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Results of standardized treatment of elbow fracture dislocations as per their injury pattern: a retrospective cohort of 89 patients

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Background: Elbow fracture dislocations represent difficult injuries to treat, with a high percentage of complications. Classically, they are divided into posterolateral, posteromedial and transulnar pattern. It is essential to distinguish them to guide intraoperative treatment to achieve an anatomic and stable reduction that allows early mobility.

Methods: A retrospective study of 89 adult patients diagnosed with elbow fracture dislocations who underwent a standardized surgery between 2013 and 2018 with a minimum follow-up of 12 months. Demographic data, characteristics of the injury, and associated procedures were collected. Patients were evaluated with functional scores (Mayo elbow performance score/Broberg and Morrey score) and ranges of movement at the end of the follow-up.

Results: The mean age was 41 ± 12 years, mostly men (82%), with an average follow-up of 29 months. We present 42 patients with posterolateral fracture dislocation (47%), 21 posteromedial (24%) and 26 transulnar (29%). The average range of motion at the end of follow-up was −12 ± 11° extension, 124 ± 20° flexion, 76 ± 16° pronation, and 73 ± 20° supination, with a Mayo elbow performance score of 88.7 ± 12 points and 87.2 ± 12 points in the Broberg and Morrey scale. Reoperation rate was 23%, with no infection or heterotopic ossification cases. Transulnar fracture dislocations have significantly worse extension and supination. As per the functional result (Mayo elbow performance score/Broberg and Morrey scale), there are no significant differences between the different patterns.

Conclusion: Proper injury pattern recognition and a standardized surgical management lead to a stable joint and good results in range of motion. Functional results are encouraging at least at short term, despite the high reoperations rate.

Elbow dislocations represent 10%-25% of elbow injuries, being the second most frequent dislocation in adults after the shoulder.[9] Most of them are simple dislocations and usually have good results and prognosis with conservative treatment. On the other hand, complex dislocations and fracture dislocations usually are due to high-energy trauma and generally require surgical treatment with poor results published in literature.[1,2,9,5]

The articular stability of elbow is given by static and dynamic components. The primary static stabilizers correspond to the ulnohumeral joint, the anterior band of the medial ligament complex, and the ulnar collateral band of the lateral ligament complex. Secondary static stabilizers correspond to the radiocapitellar joint and the joint capsule.[16] Finally, the dynamic stabilizers correspond to muscles that go through the joint, such as the triceps, biceps, brachii, anconeus, and others.[8,16]

As per the injury pattern, elbow fracture dislocations have been classified into three types: posterolateral fracture dislocation in valgus (PLRV) or terrible triad, posteromedial rotatory in varus (PMRV), and transulnar fracture dislocation (TUFD). Each is generated by a particular limb position and a force vector, leading to specific associated injuries.[22]

Among these, PLRV is the most common and is produced by an axial load with forearm in valgus and supination. This mechanism leads to an elbow dislocation, injury to lateral collateral ligament, comminuted fracture of the radial head, and fracture the coronoid tip.

This study was approved by the Ethical Committee of Mutual de Seguridad CChC Hospital.

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PMRV is generated by an axial load in a semiflexed elbow associated with varus and pronation. This mechanism produces a lateral ligament injury with an anteromedial coronoid fracture, which can compromise the distal insertion of the anterior band of the medial collateral ligament (sublime tubercle).

TUFD responds to a direct load on the posterior aspect of the proximal ulna in a flexed elbow. This compromises the greater sigmoid notch and is generally associated with a fracture of the base of the coronoid, involving more than 50% of its height, and it is associated with a radiocapitellar dislocation with or without fracture of the radial head. These injuries are characterized by bone instability because the medial and lateral ligament complexes are generally preserved.

Recognizing these patterns is essential to deduce which stabilizers are compromised to successfully repair them and restore elbow stability and decrease complications such as persistent instability, stiffness, osteoarthritis, and chronic pain.[1,2,9,16]

The main objective of this study is to evaluate the functional results in a cohort of patients with elbow fracture dislocations treated with a standardized technique as per their injury pattern. The secondary objective is to compare functional results between the different injury patterns.

Materials and methods

This is a retrospective study of patients with elbow fracture dislocations between 2013 and 2018 treated in a single level 1 trauma center (worker related hospital), with a minimum follow-up of 12 months. Patients with Essex Lopresti, history of previous traumatic elbow injuries, presence of declared osteoarthritis and sequel of joint infections were excluded. Monteggia and Monteggia-like fracture were excluded from our study owing to an absence of coronoid fracture. These types of fracture dislocation pattern have a different mechanism and different associated ligaments injuries than TUFD.

Surgery was performed by four different shoulder and elbow surgeons from the same hospital during this period of time, using a standardized treatment protocol. Heterotopic ossification prophylaxis was only used in revision surgeries.

