Posterolateral Rotatory Instability Develops Following the Modified Kocher Approach and Does Not Resolve Following Interval Repair

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Background: The modified Kocher and extensor digitorum communis (EDC)-splitting intervals are commonly utilized to approach the lateral elbow. Iatrogenic injury to the lateral ulnar collateral ligament may result in posterolateral rotatory instability (PLRI). in the present cadaveric study, we (1) evaluated lateral elbow stability following the use of these approaches and (2) assessed the accuracy of static lateral elbow radiographs as a diagnostic tool for PLRI.

Methods: Ten matched-pair cadaveric upper-extremity specimens (n = 20) were randomly assigned to Kocher or EDC-splitting approaches. Specimens underwent evaluation pre-dissection, post-dissection, and following repair of the surgical interval. Clinical evaluation of lateral elbow stability was performed with the lateral pivot-shift maneuver. Radiographic radiocapitellar displacement was evaluated with the fully extended hanging arm test and on lateral elbow 30° flexion radiographs. Paired Wilcoxon signed-rank tests with Bonferroni correction were utilized to compare groups.

Results: All Kocher group specimens (10 of 10) developed PLRI on the pivot-shift maneuver following dissection. No EDC-splitting group specimens (0 of 10) developed instability with pivot-shift testing. The fully extended hanging arm test showed no difference in radiocapitellar displacement between groups ($p > 0.008$). Lateral elbow 30° flexion radiographs in the Kocher group showed an increased radiocapitellar displacement difference (mean, 8.46 mm) following dissection compared with the pre-dissection baseline ($p < 0.008$). Following repair of the Kocher interval, the radiocapitellar displacement (mean, 6.43 mm) remained greater than pre-dissection (mean, 2.26 mm; $p < 0.008$). In the EDC-splitting group, no differences were detected in radiocapitellar displacement on lateral elbow radiographs with either the fully extended hanging arm or lateral elbow 30° flexion positions.

Conclusions: The Kocher approach produced PLRI that did not return to baseline conditions following repair of the surgical interval. The EDC-splitting approach did not cause elbow instability clinically or radiographically. The hanging arm test was not reliable for the detection of PLRI.

Clinical Relevance: The Kocher interval for lateral elbow exposure results in iatrogenic PLRI that is not detectable on the hanging arm test and that does not return to baseline stability following repair of the surgical interval.

The surgical approach to the lateral elbow is often chosen according to injury characteristics, the visualization required, and/or surgeon preference[1-3]. The modified Kocher and extensor digitorum communis (EDC)-splitting approaches are options for exposure of the elbow joint and proximal radius[4]. The anatomic differences between these approaches are important to understand because they may influence operative decision-making.

The lateral collateral ligament (LCL) is encountered in both approaches and represents a confluence of several ligaments, including the annular ligament, radial collateral ligament, lateral ulnar collateral ligament (LUCL), and the accessory lateral collateral ligament[5,6]. The LUCL is considered the primary stabilizer of the lateral elbow[7,8]. Posterolateral rotatory instability (PLRI) may result after injury to the LCL and often requires repair or reconstruction of the LUCL[9-11]. The hanging arm test has been described as an intraoperative assessment tool to evaluate lateral elbow stability[12].

Compared with the more anterior EDC-splitting approach, the Kocher interval between the extensor carpi ulnaris and anconeus directly overlies the LUCL, placing it at risk with dissection[13,14]. Thus, the EDC-splitting approach may be less likely to

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disrupt the ligament[4,15]. The original Kocher approach included release of the LUCL origin after incision of the anterior capsule, and the approach was later modified to include a more anterior capsulotomy in an attempt to preserve the stability of the LUCL[16-18]. To our knowledge, a direct comparison of the modified Kocher (denoted as "Kocher" in the remainder of this manuscript) and the EDC-splitting approaches with regard to the development of PLRI has not been performed. The present study evaluated elbow stability following these approaches in a cadaveric model. The goals of this study were to (1) assess the development of lateral elbow instability following each procedure with use of the clinical lateral pivot-shift test and (2) compare the diagnostic accuracy of PLRI with static lateral elbow radiographs, positioned in full extension (hanging arm position) and with 30° elbow flexion. We hypothesized that the incidence of PLRI following each surgical approach would not be different.

Materials and Methods

Power Analysis

A power analysis was performed to determine the adequate sample size to detect a difference in PLRI between the 2 surgical approaches. The study was powered to detect a meaningful difference of 20% displacement between the groups. Group sample sizes of 10 matched-pair cadaveric specimens (n = 20) achieved >80% power to reject the null hypothesis that no difference exists in radiocapitellar displacement with a significance (alpha) of 0.05.

Specimen Selection

Ten matched-pair upper-extremity specimens, intact distal to the mid-humerus, were obtained (via Science Care) and randomized to a Kocher or EDC-splitting approach. The specimens in each matched pair were separated and 1 was randomly assigned to each group with use of a stratified design, ensuring an equal distribution of right and left extremities in each group. Consequently, each cadaver contributed 1 limb to the Kocher and 1 limb to the EDC-splitting group, thus ensuring equal distribution of variables including age, sex, body mass index, bone density, and baseline ligamentous laxity. All superficial and deep tissues were intact, without evidence of previous trauma. Preoperative dynamic fluoroscopic evaluation demonstrated no evidence of previous elbow trauma or ligamentous instability. Lateral pivot-shift testing demonstrated no evidence of preexisting PLRI in any specimen.

Hanging Arm Testing Position

Specimens were mounted proximally at the humerus such that the elbow was fully extended with the forearm supinated and unsupported (i.e., hanging arm position; Figs. 1-A and 1-B). Lateral elbow radiographs were made. Following pre-dissection testing, dissection using the Kocher or EDC-splitting approach assigned to each matched limb was carried out by a senior author.

Specimen Preparation and Approach

All surgical approaches were performed with a goal of obtaining maximal visualization of the radial head, neck, and radiocapitellar articulation. The forearm was pronated, and a 7-cm curvilinear incision was made centered over the lateral epicondyle and radial head. Dissection was carried through subcutaneous tissue, elevating full-thickness flaps off the extensor musculature fascia.

Kocher Group

The adipose tissue marking the intermuscular plane between the anconeus and extensor carpi ulnaris was split. The extensor carpi ulnaris was retracted anteriorly, and an arthrotomy was performed sharply in line with the anterior border of the anconeus. The dissection and radiocapitellar arthrotomy remained as anterior as possible in the interval in an attempt to preserve the LCL complex, as previously described[15]. The radiocapitellar joint was exposed 3 cm proximal and distal to the radial head.

