Review

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Surgical Treatment of Posterolateral Rotational Instability of the Elbow: a Systematic Review

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ABSTRACT Posterolateral rotational instability (PLRI) of the elbow joint can occur acutely as a result of dislocation of the bones of the forearm, and also be chronic, for example, after inadequate healing of a previous rupture of the lateral ligamentous complex, in particular the lateral ulnar collateral ligament (LUCL). It is necessary to take into account that, as a result of repeated microtraumas, persistent pain syndrome and recurrence of dislocation develop, which can lead to disability. We conducted a systematic review of the literature according to the protocol outlined in the PRISMA guidelines. From 1,903 publications, 11 studies were selected that met our criteria and assessed the results of treatment of 181 patients. The main reason for the development of PLRI was simple traumatic dislocation of the forearm bones (37.5%). Of the studies that assessed the elbow joint using the MEPS, 86.5% of patients had excellent or good results, with a mean MEBS score of 91 points. Before surgery, pain syndrome was present in 131 patients (87.3%) out of 150, and in the postoperative period it was observed in 55 (36.6%) out of 150 (p=0.01). The incidence of recurrent instability after surgery was observed in 6.6% of patients. A review of the literature on the problem of the elbow joint shows that this problem has not been fully studied, treatment strategies differ and should be performed based on the surgeon's experience and available data, however, it has been proven that the key to the stability of the elbow joint is the LUCL, which requires its restoration through its refixation or plastic surgery.

LEVEL OF EVIDENCE IV

Keywords: posterolateral rotational instability, elbow instability, lateral ulnar collateral ligament, reconstruction

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AT– Achilles tendon
LPM – long palmar muscle
PLRI – posterolateral rotational instability
APET – artificial polyester tapes
LCL – lateral collateral ligaments
LUCL – lateral ulnar collateral ligament
MCL – medial collateral ligament
MRI – magnetic resonance imaging
STM – semitendinosus muscle
TBT – triceps brachii tendon
TM – thin muscle

INTRODUCTION

Elbow dislocations are estimated to occur in 5.2–6 cases per 100,000 annually. The second most common dislocation in the large joint after shoulder dislocation in adults and ranks first in childhood (adolescence), which accounts for 11–28% of all injuries to the elbow joint [1, 2]. The average age is approximately 30 years [1]. Forearm dislocations can be classified based on the presence or absence of bone damage. Simple dislocations of the forearm bones are soft tissue injuries without an accompanying fracture, while complex dislocations are accompanied by a fracture [3–5]. Simple dislocations are much more common, accounting for up to 74% of all dislocations of the forearm bones [1, 2]. Dislocations are the most common cause of elbow ligament injury leading to instability. Of these dislocations, more than 95% occur in the posterolateral direction. After a dislocation, 15–35% of patients remain unstable in the elbow joint, and recurrence of dislocation of the forearm bones is also possible [6, 7].

Posterolateral rotational instability (PLRI) of the elbow was described by O'Driscoll in 1991 as acute, recurrent, and then progressing to chronic instability of the elbow. This condition is part of a complex instability caused by failure of the lateral collateral ligament (LCL) complex and, primarily, the lateral ulnar collateral ligament (LUCL) [8]. In 2008, Charalambous et al. reported that PLRI of the elbow joint is the most common type of chronic instability of the elbow joint [9]. In PLRI, the proximal forearm bones rotate together as a unit relative to the humerus, causing posterior subluxation or dislocation of the radial head relative to the capitate eminence without associated instability of the proximal radioulnar joint.

The lateral collateral ligament complex, namely the lateral ulnar collateral ligament (LUCL), is a key structure that provides lateral stability of the elbow joint [8]. It is almost always damaged in posterolateral dislocations of the forearm bones, which account for 86% of traumatic dislocations [8–12].

LUCL reconstruction has been proposed as the primary treatment option for PLRI and is still used as the "gold standard" by many surgeons [8, 12–15]. However, in real surgical practice, it is not easy to establish the isometric point, and there is no consensus on the bone tunnel made in the arch of the supinator on the ulna [8, 10, 17–19].

Historically, Bennell sutures were placed on the humeral end of the LCL and capsule, which were then passed through bone tunnels drilled in the lateral epicondyle at the anatomical point of fixation [10, 19, 21–23].

Several surgical techniques have been described for the treatment of PLRI, including the Jobe technique [23–25], also called the figure-of-eight technique, the docking technique, and the single-strand technique [16, 17, 27, 28]. All these methods showed good and reliable results. However, in the current literature there is no consensus regarding the optimal surgical technique for the treatment of PLRI, which provides the best postoperative clinical and functional results [27, 29, 30]. In summary, this systematic review aims to determine the optimal surgical option and to evaluate the clinical outcome and complication rates of surgical techniques currently used to treat elbow PLRN.