Demographic data, description of associated bone and ligament injuries, range of movement, functional results with Mayo elbow performance score (MEPS) and Broberg and Morrey (B&M) score, incidence of complications, and rate of reoperation were obtained from the review of clinical records. Patients were evaluated clinically and radiologically by an independent observer at the final follow-up. This study was approved by the Ethical Committe of Mutual de Seguridad CChC Hospital.

Initial evaluation

All patients were evaluated clinically and radiologically. The injury mechanism, neurovascular, and soft-tissue status were taken from our clinical data. Anteroposterior- and lateral-view x-ray and computed tomography scan with 3-dimensional reconstruction were performed after elbow reduction in the emergency room. The Mason classification[5] was used for radial head fracture and O'Driscoll classification for coronoid fractures.[19]

Injuries were classified by three shoulder and elbow surgeons as per the type of coronoid fracture pattern, radial head injuries, ligament injuries, and direction of the dislocation when available, as shown in Figure 1. If a different type of classification was found among observers, coronoid fracture type was used as the most important part to classify the injuries.

Surgery was performed within the first 2 weeks after the accident, depending on the conditions of soft tissue, comorbidities, and clinical evolution of the patient.

Standardized surgical procedure

Surgery was performed in all patients under general anesthesia and ultrasound-guided interscalenic regional block with 15 ml of 0.25% bupivacaine. Patients were in supine position with a tourniquet applied to the limb with a pressure of 250 mmHg. The standardized surgical procedure as per the type of lesion was presented in the Figure 2.

Posterolateral rotary pattern or terrible triad

A sequential management was performed in all cases, following the recommendation from McKee et al[13] and Mathew et al.[11] A universal posterior elbow approach was performed in all cases with lateral fasciocutaneous flap. The Kocher interval was performed, between the anconeus and extensor carpi ulnaris, and lateral ulnar colateral ligament involvement was observed. The decision of a radial head arthroplasty (Evolve; Wright Medical Technology, Inc., Memphis, TN, USA) was taken if the radial head fracture had more than three fragments as recommended by King,[7] otherwise, screw fixation was used. Subsequently, osteosynthesis of the coronoid is performed using a cannulated retrograde screw or anterior capsular reinsertion using a pullout technique depending on the fragment size.[4] If the bony fragment was less than 5 mm, pull out was performed, otherwise screw was used unless comminution of the coronoid was present.

A 5.5 double-loaded suture anchor (Corkscrew, Arthrex, Naples, FL, USA) was used in the capitellar isometric point under fluoroscopy. The lateral capsule ligamental repair was performed using a Krackow knot and above it, the muscular plane was sutured in the same fashion. Both knots were tied with the elbow at 90 degree, with the forearm in pronation and with no valgus or varus stress[23] (Fig. 3).

Before definitive closure, stability was evaluated by fluoroscopy using varus-valgus stress maneuvers at 30° of flexion looking for a medial or lateral ulno humeral articular widening. Hypersupination-pronation test in 90° of elbow flexion by fluoroscopy were also performed looking for an anterior-posterior radial head subluxation. If instability persisted, a medial fasciocutaneous flap was performed, to repair anterior band of the medial collateral ligament through a split in the flexor carpi ulnaris muscle (FCU-split) with a corkscrew 3.5 (Arthrex, Naples, FL, USA) or though transosseous tunnel depending on the surgeon preference. If instability continued, a fixed-angle monoplanar external elbow fixator at 90° of flexion or an ulnar-humeral bridge plate was applied.

A deep drain was used for 24 hours, and an anterior cast was installed at a 90° flexion and neutral position until discharge from the hospital, where an articulated elbow splint with controlled range was installed with free flexion and extension locked at 90°.

Posteromedial rotary pattern

A universal posterior elbow approach was performed in all cases with lateral and medial fasciocutaneous flap. Initially, an FCU-split approach was performed, after releasing the ulnar nerve, for internal fixation of the coronoid fracture involving the anteromedial facet. An anatomic coronoid plate (Acumed LLC, Hillsboro, OR, USA) was used as a buttress plate for coronoid fixation. Retrograde screws were used if a noncomminuted coronoid fracture was present with good stability after reduction and/or in addition to the coronoid plate to help reduction. Integrity of the anterior band of the medial ulnar collateral ligament was evaluated. If an injury was suspected, it was repaired using a 3.5 Corkscrew suture anchor (Arthrex, Naples, FL, USA). Through the lateral flap, a Kocher

