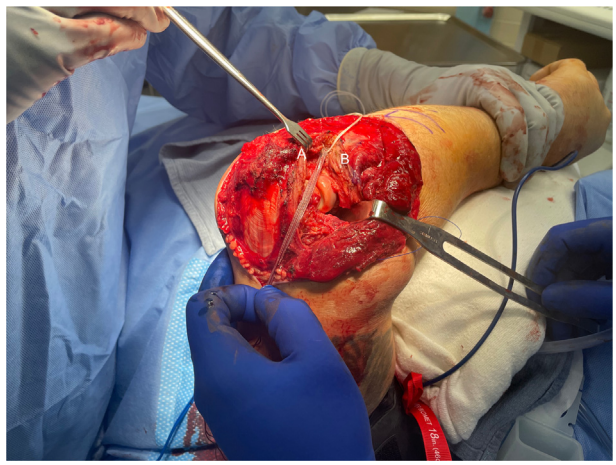

FIGURE 3: Clinical intraoperative photograph after anchor placement in the ulna. The elbow is taken through a complete flexion-extension arc while checking for equal tension on the suture tape throughout ROM. The anchor insertion point on the humerus can then be slightly adjusted to ensure appropriate tension. A = anconeus, B = extensor carpi ulnaris

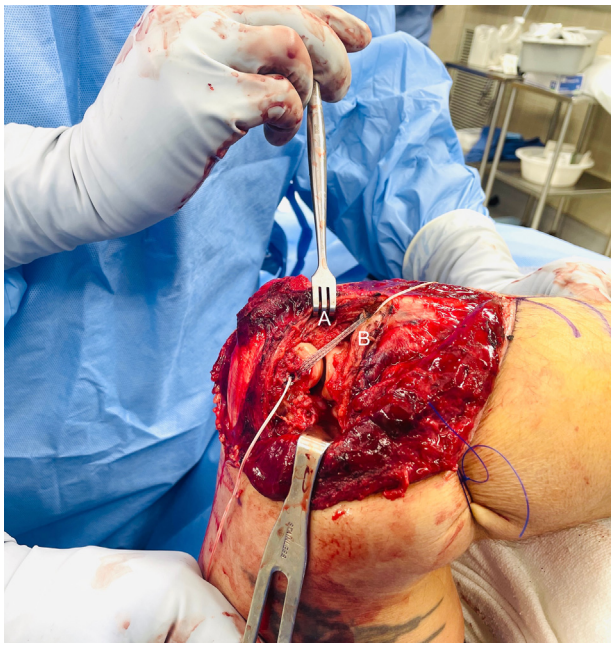

FIGURE 4: Clinical intraoperative photograph showing the insertion of the anchor at the isometric point on the lateral aspect of the distal humerus as part of a LUCL repair with internal-brace augmentation. A = anconeus, B = extensor carpi ulnaris

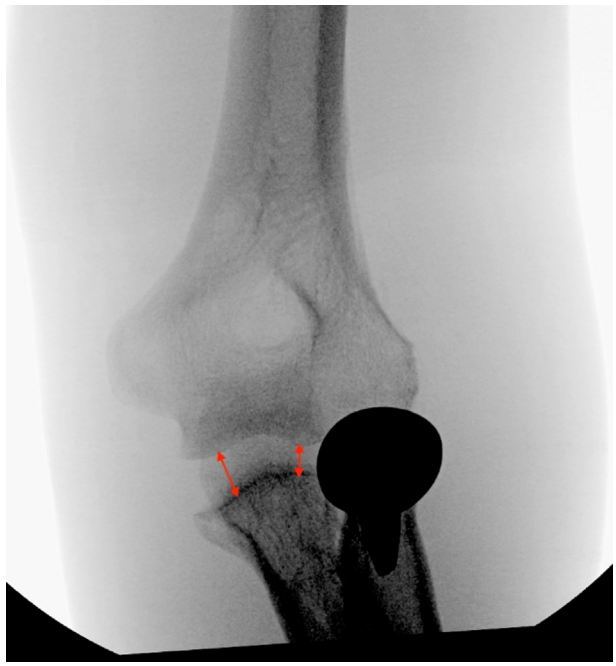

FIGURE 5: Intraoperative radiograph depicting the valgus alignment of the elbow after placement of an internal-brace due to overtensioning. Red arrows indicate larger joint space gapping on the medial aspect of the ulnohumeral joint.

radiograph) caused by the suture-tape material against the lateral aspect of the distal humerus. All postoperative radiographic assessments were made at the time of the final follow-up. All radiographs were reviewed by 2 study authors (J.R.N., B.K.F.) (senior hand surgery residents). Disparate radiographic assessments were reviewed by the senior author (L.C.G.), and the decision was then determined by consensus.