EDC-Splitting Group

The EDC muscle and proximal tendon were identified. A full-thickness incision was made sharply in the midportion of the tendon from its origin on the lateral epicondyle to the musculotendinous junction. Deep dissection was then performed through the joint capsule anterior to the equator of the capitellum. The radiocapitellar articulation was exposed 3 cm proximal and distal to the radial head.

Experimental Testing

Evaluation of elbow instability following the surgical approach was performed radiographically and clinically. Radiographically, assessment following dissection and prior to surgical interval repair included the use of (1) a fully extended hanging arm lateral elbow radiograph and (2) a 30° flexion static lateral elbow radiograph. After radiographs were made, the specimens were removed from the mount and assessed clinically with a lateral pivot-shift maneuver, which served as the benchmark standard diagnostic tool to identify PLRI[19]. Any subluxation of the radiocapitellar joint was considered diagnostic for instability.

Anatomical Description

The components of the LCL complex were subsequently individually evaluated for disruption in each specimen by a second senior author who was blinded to the original dissection and pivot-shift testing. High-resolution photographs of each specimen were subsequently reviewed by the research group to confirm ligamentous integrity.

Radiographic Data Collection

After the first 7 specimens were assessed, it was noted that the radiographic appearance of radiocapitellar congruency with the hanging arm test did not grossly correlate with instability identified with the pivot-shift maneuver. The testing protocol (Fig. 2) was subsequently modified to perform radiography with elbows flexed 30° for the remainder of testing. As a result of this modification, 2 Kocher and 5 EDC-splitting specimens had incomplete data for pre-dissection static 30° elbow flexion radiographs. All 20 specimens underwent post-dissection radiographic assessment in 30° of elbow flexion. For any specimen in

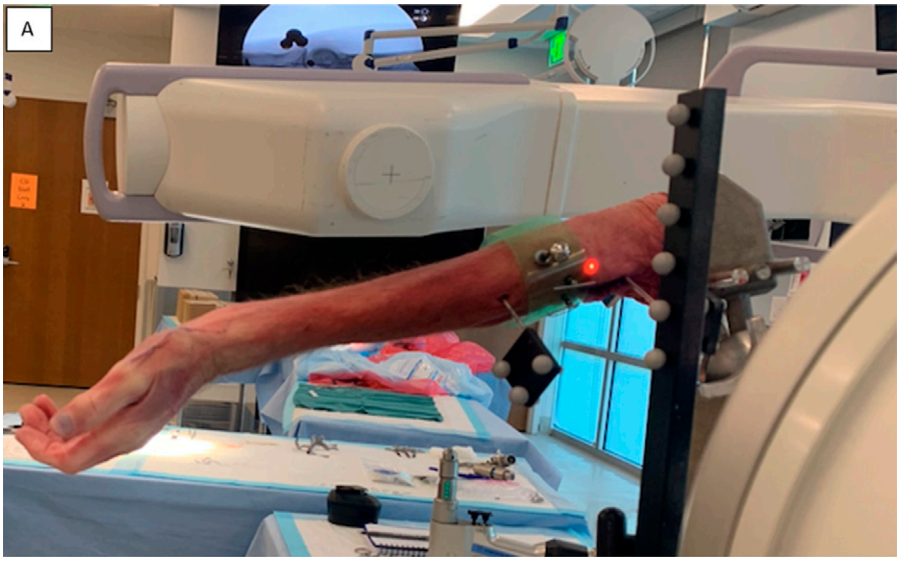

Fig. 1-A

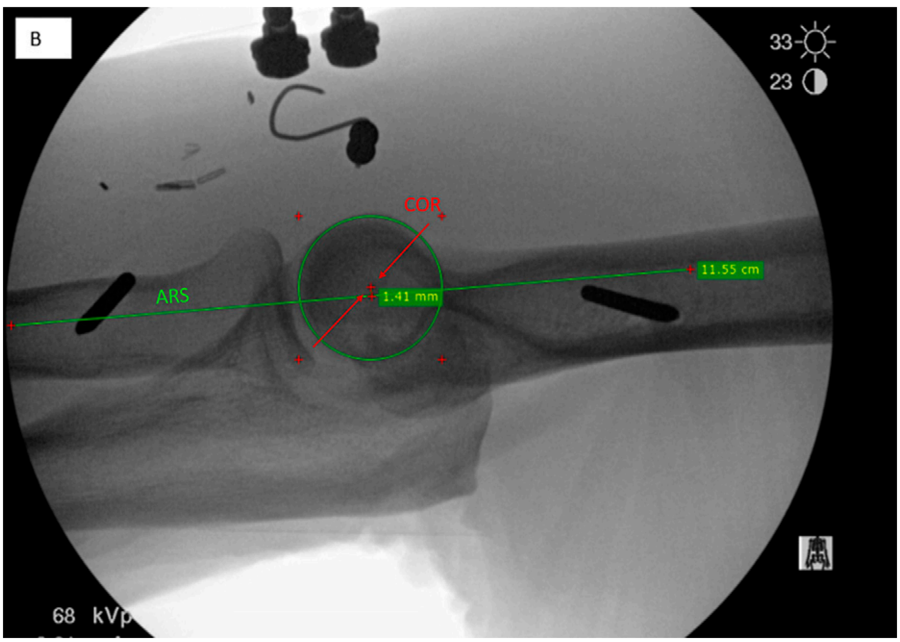

Fig. 1-B

Figs. 1-A and 1-B Radiographic hanging arm test. **Fig. 1-A** The arm was supported at the distal third of the humeral shaft, allowing gravity to extend the elbow. **Fig. 1-B** Radiocapitellar displacement was assessed on lateral radiographs by comparing the line formed by the axis of the radial shaft (ARS) to the center of rotation (COR) of the capitellum (arrows point to the COR, measurement performed between the 2 red "+" symbols).

which instability was detected following the surgical approach, repair of the surgical interval was performed with #2 braided nonabsorbable suture (FiberWire; Arthrex) in a locked, running fashion, repairing the fascial and capsuloligamentous tissue in a layered fashion. The LCL complex was not separately repaired with bone tunnels or anchors[4]. Radiographic testing was repeated to assess stability following repair.

Radiographic measurements were made by a single observer, who was blinded to testing conditions, with use of the digital picture archiving and communication system (PACS) RadiaAnt DICOM Viewer (Medixant). An axis line centered and parallel to the radial shaft was drawn in reference to the center of the capitellum. The distance from this line to the center of the capitellum was measured to determine radiocapitellar displacement (Figs. 1-A and 1-B). A radiopaque calibration marker was attached to each specimen in order to standardize the measurements.