Aim of study: to analyze literature data and determine the optimal option for surgical reconstruction of the lateral ulnar collateral ligament for posterolateral rotational instability.

MATERIAL AND METHODS

A systematic literature search was conducted in the international medical databases Pubmed and Scopus, resulting in 1,903 publications identified and assessed stepwise. The data from the studies were initially classified into: review articles, coherent articles, description of technique, comparison of two surgical techniques, biomechanical articles, and systematic reviews. These data were then extracted from each subgroup. We then compiled the data into a narrative literature to ensure comparability, and we further defined success rates in terms of the number of excellent and good results for the specific outcome measures used. Seventy-seven potential articles were identified, 11 articles met the inclusion/non-inclusion criteria. The number of patients was a total of 181. Data were pooled and analyzed with emphasis on patient demographics, as well as functional outcomes, subjective and objective treatment outcomes, and complications. A systematic review was conducted when the collected data were sufficiently homogeneous.

Inclusion criteria:

— full-text articles;
— all levels of evidence;
— research on humans;
— studies with detailed clinical outcome;
— presence of PLRI of the elbow joint due to trauma, iatrogenic damage;
— the presence of recurrent dislocations, limb weakness and other symptomatic factors;
— analysis of functional indicators was carried out;
— availability of patient demographic data, including age;
— restoration or reconstruction of the LUCL in case of PLRI of the elbow joint (adults and children).

Non-inclusion criteria:

— average follow-up time less than 2 years;
— studies in which patients did not undergo reconstructive plastic surgery;
— lack of functional results;
— loss of more than 20% of patients at last follow-up;
— studies on corpses and animals;
— studies without clinical results;
— studies examining surgical techniques involving reconstruction of the medial collateral ligament or other types of surgery;
— systematic reviews;
— excerpts from unpublished reports, scientific meetings, review articles, expert opinions.

LITERATURE SEARCH

This systematic review was conducted in accordance with the protocol outlined in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Fig. 1) [31]. The initial search identified 1,903 publications. After citation chaining and duplicate screening, 1,098 publications were excluded. After assessing their abstracts, the remaining 77 studies were assessed for eligibility criteria. A total of 11 studies were selected for inclusion in the systematic review. All were case series, 10 had strenghth of evidence of level IV and 1 had the strength of evidence of level III. Example search terms included: “lateral ulnar collateral ligament” “lateral collateral ligament complex”, “varus instability”, “posterolateral rotational instability”, “reconstruction”, “refixation”, “palmaris longus”, “triceps”. Search terms were combined into various permutations and combinations using Boolean operators to maximize the identification of relevant studies. Reference lists of included studies were also screened to identify additional related studies.

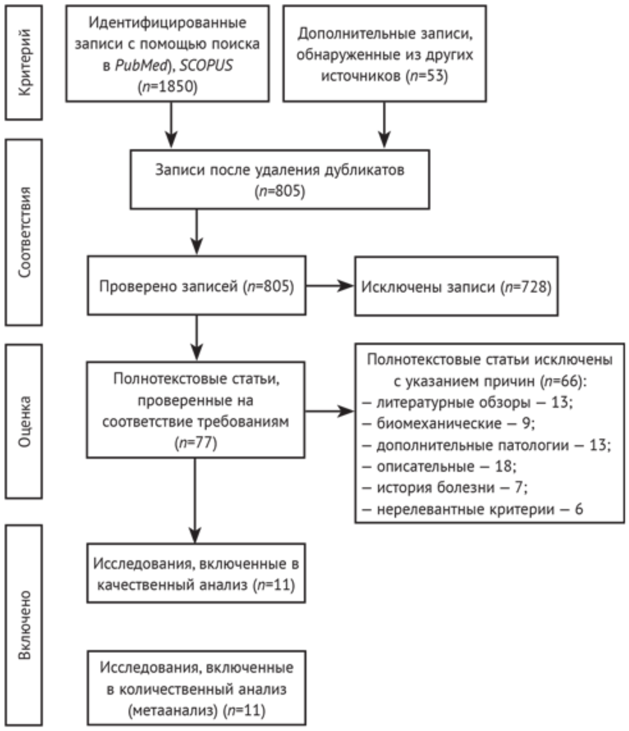


Fig. 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart for systematic review/meta-analysis design [31]

ASSESSING STUDY QUALITY AND RISK OF RESEARCH BIAS

When a study met the inclusion/non-inclusion criteria, we reviewed the entire text for qualification testing. There was no discrepancy between the authors' conclusions, and each study was assessed for risk of bias and methodological quality using the 12-item Methodological Index for Non-Randomized Studies (MINORS), which has been validated for this purpose [12]. Each question is scored from 0 to 2, with 0 for an item that was not reported, 1 for an item that was reported but inadequately, and 2 for an item that was fully reported. Important aspects of the methods included: study design, duration of follow-up, grafts used, techniques and outcomes. MINORS scores ranged from 14 to 24. All selected studies were considered eligible for inclusion.