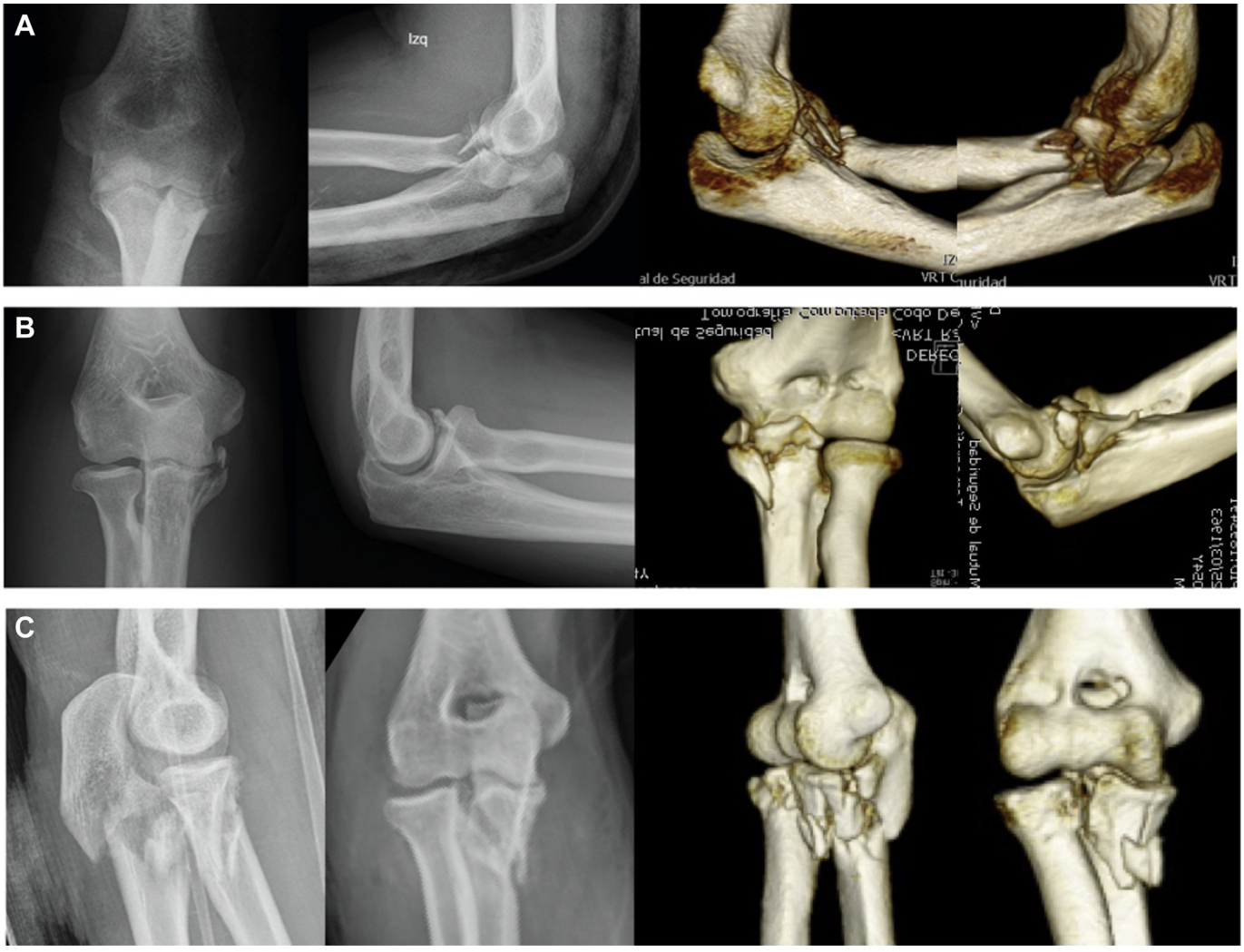

Figure 1 Complex elbow dislocations patterns after primary or spontaneous reduction (x-ray/3D CT). (**A**) Posterolateral fracture dislocation in valgus (PLRV) or terrible triad with a comminuted radial head and coronoid tip fracture. (**B**) Posteromedial rotary in varus (PMRV) with an anteromedial facet fracture. (**C**) Transulnar (basal coronoid) fracture dislocation (TUFD) with a fracture of the greater sigmoid notch and base of the coronoid process. *3D*, 3-dimensional; *CT*, computed tomography.

approach was then performed to repair lateral ligaments, and if necessary, an open reduction and internal fixation or arthroplasty of the radial head was performed, in the same fashion than in terrible triad. The ulnar nerve was transposed subcutaneously in all cases. Skin closure and immobilization are similar to those described previously for PLRV (Fig. 4).

Transulnar (basal coronoid) pattern

Universal posterior elbow approach was performed. If a radial head fracture was present, it was fixed or replaced through the olecranon fracture using the same criteria as PLRV. If injured, lateral ulnar colateral ligament was repaired through a Kocher approach as in PLRV.