Statistical Analysis

Statistical analyses were performed with JMP Pro (version 16; SAS Institute) to compare radiocapitellar displacement with the fully

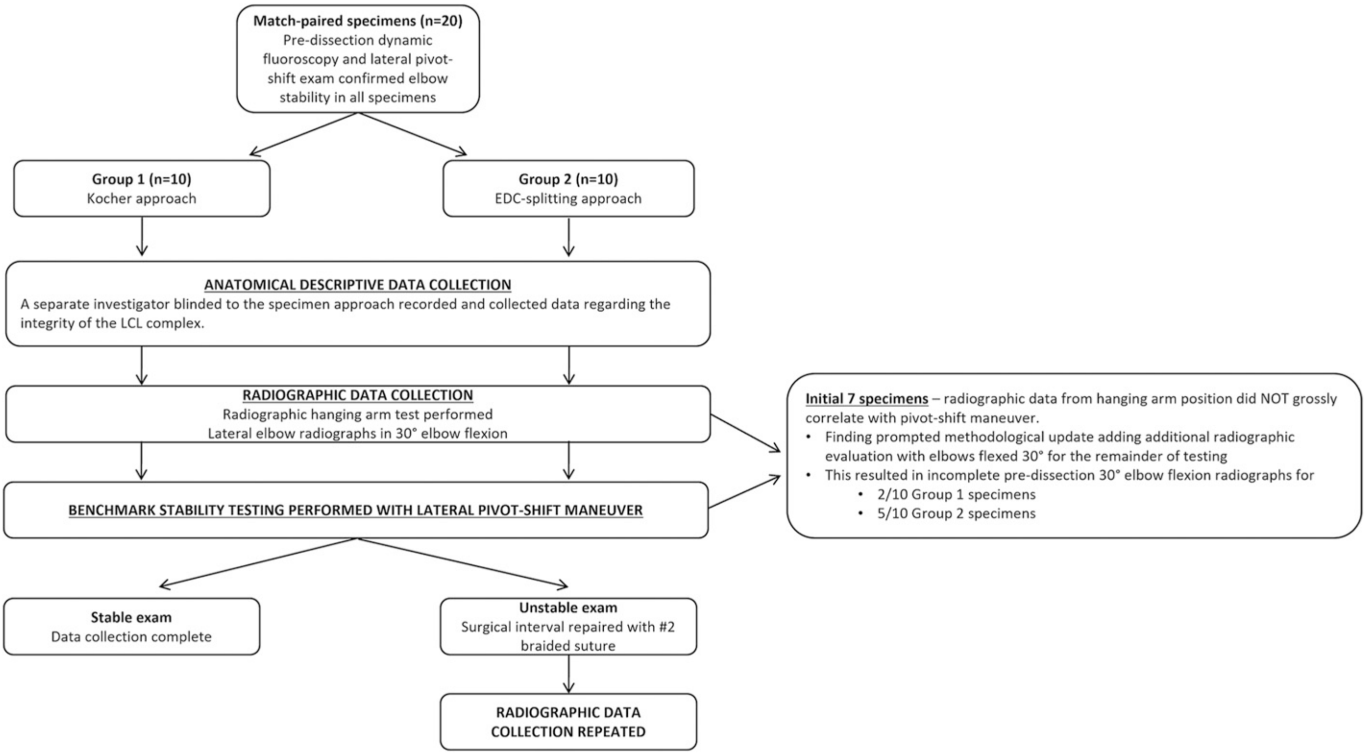

Fig. 2
Flowchart showing the study design methodology.

extended hanging arm test and the lateral static 30° elbow flexion radiograph for both groups. All data were determined to be non-parametric by the Shapiro-Wilk W test ($p < 0.0001$). The Wilcoxon signed-rank test was therefore utilized to conduct matched-pair analyses between cadaveric specimens. Bonferroni corrections were applied to all intra-group comparisons between the dissected specimen and its pre-dissection baseline (6 comparisons), thus defining significance as $p < 0.008$. Similarly, Bonferroni corrections were applied to inter-group comparisons between specimens undergoing the Kocher and the EDC-splitting approach (2 comparisons), thus defining significance as 0.025.

Source of Funding

No external funding was obtained for this study.

TABLE I Anatomical Findings Following Surgical Dissection

			Kocher Group		EDC-Splitting Group	
Specimen	Age *(yr)*	Sex	Ligaments Disrupted*	Lateral Pivot-Shift Test Instability	Ligaments Disrupted	Lateral Pivot-Shift Test Instability
1	69	F	LUCL, RCL, annular	Y	Partial annular	N
2	68	M	LUCL, RCL, annular	Y	Annular	N
3	67	F	LUCL, RCL, annular	Y	Annular	N
4	62	M	LUCL, RCL, annular	Y	Annular	N
5	69	M	LUCL, RCL, annular	Y	Annular	N
6	54	M	LUCL, RCL, annular	Y	Annular	N
7	52	M	LUCL, RCL, annular	Y	Annular	N
8	65	M	LUCL, RCL, annular	Y	Annular	N
9	67	M	LUCL, RCL, annular	Y	Annular	N
10	70	F	LUCL, RCL, annular	Y	Annular	N

*RCL = radial collateral ligament.

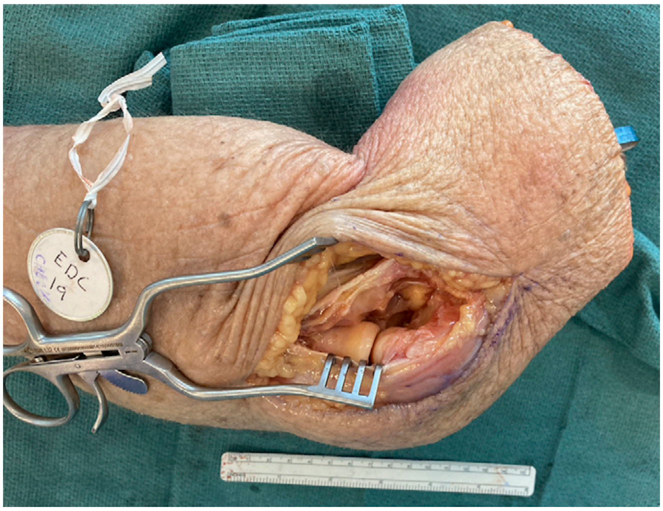

Fig. 3-A

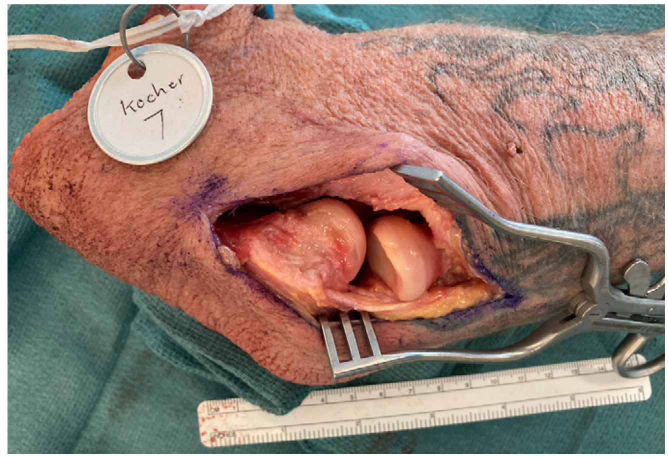

Fig. 3-B

Figs. 3-A and 3-B Surgical dissection. **Fig. 3-A** The EDC-splitting approach with maintained radiocapitellar congruency (left elbow). **Fig. 3-B** The Kocher approach with subsequent posterolateral radiocapitellar displacement (right elbow).