STUDY SELECTION

We extracted and analyzed data including:
1) year of publication;
2) study design;
3) strength of evidence;
4) number of patients;
5) demographic parameters;
6) the cause of PLRI of the elbow joint;
7) time from injury to surgery;
8) surgical technique and type of graft;
9) clinical outcome (eg: pain, Mayo Elbow Performance Score (MEPS), Nestor score, Quick-DASH, VAS);
10) graft type and functional results, including subjective and objective stability;
11) rehabilitation protocol and satisfactory condition of the patient;
12) complications and revision interventions.

Then we compared the data verified by another author. The key outcome of interest was ongoing or recurrent instability after surgery. It was considered positive if patients had symptoms of instability (eg, clicking, subluxation, dislocation) and/or had clinical signs of recurrent instability, such as a positive pivot shift test.

Patient-reported outcome measures were recorded when available.

Disagreements between reviews were carefully examined and discrepancies were resolved through consensus discussion and mediation by two senior review authors (FL and AP) where necessary. If several articles about one study were found, the most detailed and complete publication was selected. The full manuscript was reviewed if the title and abstract of each study did not provide sufficient information to determine its suitability for inclusion.

DATA EXTRACTION

Statistical analysis. Weighted means were calculated for demographic and outcome data. Categorical data such as outcomes were pooled from studies and used to determine overall elbow stability, patient satisfaction, and persistent pain. The most commonly used outcome measure was the Mayo Elbow Functional Score (MEPS) in 10 studies [13]. Range of motion (ROM) in 8 studies. The Abbreviated Disability Score of the Arm, Shoulder, and Hand (QuickDASH) [14], which was used in 3 studies (nos. 7, 9, and 10), and the scoring system described by Nestor in 3 studies (nos. 1, 2, and 5) [15]. The 4 studies included in the systematic review additionally used the Oxford Elbow Score (OES) and the Visual Analog Scale (VAS) [16].

Excel 16.52 (Microsoft, USA) was used to create the databases. Statistical data processing was carried out using the Statistica 10 program (StatSoft, USA).

Two-tailed independent sample Student's t-test (unpaired) was used to compare means between groups of continuous data. A p value of less than 0.05 was considered statistically significant.

The authors assessed the homogeneity of each aforementioned data set. Heterogeneous data were excluded from the meta-analysis.

Surgical technique. Various surgical techniques for reconstruction were also identified and commented on. These techniques include the original Jobe tunneling technique [10] and the modern docking technique [18, 19].

Stability of the elbow joint. The key outcome of interest was ongoing or recurrent elbow instability after surgery, as evidenced by symptoms of instability (eg, clicking, pain, subluxations, dislocations) and/or clinical evidence of recurrent instability, such as a positive pivot shift test. [20].

Elbow joint stability was assessed both objectively and subjectively. Objective stability was determined by a member of the operating team during postoperative clinical examination and was assessed in 8 studies in 122 of 181 patients available for follow-up. Patient-reported subjective assessment (satisfaction) with activities of daily living was assessed at last follow-up in 8 studies in 128 of 181 patients.

RESULTS

All included studies are shown in Table 1, 2. A total of 11 studies were included, evaluating 181 patients with a mean age of 34.4 years (range 9–80), and the population was predominantly male, 101 versus 80 female. The mean time between injury and surgery was 32.2 months (range, 1 week to 180 months). The mean follow-up time was 65.8 months (range 7 to 264 months). As can be seen from Fig. 2, the most common cause of PLRI of the elbow joint was simple traumatic dislocation in 68 cases (37.5%), complex dislocations – 22 cases (12.1%). In 42 patients (23.2%), the cause was iatrogenic (postoperative cases). Fractures – 12 patients (6.6%) and unspecified trauma – 23 cases (12.7%). Unknown – 14 patients (7.7%) or could not identify an obvious injury that could be the cause of their illness. Of these, 51 of 181 patients underwent at least one operation (28.1%).