Olecranon fracture was fixed using an anatomic plate (Acumed LLC, Hillsboro, OR, USA). In cases of lack of bone stability, a coronoid anatomic plate (Acumed LLC, Hillsboro, OR, USA) was added through a medial FCU-split approach. Skin closure and immobilization was performed as in PLRV injuries (Fig. 5).

Rehabilitation protocol

Patients used an elbow splint with controlled range of motion, allowing free flexion but locked at 90° of flexion to protect bony structure and ligament repair. Patients were encouraged to perform hand, wrist, and elbow exercises since the day after the surgery using the elbow splint with controlled range. Patients started active assisted exercises and overhead rehabilitation after being discharged from the hospital. Two weeks after surgery, patients started exercises assisted by a physical therapist. The objective is to achieve a progressive extension of 10° per week until full extension is reached. If patients had an extension stiffness at the 6th week, a fixed extension brace was used during nights. If a flexion stiffness was present at the same week, a dynamic (elastic band) flexion orthosis was daily used.

Functional evaluation and statistical analysis

Range of motion was measured with a goniometer, evaluating flexion, extension, supination, and pronation. Functional evaluation

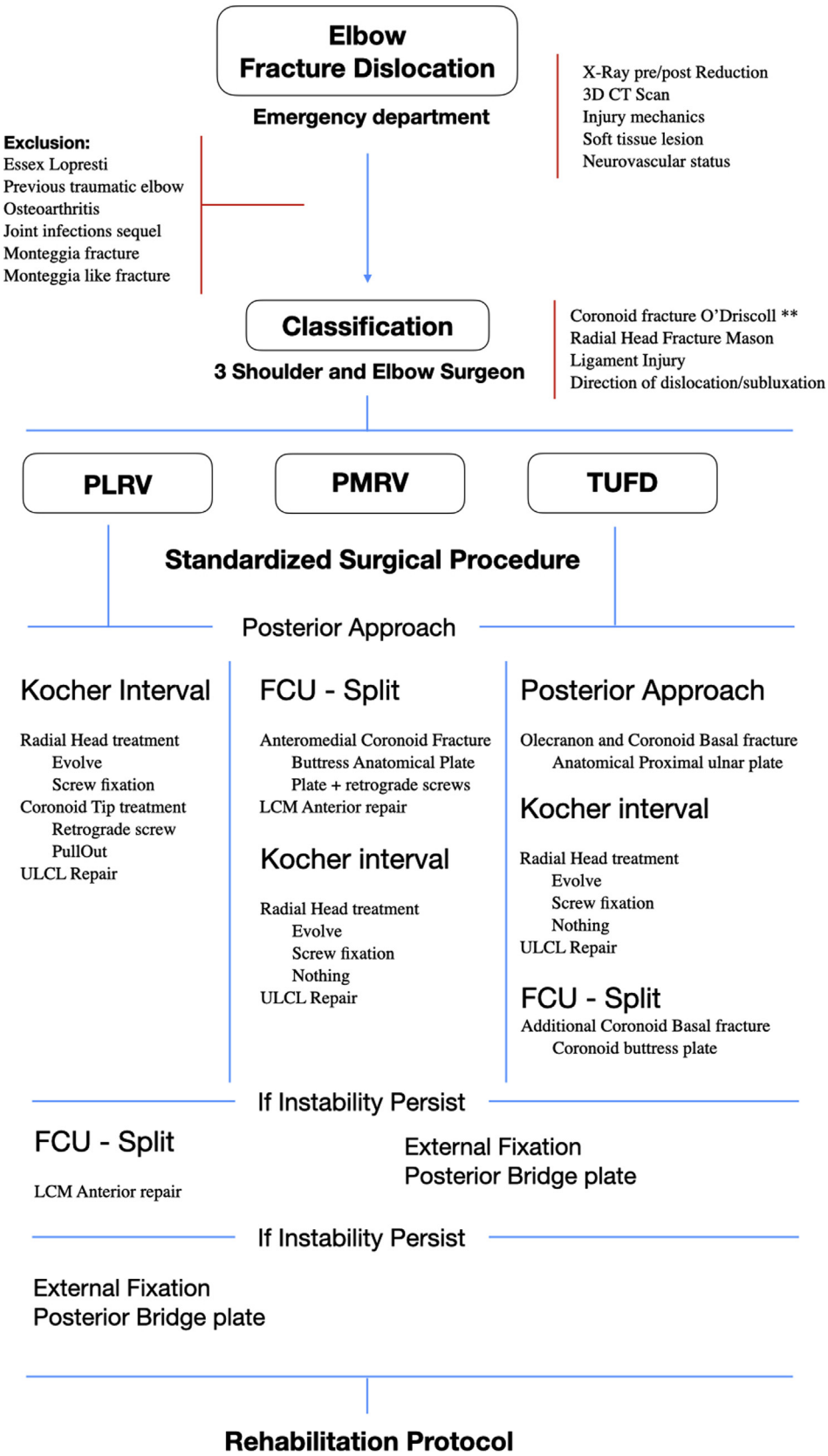

Figure 2 The standardized surgical procedure according to the type of lesion. *FCU*, flexor carpi ulnaris; *PLRV*, posterolateral fracture dislocation in valgus or terrible triad; *PMRV*, posteromedial rotary in varus; *TUFD*, transulnar (basal coronoid) fracture dislocation. ** If a different type of classification was found among observers, coronoid fracture type was used as the most important part to classify the injuries.