Results

Study Sample Demographics and Stability Analysis

The mean cadaveric specimen age was 64.1 years (range, 52 to 70 years). The specimens were from 7 male and 3 female donors. Lateral pivot-shift tests in the pre-dissection baseline state demonstrated no instability in any specimen.

All 10 Kocher group specimens developed PLRI according to lateral pivot-shift testing following dissection. Additionally, all 10 Kocher group specimens demonstrated a disrupted LUCL, radial collateral ligament, and annular ligament (Table I).

In contrast, none of the 10 EDC-splitting group specimens demonstrated lateral pivot-shift instability following dissection. Nine of the 10 EDC-splitting group specimens demonstrated complete division of annular ligament fibers, and 1 specimen had 25% of the distal annular ligament fibers intact (Figs. 3-A and 3-B; Table I).

Radiographic Analysis

No evidence of radiocapitellar or ulnotrochlear malalignment, radiocapitellar dislocation or subluxation, or intra-articular pathology was identified on pre-testing dynamic lateral elbow fluoroscopy. Figs 4-A through 4-D depict a representative case example of radiographic testing. Table II presents the radiographic results for each testing condition.

Hanging Arm Test

There was no difference in pre-dissection radiocapitellar congruency between the Kocher group and EDC-splitting group (Table II). There was no detectable difference in radiocapitellar congruency with the hanging arm test between the Kocher group and EDC-splitting group following dissection ($p = 0.643$). The mean radiocapitellar displacement in the Kocher group was 1.48 mm before and 2.37 after dissection, as measured with use of the hanging arm test ($p < 0.008$), demonstrating substantial post-dissection instability when using a digital PACS measurement tool. In contrast, the mean radiocapitellar displacement in the EDC-splitting group was 1.62 before and 1.94 after dissection ($p = 0.363$), demonstrating no detectable instability.

Elbow Flexion of 30°

Radiographic comparisons within and between groups are also reported in Table II. The mean radiocapitellar displacement with the elbow flexed (mean flexion angle, 25.3°) was 10.7 mm (range, 7.7 to 13.3 mm) following the Kocher approach, which was significantly increased from the pre-dissection condition ($p < 0.008$) (Table III). Within the Kocher group, the radiocapitellar displacement observed on lateral flexion radiographs (10.19 mm) was also significantly greater that that observed on radiographs made with use of the extended hanging arm position (2.37 mm; $p < 0.008$), indicating that radiographic instability was not identifiable with the extended hanging arm test. There was no difference in radiocapitellar displacement before and after the EDC-splitting approach, as measured with either the hanging arm testing position or 30° of elbow flexion.

Interval Repair in Specimens with Instability Following Dissection

Lateral elbow instability was only identified in Kocher group specimens. Accordingly, the Kocher interval in these specimens was repaired with #2 running, locked, braided suture incorporating a full-thickness repair of the dissected capsuloligamentous and tendinous tissue. Radiographic radiocapitellar displacement following repair remained significantly greater than that of the pre-dissection condition ($p < 0.008$), demonstrating persistent instability despite repair. Surgical repair following use of the EDC-splitting approach was not performed because instability was not identified with any testing condition.

Discussion

PLRI is the most common cause of elbow instability, resulting from either traumatic or iatrogenic injury to the