Table 1

Included studies, study characteristics and results

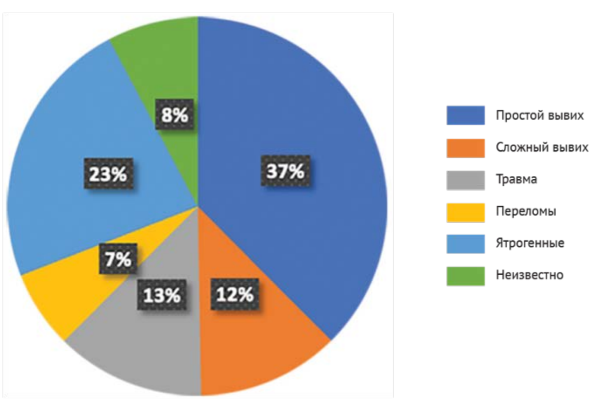
Authors research	Quantity of patients	Average age (years)	Gender m/f	Average time to surgery (months)	Cause PLRI	Average follow-up time (months)	MEPS Score	Results
1. Lee [20] (2003)	10	34 (20–50)	6/4	10.4 (1 week–36 months)	Injury	24.1 (7–52)	No	10/10 (100%) objective stability and satisfied with the results 3 excellent, 5 good, 2 satisfactory according to Nester
2. Sanchez-Sotelo [21] (2005)	44	35 (9–80)	28/16	33.8 (4–144)	Trauma 31 Iatrogenic 8 Unknown 5	72 (24–180)	85 (60–100)	38/44 satisfied with the results 38/44 objective stability
3. Jeon [22] (2011)	4	18.5 (13–23)	3/1	54 (24–60)	Injury	40.3 (26–68)	90 (80–100)	2/4; 1 or 2 episodes of subjective instability
4. Jones [17] (2012)	8	39.8 (17–57)	4/4	10.3 (6–16)	Trauma 4 Iatrogenic 4	85.2 (62.4–112.8)	87.5 (75–100)	— 8/8 (100%) objective stability and satisfied with the results — 3/8 (38%) mild pain during exercise – 1/8 (13%) constant mild pain
5. Lin [23] (2012)	14	31.6 (18–60)	10/4	45 (4–108)	Injury	49 (24–72)	93.2 (65–100)	— 13/14 (93%) objective stability 14/14 satisfied with the results – 5/14 (36%) moderate pain with activity
6. Tawari [24] (2013)	7	28 (16–47)	2/5	32.4 (6–180)	Trauma 5 Iatrogenic 2	26.8 (12–71)	95 (65–100)	6/7 (90%) objective stability and satisfied with results
7. Vernet [25] (2015)	19	37.8 (20–63)	11/7	17 (5–29)	Injury	61.1 (12–145)	89.9 (60–100)	— 18/18 objective stability and satisfied with the results — 5/18 pain is related to climate 1/18 pain with activity
8. Kastenskov [26] (2017)	15	34 (13–48)	3/12	37 (7–96)	Injury	228 (204–264)	89 (70–100)	13/15 objective stability 1/15 pain during exercise — 4/15 mild decrease in range of motion
9. Rodrigues [27] (2018)	23	31.2 (19–46)	20/3	19.5 (0.6–128)	Trauma 12 Iatrogenic 2 Unknown 9	55.5 (26–91)	85.9	3/23 elbow disability 21/23 satisfied with the results 83% returned to their previous level of performance
10. Chanlalit [28] (2018)	6	46 (39–58)	5/1	32 (12–120)	Iatrogenic	24.2 (7–50)	97.5 (95–100)	5/6 objective stability
11. Stephanie Geyer [29] (2021)	31	42.9 (31–53)	13/18	51.3	Trauma 14 Iatrogenic 17	57.7±17.5	93.5	29/31 objective stability 31/31 subjective stability
General	181	34.4	101/80	32.2	Iatrogenic 42 Injury 125 Unknown 14	65.8	Average value 90.65	

Note: PLRI - posterolateral rotational instability

Table 2
Graft selection, technique, and complexity rates

Author	Transplant	Technique	Complications	Audit (quantity/%)	Level evidence
1. Lee (2003)	LPM (5) STM (1)	Bone tunnels	Postoperative hematoma	1/10	4
2. Sanchez-Sotelo (2005)	LPM (20) TBT (4) Allogenous graft (6) STM (2)	Bone tunnels	1. Development of arthrosis (2) 2. Deep vein thrombosis (1) 3. Recurrent instability (5) 4. Ulnar nerve neuropathy (1) 5. Superficial infection (2) 6. Heterotopic ossification (1)	6/13.6	4
3. Jeon (2011)	LPM	Unknown	Moderate recurrent instability (1)	0	4
4. Jones (2012)	LPM	Docking technique	Recurrent instability (2)	0	4
5. Lin (2012)	TM (6) LPM (8)	Jobe	Recurrent instability (1)	1/7	4
6. Tawari (2013)	APET	Bone tunnels	Recurrent instability (1)	0	4
7. Vernet (2015)	LPM (18) TBT (1)	Jobe	0	0	4
8. Kastenskov (2018)	TBT	Modified docking technique with anchor clamps	0	0	4
9. Rodriguez (2018)	LPM (13) Allogenous graft (6) STM (3) Unknown (1)	Unknown	1. Deep infection (1) 2. Ulnar nerve neuropathy (2) 3. Flexion contracture + neuropathy (1)	3/13	4
10. Chanlalit (2018)	LPM	Modified docking technique with anchor clamps	0	0	4
11. Stephanie Geyer (2021)	TBT	Anchor fixation on humerus, intramedullary button on ulna	1. Deep infection (1) 2. Ulnar nerve neuropathy (2) 3. Contracture (arthrofibrolysis) (1) 4. Recurrent instability (2)	4/12.9	3