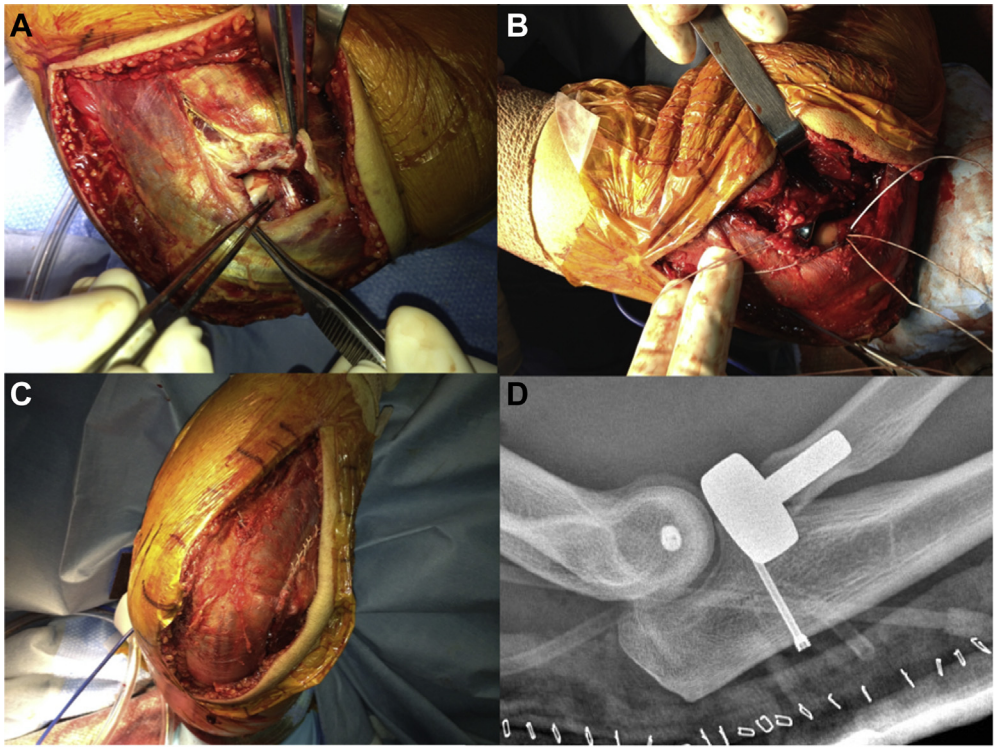

Figure 3 Posterolateral rotary pattern surgery. (**A**) Kocher approach, lesion of humeral insertion of U-LCL. (**B**) Radial head replacement and suture anchor for LCL repair. (**C**) Close lateral approach. (**D**) Postoperative x-ray.

was performed using MEPS and B&M score at the final follow-up. Complications and reoperations were assessed.

STATA V.14 program (StataCorp, College Station, TX, USA), with a 95% confidence interval and a level of statistical significance defined as a P value $< .05$, was used. Results were presented as mean with standard deviation, and analysis of variance test (Bonferroni method) was used to compare results between injury patterns.

Results

A total of 110 patients were treated for a fracture dislocation of the elbow during this period of time at our hospital. Finally, eighty-nine patients met the inclusion and exclusion criteria (ten patients with Monteggia fracture, 5 patients with osteoarthritis, and 6 patients with previous fracture sequel). There was no loss of patients to the follow-up. Among these, 42 patients (47%) had a PLRV, 26 patients (29%) had a TUFD pattern, and 21 patients (24%) had a PMRV. The average follow-up was 2.2 years (116 weeks, range: 48-130 weeks). The mean age was 41 ± 12 years with 82% men. The description of injuries and their specific treatment in each injury pattern are described in Table I.

The average flexion-extension arch was 112° ± 21°, with a mean pronation and supination of 76 ± 16° and 73 ± 20°, respectively. Functional evaluations were obtained at the final follow-up with a MEPS score of 88.7 ± 12 points and a B&M score of 87.2 ± 12 points. As per the MEPS score, 52% had excellent results, 40% good, 6% fair, and 2% poor.