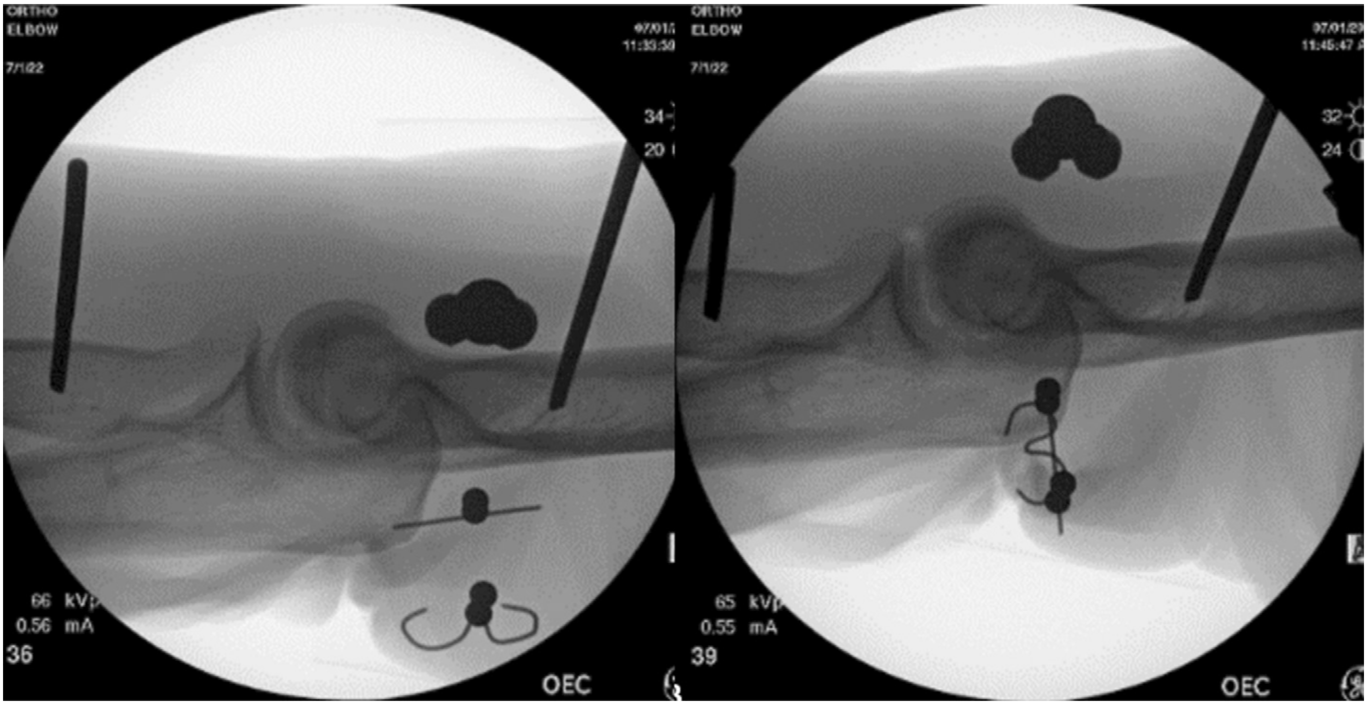

Fig. 4-A

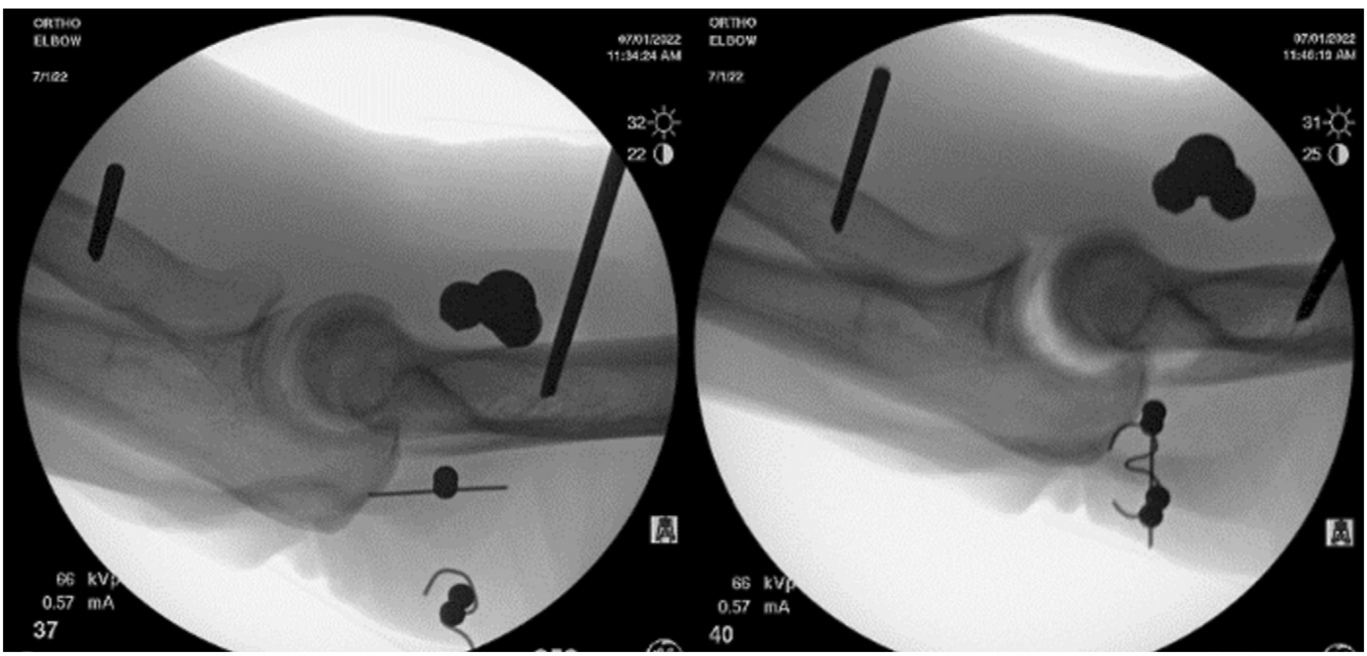

Fig. 4-B

Figs. 4-A through 4-D Radiographic findings following Kocher and EDC-splitting approaches in the case example of Specimen 8. **Figs. 4-A and 4-B** Kocher approach. **Fig. 4-A** Pre-dissection hanging arm test radiographs (left) demonstrated no instability compared with post-dissection (right). **Fig. 4-B** Pre-dissection 30° elbow flexion radiographs demonstrated concentric reduction without radial head posterior subluxation (left); notable posterior subluxation of the radial head and gapping of the ulnotrochlear joint were observed following the Kocher approach (right).

LCL complex[9,20-22]. PLRI can be assessed clinically with use of the lateral pivot-shift test or the posterolateral rotatory drawer test, both of which elicit posterior radial-head subluxation with the forearm fully supinated and the elbow flexed to approximately 30° to 40°. The hanging arm test has been described to detect elbow instability intraoperatively following fixation of elbow fracture-dislocations by allowing the weight of the arm to stress the lateral elbow when supinated