Statistical analysis

Descriptive statistics were reported with mean values and SD for continuous variables and frequencies were used for categorical data.

Indications for augmentation

For the LUCL, we performed an LRSTA, as opposed to repair alone, in acute cases of complex elbow instability that met one of the following criteria: (1) high-energy injury mechanism, (2) elbow redislocated in the orthosis after closed reduction in the emergency department, (3) "bald" lateral condyle observed intraoperatively, and (4) persistent elbow instability in extension after fracture fixation and ligament repair. In cases of persistent instability after repair, the repair is taken down (and the humeral anchor removed), and LRSTA is performed with a re-repair of the LUCL. We defined a bald lateral condyle as a complete avulsion of the LUCL complex and extensor-supinator tendinous origin. We additionally performed LRSTA for cases of chronic PLRI that underwent operative treatment during the study period.

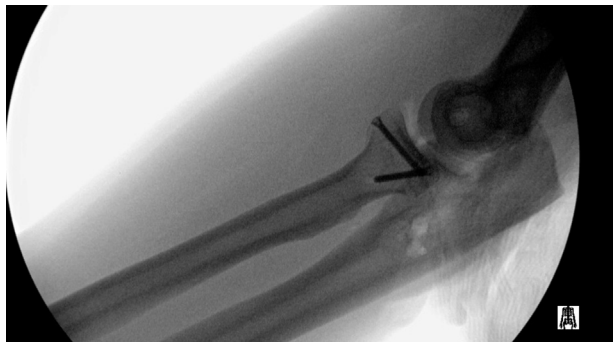

FIGURE 6: Intraoperative gravity-assisted lateral elbow radiograph in full extension is obtained to ensure that the radiocapitellar joint is symmetrically reduced and there is no excessive ulnohumeral gapping.

Surgical technique

The surgical technique used for this investigation is described in the context of the treatment of a terrible triad elbow fracture dislocation since this was the most common indication for surgery.

TABLE 1. Baseline Demographics for Included Patients That Underwent Elbow LUCL Repair With Suture-Tape Augmentation

	All, n (%)
Cases, (n)	18
Age (y), mean (SD)	51 (18)
Male	8 (62)
Laterality right	10 (56)
Body mass index, mean (SD)	33 (6)
Active tobacco use	3 (17)
Diabetes	2 (11)
Rheumatoid arthritis	0 (0)
Mental, behavioral, or neurodevelopmental disorder	4 (22)
Currently employed	11(62)
Married	11(62)

TABLE 2. Injury Demographics for Included Patients That Underwent Elbow LUCL Repair With Suture-Tape Augmentation

	ALL, n (%)
Cases, (n)	18
High-energy mechanism	5 (25)
Open injury	0 (0)
Indication	
Terrible triad	11 (62)
Simple recurrent elbow dislocation, acute PLRI	2 (11)
Chronic PLRI	5 (28)
Cases with associated ipsilateral upper-extremity injury	5 (28)
Cases with any associated orthopedic injuries	8 (44)

The patient is placed in the supine position, and a radiolucent hand table is attached to a regular bed. After sterile skin preparation and draping, a sterile brachial arm tourniquet is placed as proximally as possible on the humerus to allow for extensile exposures.

Incision placement varies by case, but most commonly, a straight posterior incision is used directly over the tip of the olecranon, allowing for lateral and medial subcutaneous flap elevation, if required. When an augmented repair was planned, a Kocher interval was used between the anconeus and extensor carpi ulnaris. However, this can be performed through a more anteriorly based extensor digitorum communis split. The Kocher approach allows for excellent visualization of the supinator crest of the ulna and the radial head and lateral humerus (Fig. 1).