Notes: AT — Achilles tendon; LPM —long palmar muscle; APET — artificial polyester tapes; STM — semitendinosus muscle; TBT — triceps brachii muscle tendon; TM — thin muscle



37 % simple dislocation,
12% complex dislocation,
13% trauma,
7% fractures,
23 % iatrogenic,
8% unknown

Fig. 2. The structure of the causes of posterolateral rotational instability of the elbow joint

GRAFT SELECTION

Grafts used: autograft (n =145/165), allograft (n =12/165), synthetic graft (n =7/165), unknown (n =1). Types of autografts included palmaris longus tendon grafts (n = 82), triceps tendon grafts (n = 51), semitendinosus tendon grafts (n = 12) (Fig. 3).

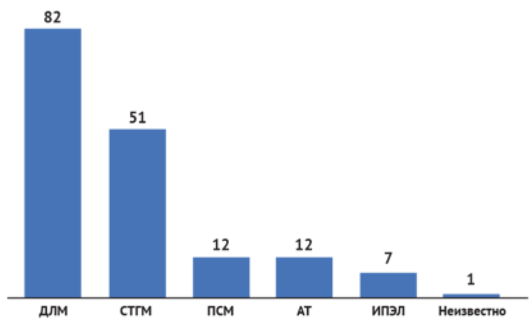


Fig. 3. Grafts used

Notes: LPM — long palmar muscle; APET - artificial polyester tapes; STM — semitendinosus muscle; TBT — triceps brachii muscle tendon

AUTOGRAFTS AND ALLOGRAFTS

The mean postoperative MEPS for autografts was 91.2 points versus 87.5 points for allografts (p >0.05).

SIMPLE AND COMPLEX DISLOCATIONS

The mean postoperative MEPS was 90.7 points for simple dislocations and 86.6 points for complex dislocations (P =0.09).

REFIXATION AND RECONSTRUCTION USING GRAFTS

In patients with acute injuries, restoration of the LUCL is indicated. Unlike patients with acute LUCL rupture, many with subacute and chronic instability do not have adequate tissue for refixation and usually require ligament reconstruction using autografts or allografts [9, 15].

The mean MEPS score for reconstruction using grafts was 90.88 points (159 patients) and 78.75 points (12 patients) for refixation (p >0.05).

In the Lee and Teo series, all 3 patients underwent tendon graft reconstruction with excellent results.

SURGICAL METHODS OF TREATMENT

Open LUCL repair of the elbow joint is often performed using the standard Kocher approach to the lateral compartment of the elbow joint. The ligament is then repaired by fixing it to its insertion on the humerus using anchors or transosseous sutures.

The most common surgical techniques were the following: Jobe technique (n =33; 18.2%) (mean MEPS =91.3) and docking technique (n =8; 4.4%) (mean MEPS =87.5), as well as a modified technique for docking with bone anchors (n = 21; 11.6%) (mean MEPS = 91.4). The use of bone tunnels included both the Jobe and docking techniques (n =61; 33.7%). Other methods included suture anchors (n = 31; 17.1%) and unknown surgical techniques (n = 27; 14.9%).

When comparing the two Jobe and docking techniques, there were no significant differences in terms of complications. Patients operated on using the Jobe technique had better clinical and functional results compared to patients treated with the docking technique. However, this difference is not significant due to the very small sample size in the docking technique group (p =0.18) (Table 3).

Table 3

Two-sample t-test (1. Jobe technique. 2. Docking technique)

	Variable 1	Variable 2
Average	91.34375	87.4375
Dispersion	131.0715726	89.67410714
Observations	32	8
Pooled Variance	123.4457237	
Hypothetical mean difference	0	
df	38	
t -statistic	0.889430456	
p (T⩽t) one-sided	0.189684017	
t critical one-sided	1.68595446	
p (T⩽t) two-way	0.379368033	
t critical two-way	2.024394164	

POSTOPERATIVE REHABILITATION

The average duration of elbow cast immobilization after surgery was 2 weeks (range, 2 days to 6 weeks), followed by continued immobilization in an articulated orthosis to gradually increase range of motion for an average of 4 additional weeks, and a rehabilitation program to strengthen the muscles of the upper extremity was initiated. Plaster immobilization was performed in the forearm pronation position in 95 cases at an angle of 900 and in a neutral position in 17 cases. In studies No. 9 and No. 11, 54 patients underwent very short immobilization of 2–3 days. Active movements in all planes were limited for an average of 8 weeks (range, 2–12 weeks). Exercise, heavy lifting, and return to sports were limited for an average of 24 weeks after surgery.