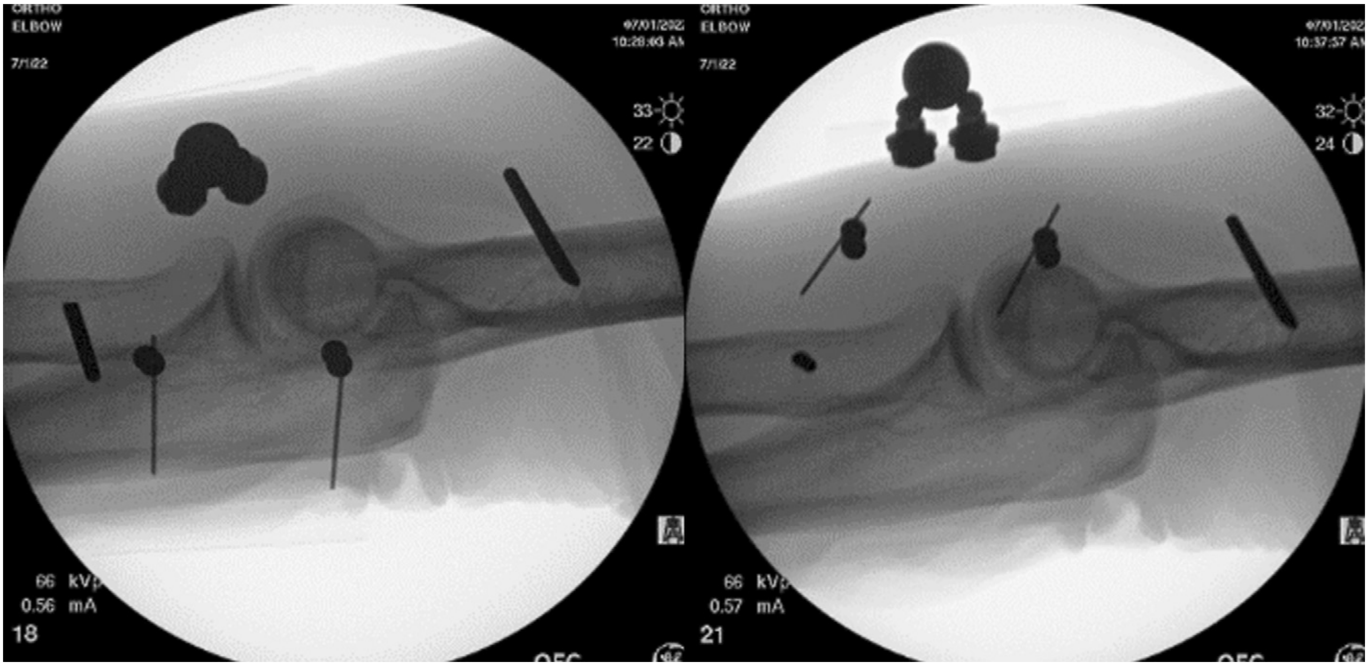

Fig. 4-C

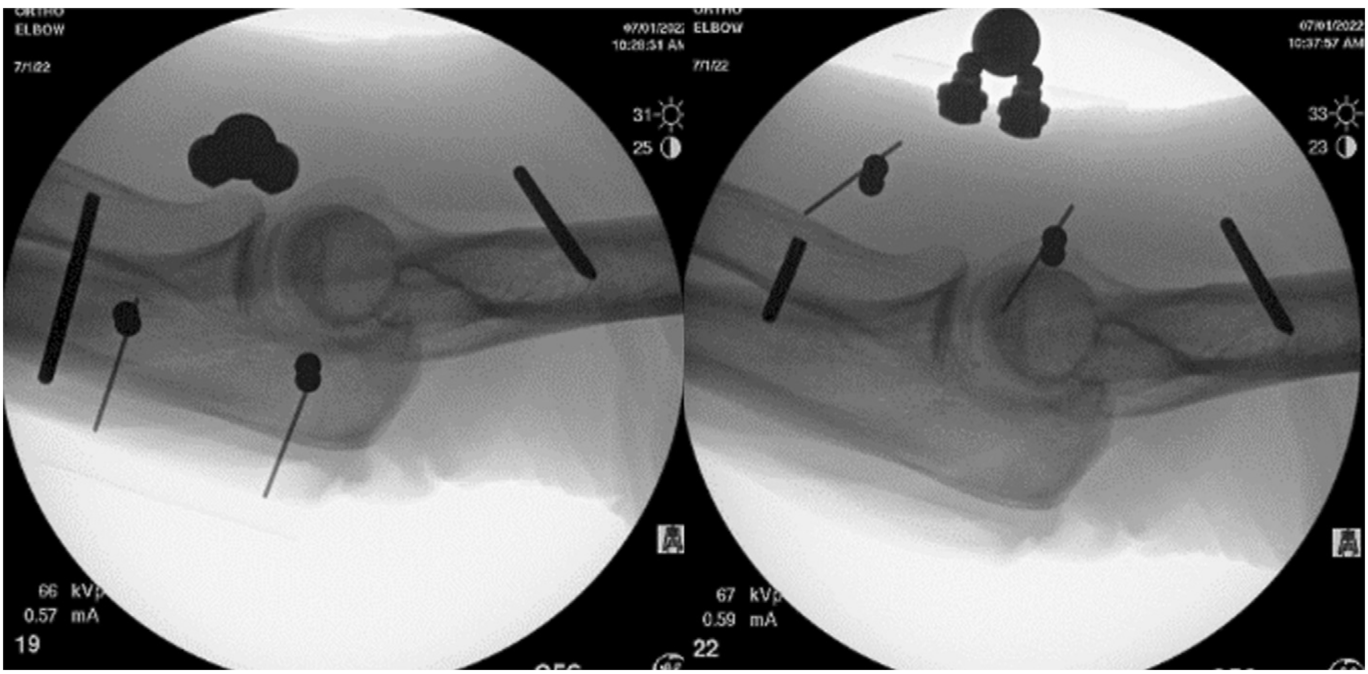

Fig. 4-D

Figs. 4-C and 4-D EDC-splitting approach. **Fig. 4-C** Pre-dissection hanging arm test radiographs (left) demonstrated no instability compared with post-dissection (right). **Fig. 4-D** Pre-dissection 30° elbow flexion radiographs demonstrated concentric reduction without radial head subluxation (left), which was unchanged following the EDC-splitting approach (right).

and suspended[12,23,24]. However, this maneuver has not been specifically validated, and the reliability of static radiographs for detecting PLRI has been questioned[25].

The presence of a discrete LUCL is inconsistently described in the literature. One cadaveric analysis identified the LUCL as a consistent distinct structure[25]. Conversely, Bellato et al. performed a Kocher approach in 20 cadavers, noting a distinct LUCL in only 80% of specimens[13]. A recent anatomic analysis concluded that the LUCL was indistinguishable as part of a capsuloaponeurotic membrane of the EDC and extensor carpi ulnaris[26]. These results depict an anatomical spectrum of LCL components, inferring inconsistency in the ability to isolate discrete ligaments.

TABLE II Radiographic Assessment of Elbow Stability

Comparison	Radiocapitellar Displacement *(mm)*		P Value
	Mean (Range)	Mean Difference (95% CI)	
Hanging arm test			
Kocher		0.89 (0.39 to 1.39)	0.0020*
Pre-dissection	1.48 (0.25-2.76)		
Post-dissection	2.37 (0.28-4.28)		
EDC-splitting		0.31 (−0.37 to 1.00)	0.3625
Pre-dissection	1.62 (0.18-3.64)		
Post-dissection	1.94 (0.73-3.28)		
Post-dissection group comparison		0.43 (−0.52 to 1.38)	0.6426
Kocher	2.37 (0.28-4.28)		
EDC-splitting	1.94 (0.73-3.28)		
Elbow flexion 30°			
Kocher		8.46 (6.83 to 10.09)	0.0078*
Pre-dissection†	2.26 (0.98-3.95)		
Post-dissection	10.73 (7.68-13.3)		
EDC-splitting		−0.68 (−2.59 to 1.23)	0.3750
Pre-dissection†	2.58 (1.60-3.34)		
Post-dissection	1.89 (0.92-3.67)		
Post-dissection group comparison		8.11 (6.60 to 9.62)	0.0020*
Kocher	10.19 (7.68-13.3)		
EDC split	2.08 (0.92-3.67)		
Post-dissection Kocher comparison		7.82 (6.96 to 8.68)	0.0020*
Hanging arm	2.37 (0.28-4.28)		
Elbow flexion 30°	10.19 (7.68-13.3)		
Interval repair, Kocher group only		−4.17 (−6.40 to −1.93)	0.0078*
Pre-dissection†	2.26 (0.98-3.95)		
Post-repair	6.43 (2.82-10.00)		

*The P value of <0.008 was considered significant based on Bonferroni correction. †5 EDC-splitting and 2 Kocher specimens were missing pre-dissection flexion data due to change in study design leading to matched-pair comparisons of n = 8 for the Kocher pre-dissection compared to post-dissection, and n = 5 for EDC-splitting pre-dissection versus post-dissection where noted. The missing pre-dissection data where noted resulted in minor differences in displacement values for the separate matched-paired analyses.