We used an "inside-out" approach for the fixation and repair sequence. Coronoid fixation (when performed) is accomplished prior to radial head fixation or arthroplasty. Attention is then turned to the augmented LUCL repair. First, the supinator crest and lateral collateral ligament (LCL) insertion are directly visualized and palpated. A 2.4 mm guidewire is placed in the anatomic insertion of the LCL, approximately 3 mm from the apex of the supinator crest.[33] The radial head can serve as a helpful anatomic landmark: the insertion of the 2.4 mm guidewire is typically 15-mm distal to the head-neck junction of the radius and 10-mm anterior to the subcutaneous border of the ulna. A 4.5-mm cannulated drill bit is then used to create a pilot hole for the anchor. A 4.75-mm absorbable anchor is preloaded with braided suture tape and an additional #2 braided, nonabsorbable suture.

Attention is turned to the humerus. The anatomic origin of the LUCL complex on the lateral aspect of the distal humerus is identified. Although this can also be accomplished radiographically by identifying the central portion of the capitellum on a lateral radiograph, intraoperative anatomic landmarks are used to determine the appropriate anchor position. First, the bisection of a line that runs parallel to the anterior cortex of the humerus and a line that runs parallel to the radial neck is identified (Fig. 2). This bisection is marked with electrocautery. Then the suture tape is taken from the anchor in the ulna and held in place at this premarked point on the lateral humerus (Fig. 3). The elbow is taken through a complete flexion-extension arc and checked for equal tension on the suture tape throughout the ROM. The insertion point on the humerus can then be slightly adjusted to ensure appropriate tension. A guidewire is placed in an appropriate position on the lateral aspect of the humerus using the 4.5-mm drill bit. The suture tape is then loaded through a second, identical anchor. With the arm across the chest in 90° of elbow flexion and neutral forearm rotation, the anchor is docked into the humeral LCL origin (Fig. 4). The suture tape is superficial to the joint capsule and torn LUCL but deep to the anconeus and extensor-supinator muscles. Prior to definitive anchor fixation, a Freer elevator was placed between the tape and the humerus to avoid overtensioning. Overtensioning can result in postoperative stiffness, cause joint space gapping medially, and even lead to

TABLE 3. Postoperative Results and Complications for Patients That Underwent Elbow LUCL Repair With Suture-Tape Augmentation at the Time of Final Follow-Up

Variable	All, mean (SD)
Cases, (n)	18
Follow-up duration (mo)	20 (10)
Range	6–48
PROMs	
*Quick*DASH	17 (19)
VAS pain scale	2.0 (2.1)
ROM	
Flexion	136° (13)
Extension	−12° (12)
Flexion-extension arc	124° (24)
Cases with <100° flexion-extension arc, n (%)	2 (11)
Pronation	79° (8)
Supination	72° (17)
Pronosupination arc	150° (23)
Cases with <100° pronation-supination arc, n (%)	1 (4)
Radiographic Outcomes	
HO[31], n (%)	
Class I	16 (89)
Class IIA	5 (5.5)
Class IIB	0 (0)
Class IIC	1 (5.5)
Class IIII	0 (0)
Degenerative changes[30], n (%)	
None or grade I	9 (50)
Grade II	7 (39)
Grade III	2 (11)
Complications	
Cases with postoperative complication, n (%)	2 (11)
Total postoperative complications, n	2
Instability/subluxation, n	2
Cases with any reoperation, n (%)	2 (11)

valgus or rotational instability, particularly when medial collateral ligament insufficiency is present (Fig. 5).

After definitive anchor placement, the elbow is again taken through a full ROM to ensure appropriate stability. The remainder of the LCL complex can be repaired over the suture tape using the braided, nonabsorbable sutures preloaded in the anchors. Final radiographs are obtained. The anteroposterior radiograph of the elbow should be critically assessed to ensure a symmetric joint space on the medial and lateral aspects of the ulnohumeral joint. Again, excess tension on the suture tape may cause the lateral aspect of the ulnohumeral joint to be narrow relative to the medial side (Fig. 5). A gravity-assisted lateral radiograph in full extension was obtained to ensure that the radiocapitellar joint is symmetrically reduced and that there is no excessive ulnohumeral gapping (Fig. 6). The deep fascia and skin are then closed after hemostasis is ensured.