The results of each injury pattern are described in Table II.

The use of an external elbow fixator or a bridge plate because of residual instability was not necessary in any case.

There were no cases of infection at the operative site and no need for hardware removal. Four patients from our PMRV group had a transient neuritis of the ulnar nerve with complete recovery at the end of the follow-up.

Revision surgery was performed in 21 patients (23%) as per the injury pattern: 8 cases (19%) of PLRV, 5 cases (23%) of PMRV, and 8 cases (30%) of TUFD; open fibroarthrolysis was performed in 20 patients owing to stiffness and 1 revision of an ulnar fracture nonunion. All revision surgeries were performed within the first 6 months after the initial surgery. These complications did not correlate with worse clinical outcomes ($P > .05$).

Comparative analysis of subgroups

A higher extension deficit was showed in the TUFD subgroup compared with PLRV and PMRV pattern, −19°, −9°, and −9°, respectively ($P < .05$). Elbow flexion did not show significant difference between subgroups (128° PLRV; 124° PMRV; 122° TUFD). These results are shown in Figure 6.

Pronation was greater in PMRV injuries with 82°, followed by PLRV 80° and TUFD 68°. However, these differences were significant only between posteromedial and transulnar injuries ($P < .05$). Supination was greater in posterolateral and posteromedial injuries 78° in both. The TUFD pattern had significantly worse supination results with 68° ($P < .05$). These results are shown in Figure 7.

Despite the differences found in the range of movement between the 3 injury patterns, MEPS and B&M functional scores did not have statistically significant differences ($P > .05$). These results are shown in Figure 8.

Discussion

We present a study of 89 patients diagnosed with complex elbow fracture dislocations, undergoing standardized and