TABLE III Mean Radiographic Elbow Flexion Measurements During Each Testing Condition Measured with Radial-Humeral Angle

	Mean Flexion Angle	Mean Difference (95% Confidence Interval)	P Value
Pre-dissection*	23.5°	1.8° (−3.6° to 7.3°)	0.5469
Kocher*	25.3°		
Repaired interval	27.4°	2.4° (−1.4° to 6.2°)	0.1250
Kocher	25.0°		
EDC	24.4°	0.6° (−3.1° to 4.3°)	0.8457
Kocher	25.0°		

*Five EDC-splitting and 2 Kocher specimens were missing pre-dissection flexion data due to change in study design leading to matched-pair comparisons of n = 8 for the Kocher pre-dissection compared to post-dissection, and n = 5 for EDC-splitting pre-dissection versus post-dissection where noted. The missing pre-dissection data where noted resulted in minor differences in values for the separate matched-paired analyses.

Iatrogenic PLRI is a recognized complication following surgical intervention in the lateral elbow[27]. In a series of 44 patients undergoing LUCL repair or reconstruction for chronic PLRI, 16% of patients had a suspected iatrogenic etiology related to a prior debridement for lateral epicondylitis or loose body removal from a lateral approach[11]. Several reports documented the development of PLRI following surgical treatment of lateral epicondylitis[10,28]. Hall and McKee evaluated 42 patients with radial head fractures without associated dislocation treated with radial head resection, and reported that 17% (7) developed symptomatic PLRI[27]. In a cadaveric study, Bellato et al. reported that 75% of specimens (15 of 20) developed elbow instability attributable to the Kocher approach[13].

The present study assessed elbow stability following 2 approaches to the lateral elbow in a cadaveric model. PLRI was identified following the Kocher approach. This finding is supported by the anatomy of the LCL complex, with the LUCL underlying the Kocher interval[13,26]. Our findings do not support the use of radiographs made in the fully extended hanging arm position to diagnose PLRI. The radiographic hanging arm test was only able to detect instability when radiocapitellar congruency was carefully assessed on a digital PACS viewing system. Thus, the use of conventional intraoperative radiographic assessment with the hanging arm test seems unreliable. The 30° elbow flexion lateral radiographs were substantially more accurate and correlated better with clinical findings during pivot-shift testing.

We surmise that these findings are the result of intimate osseous congruency of the ulnotrochlear articulation with the elbow fully extended, allowing complete engagement of the olecranon within the olecranon fossa following anterior capsular tensioning. In full extension, osseous structures become the primary stabilizers of the elbow, masking lateral instability when present[29,30]. During flexion, the olecranon disengages from the olecranon fossa, allowing improved assessment of the lateral soft-tissue stabilizers[30].

Prior studies have discussed the importance of repairing capsuloligamentous structures following a Kocher approach[4,20]. The present study found that repair of the Kocher interval without the use of a suture anchor or transosseous fixation of the LUCL improved stability but did not restore the elbow to its pre-dissection baseline. This observation suggests that clinically, repair of only the capsuloligamentous structures may be insufficient to restore stability following this surgical approach.

The results of the present and other cadaveric studies suggest that PLRI consistently develops following the Kocher approach; however, clinical reports do not describe similar rates of instability[13]. This discrepancy may be the result of a minimum threshold of clinically relevant instability, below which a small degree of PLRI is not appreciable. Alternatively, robust scarring and healing potential following elbow arthrotomy, repair, and postoperative immobilization may obviate any iatrogenic instability imparted from surgical dissection. This biological response cannot be accounted for in a cadaveric sample.

The main strengths of the present study are (1) that it was appropriately powered to compare differences between surgical approaches in a cadaveric model and (2) that analyses were performed in a matched-pair fashion to account for intrinsic variables such as bone density and ligamentous laxity, which allowed for comparison of small-sample nonparametric data.

Limitations inherent to a cadaveric study include postmortem ligamentous and soft-tissue changes, repeated testing scenarios in a single specimen, and inability to completely control for intrinsic ligamentous integrity differences that may exist between matched-pair specimens. Additionally, motion observed in the positioning of a cadaveric specimen may not replicate in vivo kinematics because of a lack of muscular contraction. Although this testing design lacked dynamic stabilization, it may be a reasonable surrogate for the hanging arm test, which has been described for intraoperative testing in a sedated patient, in whom muscle tension would be minimal. Third, the surgical sectioning of specific ligaments cannot fully replicate all of the destabilizing conditions observed in various elbow fracture patterns and ligamentous injuries. Fourth, a cadaveric setting cannot replicate a biological healing response; thus, it is speculative to infer clinical conclusions regarding persistent elbow instability following repair of the Kocher interval. The final major limitation of this study derives from the methodological update following testing of the initial 7 specimens. The testing protocol was adjusted after gross instability was detected in Kocher group specimens with use of the lateral pivot-shift stress test but not with use of the radiographic hanging arm test. This discrepancy prompted additional assessment with use of the static lateral elbow 30° flexion radiograph in the remaining specimens. As a result, the initial specimens (2 in the Kocher group and 5 in the EDC-splitting group) did not have baseline static flexion radiographic measurements. We do not believe that this negatively impacts the overall study conclusions for the following reasons: (1) all specimens had pre-dissection dynamic fluoroscopy and pivot-shift examination, which did not identify instability; and (2) the 5 EDC-splitting specimens that lacked pre-dissection radiographs did not demonstrate instability with any testing condition following surgical dissection. Despite these limitations, this study provided considerable evidence that instability developed following the Kocher approach and did not return to baseline following interval repair.

Conclusions

The modified Kocher approach produced PLRI, which did not return to baseline conditions following repair of the surgical interval, in all specimens. The EDC-splitting approach did not result in lateral elbow instability in any specimen. The radiographic hanging arm test was unable to identify lateral elbow instability when such instability was present. Lateral static elbow radiographs made in 30° of flexion with full forearm supination were able to reliably detect instability. The present study showed that the hanging arm test may be an unreliable intraoperative assessment of elbow stability and that the Kocher approach may cause iatrogenic PLRI. ■

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References

1. Roulet S, Charruau B, Mazaleyrat M, Ferembach B, Marteau E, Laulan J, Bacle G. Modified Lateral Approach of the Elbow for Surgical Release and Synovectomy. Tech Hand Up Extrem Surg. 2020 Aug 28;25(2):84-8.