We use a postoperative long-arm plaster orthosis with the elbow in 90° of flexion for 10–14 days. In patients without diabetes, we use the perioperative glucocorticoid protocol described by Desai et al,[34] which can improve ROM. At the first postoperative visit, patients meet with a certified occupational hand therapist to begin a brace-free, supine overhead ROM exercise program similar to the protocol described by Schreiber et al.[25] We encourage patients to use pain-guided therapy and avoid "push-off" and varus stress to the elbow for 6 weeks. Patients are permitted to resume unrestricted activities beginning at 3 months postoperatively.

RESULTS

We identified 18 cases treated with LRSTA that met the inclusion criteria. The mean age of included patients was 51, with an average follow-up of 20 months (range 6–48 months). Table 1 includes baseline demographics for all included cases in our series; no patients had evidence of prior elbow trauma or instability.

Table 2 shows the injury characteristics of the patients in our series. Five (28%) cases involved a high-energy mechanism injury, and there were no open injuries. Eleven (62%) cases were terrible triad injuries, and 2 (11%) were chronic PLRI injuries. Eight (44%) cases had other associated orthopedic injuries, and 5 (28%) cases had an upper-extremity injury.

For radiographic outcomes, 2 (11%) cases had class IIA HO formation. Two (11%) cases had severe grade III posttraumatic arthritis at the time of the final follow-up. Table 3 includes postoperative PROMs and complications for all 18 cases. At the time of final follow-up, the mean *Quick*DASH and VAS Pain Scale scores were 17 and 2, respectively. The mean flexion-extension arc was 124°, and 2 (11%) cases had <100° flexion-extension arc. There were 2 (11%) reoperations across all 18 cases. Both cases involved

TABLE 4. Comparisons of Results for Recently Published Series of Elbow Stabilization Procedures

	Our Series	Greiner et al[28]	Giannicola et al[35]	Domos et al[36]	Zhang et al[37]
Cases (n)	18	17	26	22	21
Age (y), mean	51	38	52	48	38
Follow-up duration (mo), mean	19	10	31	32	32
ROM (°), mean					
Flexion	136	130	137	134	136
Extension	12	10	10	21	10
Flexion-extension arc	124	121	127	113	126
Pronation	79	NR	79	73	71
Supination	72	NR	77	64	69
Pronosupination arc	150	NR	166	137	139
Pain scale (VAS)	2	NR	2	2	NR
PROMs Test (score)	*Quick*DASH(17)	Oxford/MEPS (41/100) Simple elbow value (83%) DASH (19)	*Quick*DASH (8) MEPS (96) m-ASES (91)	*Quick*DASH (21) OES (37) MEPS (79)	MEPS (93)
Comment(s)		PLRI treated with suture-tape augmentation	Terrible triad injuries treated with LUCL reconstruction	Terrible triad injuries treated with LUCL repair	Terrible triad injuries treated with LUCL repair
Complication rate, %	11	41	34	41	17
Reoperation rate, %	11	22	23	22	0
Recurrent instability, %	11	0	15	NR	0
Deep infection, %	0	0	NR	NR	0

ASES, American Shoulder and Elbow Surgeons Score; MEPS, Mayo Elbow Performance Score; NR, not reported; OES, Oxford Elbow Score.

acute, complex elbow instability and were complicated by recurrent instability. One case was attributable to posterior subluxation of the radial head and eventually required the removal of the radial head prosthesis. The second reoperation involved recurrent subluxation of the ulnohumeral joint, which was attributed to excess tension on the suture tape resulting in medial joint space gapping. In this case, open reduction and temporary ulnohumeral cross-pinning were performed after the suture tape was removed and the joint was reduced. Table 4[35–37] includes the results from a recently published series of elbow stabilization procedures compared with the results reported in our investigation.