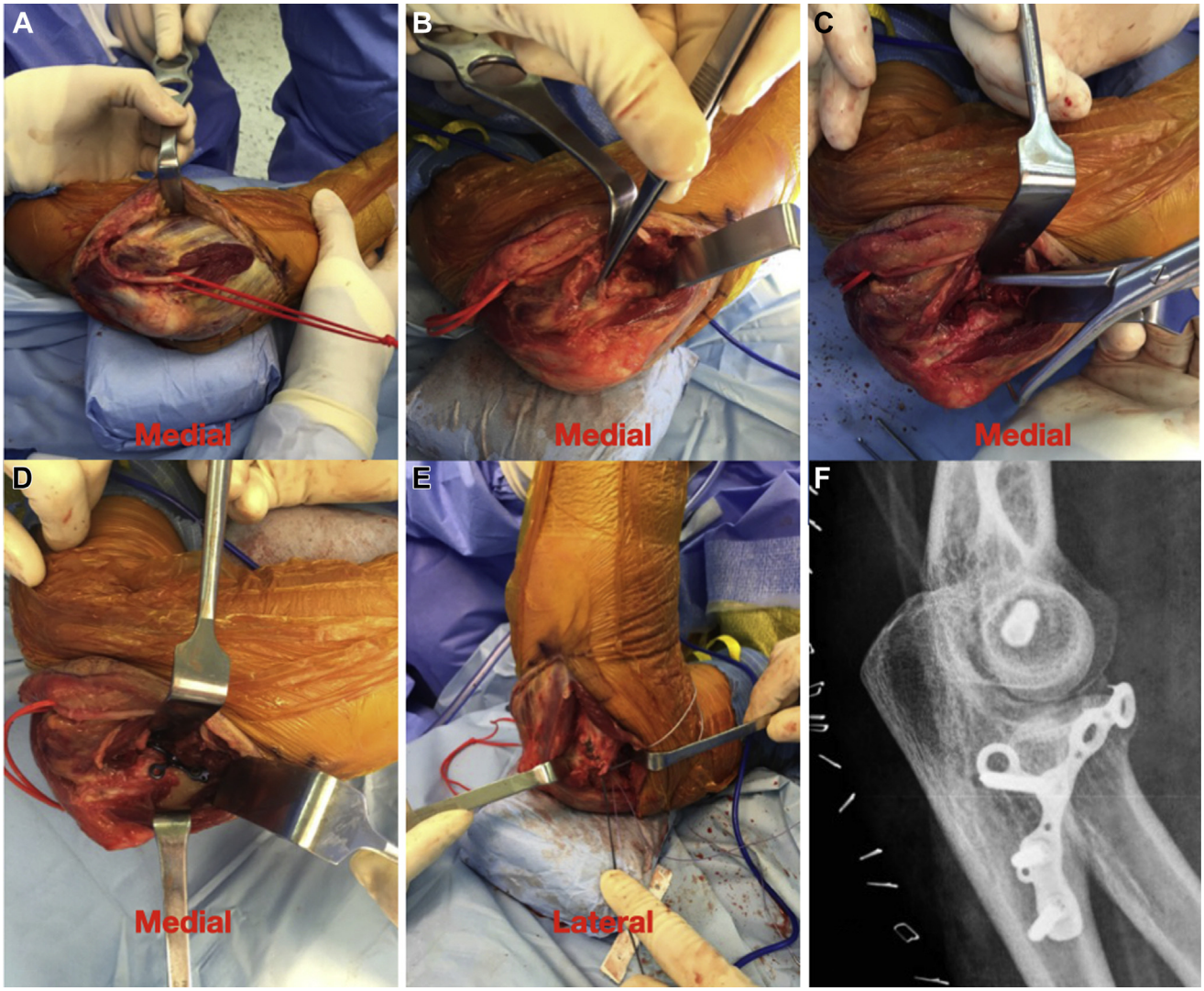

Figure 4 Posteromedial rotary pattern surgery. (**A**) Medial approach, ulnar nerve release, for FCU-split, (**B**) Identify the fracture of coronoid. (**C**) Reduction of fracture. (**D**) Fixation with coronoid plate. (**E**) Lateral Kocher approach, for repair U-LCL. (**F**) Postoperative x-ray. *FCU-split*, splint in flexor carpi ulnaris.

protocolized treatment based on the injury pattern defined by images (x-ray and computed tomography scan).

Our results were satisfactory, showing an average range of motion in flexion of 124°, −12° of extension, 76° of pronation, and 73° of supination. These results are greater than what is classically defined as a functional arc of elbow movement that allows activities of daily living; 100° of flexor extension (30°-130°) and 90° of prone supination (45°-45°).[2] We also observed a significant number of reoperations (23%) given mainly by secondary stiffness; however, this does not compromise the final functional results (MEPS 88.7; B&M 87.2).

PLVR were the most common injury pattern (47%) achieving an elbow arc of mobility of 119° flexion extension (−9° to 128°) and 155° of prone supination (77°-78°), with good and excellent average results in functional evaluations (MEPS, B&M). In a study published by Muñoz et al,[18] of 62 PLRV with a follow-up of 18 months, they observed a mean flexion/extension range of motion (ROM) of 120°/−20° and 98°-85° of pronation supination, with a MEPS score of 92 points. Radial head synthesis was performed in 14 patients (22.5%), prosthetic replacement in 45 (72.5%), and other procedures in 3 patients. This surgical approach of radial head fracture is similar to ours with 81% radial head arthroplasty owing to the highly comminuted fractures, following recommendations made by King.[7] In another retrospective study, Pierrart et al[20] reported a series of 18 terrible triads with a mean follow-up of 31 months achieving an average MEPS of 78 points and a mean ROM of 114° flexion extension (135°-21°) with complete prone supination except for 3 patients. In an interesting study of twelve terrible triad with a long-term follow-up, Zaidenberg et al[24] reported a mean ROM at 1 year of 140° of flexion, 10° of extension, 90° of pronation, and 90° of supination, with an average MEPS of 97.5, with no significative difference during a 9-year follow-up. Even if our follow-up is not as long as this study, our impression is that range of motion and clinical scores do not get worse over time.

PMRV fracture dislocation were the second most common injury pattern (29%) with satisfactory results. The mean ROM was 115°, with functional score of 92 and 88 in MEPS and B&M, respectively. All coronoid fractures from this group correspond to anteromedial facet type as per O'Driscoll classification.[19] Subtype 2 (anteromedial facet and tip) was the most frequent pattern (75%), just as described previously by Mellema et al.[14] Among these injuries, 71% were fixed with an anatomic Buttress plate. Regarding stability of the fixed coronoid fragment, biomechanical studies have shown superiority of screw over suture and of plate over screw.[6,8,15] However, no long-