2. Ballesteros-Betancourt JR, García-Tarriño R, García-Elvira R, Muñoz-Mahamud E, Fernández-Valencia JA, Llusá-Pérez M, Combalia-Aleu A. The anterior limited approach of the elbow for the treatment of capitellum and trochlea fractures: Surgical technique and clinical experience in eight cases. Injury. 2020 Apr;51(Suppl 1):S103-11.

3. Cheung EV, Steinmann SP. Surgical approaches to the elbow. J Am Acad Orthop Surg. 2009 May;17(5):325-33.

4. Berdusco R, Louati H, Desloges W, Papp SR, Pollock JW. Lateral Elbow Exposures: The Extensor Digitorum Communis Split Compared with the Kocher Approach. JBJS Essent Surg Tech. 2015 Dec 23;5(4):e30.

5. Leversedge F, Goldfarb C, Boyer M. A pocketbook manual of hand and upper extremity anatomy: primus manus. Lippincott and Williams; 2010.

6. Imatani J, Ogura T, Morito Y, Hashizume H, Inoue H. Anatomic and histologic studies of lateral collateral ligament complex of the elbow joint. J Shoulder Elbow Surg. 1999 Nov-Dec;8(6):625-7.

7. Osborne G, Cotterill P. Recurrent dislocation of the elbow. J Bone Joint Surg Br. 1966 May;48(2):340-6.

8. Fares A, Kusnezov N, Dunn JC. Lateral Ulnar Collateral Ligament Reconstruction for Posterolateral Rotatory Instability of the Elbow: A Systematic Review. Hand (N Y). 2022 Mar;17(2):373-9.

9. O'Driscoll SW, Bell DF, Morrey BF. Posterolateral rotatory instability of the elbow. J Bone Joint Surg Am. 1991 Mar;73(3):440-6.

10. Nestor BJ, O'Driscoll SW, Morrey BF. Ligamentous reconstruction for posterolateral rotatory instability of the elbow. J Bone Joint Surg Am. 1992;74:1235-41.

11. Sanchez-Sotelo J, Morrey BF, O'Driscoll SW. Ligamentous repair and reconstruction for posterolateral rotatory instability of the elbow. J Bone Joint Surg Br. 2005 Jan;87(1):54-61.

12. Forthman C, Henket M, Ring DC. Elbow dislocation with intra-articular fracture: the results of operative treatment without repair of the medial collateral ligament. J Hand Surg Am. 2007 Oct;32(8):1200-9.

13. Bellato E, Castoldi F, Marmotti A, Greco V, Pautasso A, Blonna D. Relationship Between the Lateral Collateral Ligament of the Elbow and the Kocher Approach: A Cadaver Study. J Hand Surg Am. 2021 Mar;46(3):245.e1-7.

14. Camp CL, Fu M, Jahandar H, Desai VS, Sinatro AM, Altchek DW, Dines JS. The lateral collateral ligament complex of the elbow: quantitative anatomic analysis of the lateral ulnar collateral, radial collateral, and annular ligaments. J Shoulder Elbow Surg. 2019 Apr;28(4):665-70.

15. Desloges W, Louati H, Papp SR, Pollock JW. Objective analysis of lateral elbow exposure with the extensor digitorum communis split compared with the Kocher interval. J Bone Joint Surg Am. 2014 Mar 5;96(5):387-93.

16. Hotchkiss RN. Displaced Fractures of the Radial Head: Internal Fixation or Excision? J Am Acad Orthop Surg. 1997 Jan;5(1):1-10.

17. Patterson SD, Bain GI, Mehta JA. Surgical approaches to the elbow. Clin Orthop Relat Res. 2000 Jan;(370):19-33.

18. Kocher T. Text-Book of Operative Surgery. MacMillan; 1913.

19. O'Driscoll SW. Classification and evaluation of recurrent instability of the elbow. Clin Orthop Relat Res. 2000 Jan;(370):34-43.

20. Cohen MS, Hastings H 2nd. Rotatory instability of the elbow. The anatomy and role of the lateral stabilizers. J Bone Joint Surg Am. 1997 Feb;79(2): 225-33.

21. Olsen BS, Søjbjerg JO, Nielsen KK, Vaesel MT, Dalstra M, Sneppen O. Posterolateral elbow joint instability: the basic kinematics. J Shoulder Elbow Surg. 1998 Jan-Feb;7(1):19-29.

22. Anakwenze OA, Kancherla VK, Iyengar J, Ahmad CS, Levine WN. Posterolateral rotatory instability of the elbow. Am J Sports Med. 2014 Feb;42(2):485-91.

23. Watters TS, Garrigues GE, Ring D, Ruch DS. Fixation versus replacement of radial head in terrible triad: is there a difference in elbow stability and prognosis? Clin Orthop Relat Res. 2014 Jul;472(7):2128-35.

24. Garrigues GE, Wray WH, Lindenhovius ALC, Ring DC, Ruch DS. Fixation of the coronoid process in elbow fracture-dislocations. J Bone Joint Surg Am. 2011;93: 1873-81.

25. Takigawa N, Ryu J, Kish VL, Kinoshita M, Abe M. Functional anatomy of the lateral collateral ligament complex of the elbow: morphology and strain. J Hand Surg Br. 2005 May;30(2):143-7.

26. Fukai A, Nimura A, Tsutsumi M, Fujishiro H, Fujita K, Imatani J, Akita K. Lateral Ulnar Collateral Ligament of the Elbow Joint: Reconsideration of Anatomy in Terms of Connection with Surrounding Fibrous Structures. J Bone Joint Surg Am. 2022 Aug 3; 104(15):1370-9.

27. Hall JA, McKee MD. Posterolateral rotatory instability of the elbow following radial head resection. J Bone Joint Surg Am. 2005 Jul;87(7):1571-9.

28. Morrey BF. Reoperation for failed surgical treatment of refractory lateral epicondylitis. J Shoulder Elbow Surg. 1992 Jan;1(1):47-55.

29. Wilps T, Kaufmann RA, Yamakawa S, Fowler JR. Elbow Biomechanics: Bony and Dynamic Stabilizers. J Hand Surg Am. 2020 Jun;45(6):528-35.

30. Kaufmann RA, Wilps T, Musahl V, Debski RE. Elbow Biomechanics: Soft Tissue Stabilizers. J Hand Surg Am. 2020 Feb;45(2):140-7.