DISCUSSION

In using the elbow LUCL repair technique with suture-tape augmentation, we found that PROMs were similar to results previously described for other treatment methods. Our study demonstrates a mean *Quick*DASH of 17 and a mean VAS pain score of 2 at the time of the final follow-up. Previous publications that have investigated the outcomes of surgical treatment of terrible triad injuries reported a *Quick*-DASH range of 5–21 and a VAS pain score of approximately 2.[31,32,35,36,38] Among these previous publications, the authors who performed an LUCL repair reported a *Quick*DASH and VAS of 21 and 2, respectively.[31,32,36] Additionally, in one study of repair alone, there was a mean Mayo Elbow Performance Score of 87, with 14 of 19 (74%) of patients having excellent results.[39] Greiner et al,[28] in their series of LUCL repairs with augmentation for 17 cases of simple and complex elbow dislocations, reported a mean *Quick*DASH score of 28 at a median of 10 months postoperatively. Sanchez-Sotelo et al[40]

found a mean Mayo Elbow Performance Score of 85 and noted a good or excellent result in 19 of 44 cases (43%) for patients who had repair or reconstruction of the LUCL for PLRI. Studies investigating the outcomes of an IJS for acute traumatic elbow injuries have also demonstrated a range of *Quick*DASH scores.[17,18] Range of motion results with our technique were similar to those reported by prior authors who used LUCL repair and reconstruction in the setting of acute, complex elbow dislocations (Table 4).[28,36,38,41] Ligament repair with suture-tape augmentation of the LUCL results in acceptable functional outcomes similar to previously described techniques.

At the time of follow-up, we noted 2 (11%) reoperations, both of which were for recurrent instability. The complication rate for operatively treated terrible triad injuries is as high as 55% in one systematic review.[42] Sanchez-Sotelo et al[40] showed that in 44 cases of chronic PLRI treated with either repair or reconstruction with or without graft or suture-tape augmentation, their reoperation rate for recurrent instability was also 11%. Using a transarticular ulnohumeral cross-pinning technique has a reported complication rate from 10% to 24%.[13,43] The use of a hinged external fixator is another option, which carries a complication rate from 25% to 37% and a reoperation rate of 27%.[44,45] Yet, another option is the IJS system; however, routine removal is still recommended as part of the manufacturer's instructions. Despite this, a recent series has demonstrated good results without routine IJS removal in 14 of 20 cases.[17] Our study demonstrates that LUCL LRSTA has comparable complication and reoperation rates to other techniques to address traumatic elbow instability.

Ligament repair with suture-tape augmentation of the LUCL for traumatic elbow instability may offer unique practical and theoretical advantages. The added morbidity related to LRSTA, compared with the primary repair, is 1 additional drill hole and anchor in the supinator crest. This may be less morbid than other methods of LUCL reconstruction and dynamic external fixation. Furthermore, there is less hardware than dynamic external fixation, IJS, and ulnohumeral cross-pinning. The anchor placed in the LUCL is placed in the isometric point of the lateral condyle. However, in our experience, although this placement is much less technically demanding than the placement of a hinged external fixator, it likely affords similar stability. Considering the biomechanical advantages and early return to play associated with suture-tape augmentation in the elbow and thumb ulnar collateral ligament, we believe an advantage of LRSTA of the LUCL is that it may allow for earlier return to activities with decreased bracing and rehabilitation time, particularly in highly unstable cases that may have otherwise used additional stabilization techniques. However, well-designed prospective studies are necessary to define comparative outcomes with other techniques (including simple repair alone), particularly as it relates to cost.

This investigation has limitations that should be considered. First, the retrospective nature of our study has its inherent limitations. Without a control group, our results were only comparable to previous, similar studies (that have used various PROMs) or systematic reviews. Although >50% of cases involved terrible triad injuries, there was a heterogeneous list of indications for which this procedure was used. Additionally, our sample size prevents more robust statistical comparisons between subgroups. Although our mean follow-up time was 20 months, a longer follow-up timeline would allow the capture of a more precise rate of long-term complications and reoperation rates, which may be underreported in retrospective studies. For acute cases, our indications to perform LRSTA (as opposed to repair alone) may have influenced our results because we used augmentation in more challenging or unstable cases involving high-energy mechanisms and persistent instability.

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