PATIENT-REPORTED OUTCOME MEASURES

In table 1, 2 show clinical results. Before surgery, the average value on the MEPS scale was recorded in only 2 studies (No. 3 and No. 10) in 10 patients and was 64.6 points. The postoperative QuickDASH score obtained in 3 studies was 13.8 points. Postoperative mean MEPS scores for the 171 patients in all included studies except the Lee study were 90.6 points (range 45–100 points). For MEPS, 101 patients (59%) were classified as excellent, 47 patients (27.5%) as good, 23 patients (13.5%) as fair, and 2 patients (1%) were classified as bad. The data from the 10 patients in the Lee study were assessed using the scoring system described by Nestor. In 3 cases an excellent result was obtained, in 5 cases a good result and in 2 cases a satisfactory result.

Age was the only risk factor that significantly influenced functional outcomes. In particular, age over 30 years predicted a significantly lower mean MEPS score and was 86.2 points versus 91.3 points in younger patients (p = 0.013) (Table 4).

Table 4
Two-sample t-test with equal variances

	Variable 1	Variable 2
Average	91.38596491	86.27027027
Dispersion	123.2412281	200.419104
Observations	57	74
Pooled Variance	166.91553	
Hypothetical mean difference	0	
df	129	
t -statistic	2.246848968	
p (T⩽t) one-sided	0.013174594	
t critical one-sided	1.656751594	
p (T⩽t) two-way	0.026349188	
t critical two-way	1.978524491	

PAIN

The pain was not observed in 31 patients. Before surgery, pain syndrome was present in 131/150 patients (87.3%), and in the postoperative period, 55 patients (36.6%) out of 150 experienced pain ranging from mild (during exercise) to persistent (at rest). Surgery was statistically significantly associated with pain relief (p =0.01).

RANGE OF MOTION

Range of motion was maintained or improved in most patients. In 128 of 181 patients, mean active elbow extension improved from 6.5° (0 to 50°) preoperatively to 5° (0 to 60°) at last follow-up, and mean active elbow flexion improved from 131° (85 to 155°) to 136° (100 to 155°). In 158 patients out of 181 after surgery, the range of motion was extension/flexion (5.90–136°).

Objective stability on clinical examination (negative pivot shift test) was seen in 111 patients (91.1%) out of 122.

Patient satisfaction was assessed in 128 of 181 patients, usually recorded as “yes” or “no.” We noted that 117 patients (91.4%) out of 128 were satisfied with the result.

COMPLICATIONS

In table Table 2 shows postoperative complications in all included studies. There were 27 complications (14.9%) and 15 revision surgeries (8.2%) reported.

The most common complication was recurrent instability. Postoperative instability was noted in 12 patients (6.6%). The rate of recurrent instability was significantly higher with ligament refixation (3/16 elbows; 18.7%) compared with that with reconstruction (9/165; 5.4%) (p >0.005).

There were no significant differences in the rate of recurrent instability based on graft type (P =0.48) or the presence of simple versus complex dislocation (P =0.52).

The structure of other complications was: contracture (n =2; 1.1%), ulnar nerve neuropathy (n =6; 3.3%), post-traumatic arthrosis (n =2; 1.1%), deep infection (n =2 ; 1.1%), superficial infection (n =2; 1.1%) and deep vein thrombosis (n =1; 0.55%).

The structure of reasons for revision operations included: neurolysis of the ulnar nerve (n =5), revision reconstruction of the ulnar nerve (n =3), deep infection (n =2), arthrofibrosis (n =1), hematoma drainage (n =1) and ulnar neuropathy nerve+arthrofibrosis (n =1).

The frequency of recurrence of instability of the elbow joint in the group of iatrogenic causes of PLRI was 3 cases (7.1%) out of 42, in the group of traumatic causes of PLRI – 6 cases (4.8%) out of 125, in the group of unknown causes of PLRI – 1 case (7. 1%) out of 14. In the Jones study, relapses were observed in 2 cases (25%) out of 8, but the authors did not indicate in which group for reasons of PLRI relapses occurred [17].

DISCUSSION

To the best of our knowledge, this is the first study to collect and analyze published results of isolated LUCL reconstruction for PLRI of the elbow joint. The main limiting factor of our study is the low level of evidence, the small number of samples, and the lack of a detailed description of the patients with PLRI included in the study. Most articles describe a small number of patients and series of clinical observations. Many works do not contain objective evaluation criteria for treatment outcomes. However, one strength of this review is the long mean follow-up time of 5.4 years. It also included enough patients to allow prognostic factors for surgical treatment of this pathology to be determined.

CAUSES OF POSTEROLATERAL ROTATIONAL INSTABILITY

Patients with PLRI have varied underlying disease, although some authors attribute its cause to damage to individual components of the lateral ligamentous complex, such as the LUCL [8] or the LCL and its attachment to the annular ligament [32]. Reconstruction of the LULC for the treatment of this disease is the "gold standard" [9, 13, 15, 21–23, 26, 33].

The most common cause of LUCL reconstruction identified in our study was chronic PLRI after a traumatic event (125 patients (69%) of 181). The majority of these patients did not have concomitant bone pathology (91 patients (73%) out of 125). Of these, 68 patients (74%) out of 91 had simple traumatic dislocations of the forearm bones, which occur in younger and more active patients, whose average age at the time of reconstruction was 34 years. This fact emphasizes that some patients with simple dislocations continue to experience symptomatic instability, which suggests the need for a more careful approach to such cases and more frequent use of surgical repair of the LUCL.

In a number of cases, PLRI was also the result of trauma without concomitant dislocation [22, 27]. In 42 cases, PLRI occurred as a result of iatrogenic damage to the LCL complex associated with previous operations on the lateral compartment or injections [22, 28, 30]. The ligamentous complex may be inadvertently severed from the humerus during extended release in tennis elbow or cut via the Kocher access [21, 29, 30].

DIAGNOSTICS

The diagnosis of PLRI can often be missed, requiring a more thorough history of elbow injury, as well as an in-depth physical examination and additional testing. Several patients in the review complained of pain, locking, or impingement, but did not specifically identify elbow instability [26, 27, 30]. Assessing stability using posterolateral pivot-shift tests should be part of the evaluation of any elbow with mechanical symptoms, previous trauma, or surgery near the lateral ligamentous complex [8]. The difficulty of diagnosing PLRI is confirmed by the data obtained on the average time to surgery, which was 32.2 months. For example, Lin et al. report that the average time between injury and surgery is 45 months [23]. Chanlalit and Phorkhar suggested that concomitant instability should be suspected in patients with elbow pain with a positive lateral pivot shift apprehension test [28]. When in doubt, the elbow joint should be examined under fluoroscopic guidance and anesthesia, and imaging studies such as magnetic resonance imaging (MRI) should be used. MRI may be useful in detecting subtle cases of instability when identifying LCL complex deficiency [34, 35].

Elbow arthroscopy can also help diagnose instability of the elbow joint. Arthroscopic findings include a "drive-through" sign and widening of the glenohumeral joint of more than 2 mm when force is applied to supinated forearm during elbow extension. For example, in the studies by Chanlalit and Stephanie Geyer, the diagnosis of PLRI was confirmed in all patients using arthroscopy [28, 29].

RESULTS OF SURGICAL TREATMENT

During acute injury, LUCL repair is the gold standard if the soft tissue is amenable to refixation. However, refixation is often impossible because the soft tissue cannot be restored. Therefore, LUCL reconstruction is the recommended choice to restore elbow stability in patients with subacute or chronic PLRI [17, 22, 29, 36, 37]. Despite the late diagnosis, the surgical results of treatment after LUCL reconstruction are generally excellent. So, 94% of patients achieve postoperative elbow stability on physical examination and a MEPS score of up to 90.6 at long-term follow-up. Additionally, the majority of patients in this review had full elbow strength and range of motion after surgical reconstruction. While 6.6% of patients remained unstable, only 2.7% of them underwent revision surgery. Reconstruction of the LUCL or repair of the lateral ulnar collateral ligament complex in patients with PLRI of the elbow has been effective. Extended ligament reconstruction using a tendon graft has yielded more reliable results.

SELECTION OF GRAFT FOR LATERAL ULNAR COLLATERAL LIGAMENT RECONSTRUCTION

The most commonly used graft was the long palmar tendon. Biomechanical studies show that the LPM tendon is quite strong [32]. It also has the advantage of being located within the surgical field and can be taken without additional anesthesia. However, LPM is not always available for use, as it is congenitally absent in 16% of the population [38]. If it is absent, part of the triceps tendon can be used. The utilization rate of this graft is also good, but the technique requires an extended posterior midline approach to obtain a graft of sufficient length. Also, when using this technique, a slight decrease in the strength of extension of the elbow joint was noted [27, 39]. In patients with degenerative changes or generalized ligament hypermobility, the use of a synthetic ligament for reconstruction is indicated [25].

SURGICAL TECHNIQUE

Two main surgical techniques have been described for the treatment of PLRI. This is the Jobe technique , also called the "figure eight" and docking technique. In patients treated with the Jobe technique , one complication was reported due to concomitant medial collateral ligament (MCL) injury that was not diagnosed before LUCL reconstruction. In the docking group, 2 out of 8 patients (25%) experienced recurrent instability. However, none of these patients required revision surgery. Only one patient with postoperative loss of mobility reported persistent mild pain on physical examination. Jones et al. [17], using the docking technique, observed episodic instability in 2 out of 8 patients, in contrast to the results of the long-term study by Kastenskov [26], which used a modified docking technique with additional fixation with anchors, observed weakness in 2 out of 15 patients, but no instability. The Jobe technique and the modified docking technique showed better postoperative functional and clinical outcome, assessed by MEPS, compared with the docking technique. However, the results demonstrate that both techniques are safe and effective for the treatment of PLRI.

POSTEROLATERAL ROTATIONAL INSTABILITY AND ASSOCIATED INJURIES

In Lin's study, there was 1 case of residual postoperative instability due to concomitant MCL injury that was not diagnosed before LUCL reconstruction [23]. Injuries to the MCS are not uncommon in traumatic complete dislocations of the forearm, with some studies reporting that up to 100% of patients had disruption of the MCS [40, 41].

Thus, to prevent recurrence and accurately determine the level of instability of the elbow joint, a thorough preoperative X-ray examination and stress tests under anesthesia (before surgery) are necessary.

Also in our study, some authors reported osteochondral defects of the posterior part of the capitate eminence – Osborne–Cotterill lesion [10, 23, 25]. This lesion was previously found to be associated with PLRI [10, 42]. Jeon et al. noted that isolated ligament reconstruction may not be effective in these patients [22, 24]. We hypothesize that the majority of elbow ulnar joint ligaments are caused by insufficiency of the lateral ulnar collateral ligament, but in some cases, post-traumatic bone deformities and associated osteochondral lesions can lead to chronic microinstability. In the series of Lee and Teo, 2 patients developed PLRI as a result of varus deformity of the elbow joint due to previous fracture malunion [20]. In complex cases, reconstruction of the MCS, bone grafting of the coronoid process, radial head and humeral condyle may be required.

REHABILITATION AND/OR POST-OPERATIVE ADMINISTRATION

Immobilization of the elbow joint for more than 3 weeks after an acute dislocation affects the development of contracture of the elbow joint [43–46]. According to the analyzed literature, after operations on the ligamentous apparatus only, the duration of postoperative immobilization on the range of motion in the elbow joint did not have a statistically significant effect, and the presence of concomitant bone damage contributed to the development of contracture [20, 23, 46–48].

COMPLICATIONS

Neurological problems, primarily ulnar nerve neuropathy, occupy the first place in the structure of complications after surgery for PLRI [21, 27, 29]. Also, neurological complications were the main reason for revision surgeries [21, 27, 29], and neurolysis of the ulnar nerve was the most common revision surgery. These data demonstrate the need for primary transposition of the ulnar nerve to avoid possible neurological complications in the postoperative period. Revision repairs of the ligamentous component amounted to 2.7%. The Lin study reported only one revision surgery due to concomitant MCL injury that was not diagnosed before LUCL reconstruction [23]. In the Rodriguez study, revision LUCL reconstruction was required due to deep infection [27]. And the Sanchez–Sotelo study reported two revision LUCL reconstructions, both patients complaining of severe pain at last follow-up [21].

This study has 3 main limitations. First, the results of this review are subject to bias and error inherent in the collection of retrospective data. Most of the included articles consisted of treatments performed by different surgeons, small cohorts in which bias is likely to exist, and negative results may not have been reported.

Secondly, the correct diagnoses may not always have been made, with patients with pain or MRI-diagnosed LUCL injury being misdiagnosed as having PLRI without true instability. Finally, interpretation of the results is limited by heterogeneity from report to report with different outcome measures. Preoperative range of motion and functional indicators were absent in some authors, so it was impossible to judge the objective increase in indicators by the end of the observation period. Moreover, grip strength was not measured in many studies and there was no standardization across time points and rehabilitation protocols, limiting statistical power. However, there are several strengths: the long mean follow-up time of 5.4; a sufficient number of patients to be able to determine prognostic factors for surgical treatment of this pathology. Therefore, despite the limitations, we present the largest systematic review of LUCL reconstruction for PLRI of the elbow.

CONCLUSIONS

1. The analysis of international literature shows successful results of reconstruction of the lateral ulnar collateral ligament for posterolateral rotational instability of the elbow joint in most patients, achieving joint stability, maintaining its mobility and reducing pain.

2. Early surgical intervention in patients with significant symptoms of instability and non-use of prolonged immobilization in attempts to carry out conservative treatment allows for better functional results in the treatment of dislocations and fracture-dislocations in the elbow joint, and early mobilization after surgical treatment reduces the risks of developing postoperative contractures of the elbow joint.

3. Due to the fact that the lateral ulnar collateral ligament is a key anatomical structure for the stability of the elbow joint in daily activities and for sports loads, its preservation or restoration should be a mandatory procedure during surgical interventions on the lateral part of the elbow joint, both in acute injuries and with chronic instability. The main method of choice for restoration of the lateral ulnar collateral ligament in subacute and chronic cases of posterolateral rotational instability is its reconstruction with an autotendon graft from the palmaris longus tendon.

4. To evaluate the results of treatment of posterolateral rotational instability, it is advisable to create unified protocols for describing such patients, which will allow a more detailed understanding of the results of treatment in the future.

Further comparative studies with a more rigorous approach to data collection are needed.

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