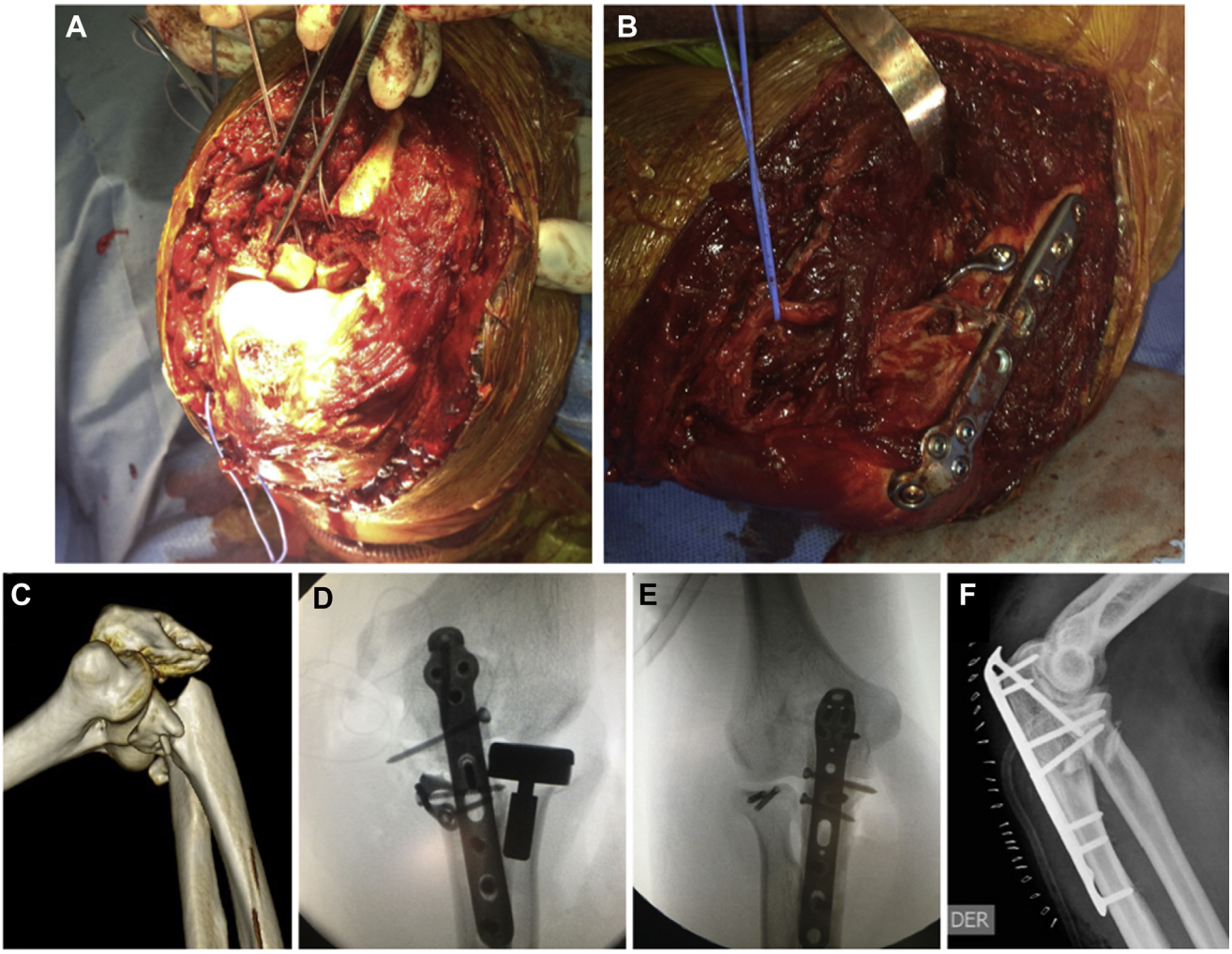

Figure 5 Transulnar pattern surgery. (**A**) Transolecranon approach for coronoid fracture fixation. (**B**) Accessory medial approach for additional anatomic coronoid plate. (**C**) 3D CT preoperative. (**D**-**E**) Intraoperative fluoroscopy of two different patients. (**F**) Postoperative x-ray. *3D*, 3-dimensional; *CT*, computed tomography.

Table 1
Description of the injuries and their specific treatment in each injury pattern.

Groups	Coronoid fracture	%	Coronoid stabilization	%	Radial head treatment	%	Proximal ulna stabilization	%	Lateral colateral repair	%	Medial colateral repair	%
Terrible triad cases 42	Tips.1	40	Nothing	10	Moth ne	0	Nothing	-	Yes	100	Yes	0
	Tips.2	31	Pullout	60	OTS screws	19 (8)	Ulna plate	-	No	0	No	100
	Anteromedial.1	29	Screws	31	Prosthesis	81 (34)	Ulna + Coronoid plate	-				
	Anteromedial.2	0	Anatomic plate	0								
	Anteromedial.3	0										
	Basal. x	0										
Posteromedial cases 21	Tips.x	0	Nothing	0	Nothing	29 (6)	Nothing	-	Yes	95	Yes	20
	Anteromedial. 1	15	Pullout	OS	OTS screws	4 (1)	Ulna plate	-	No	5	No	80
	Anteromedial.2	75	Screws	29	Prosthesis	8 (2)	Ulna + Coronoid Plate	-				
	Anteromedial.3	10	Anatomic plate	71	Total	43 (9)						
	Basal.x	0										
Transulnar (basal coronoid) cases 26	Tips.x	0	Nothing	-	Nothing	4 (1)	Nothing	0	Yes	34	Yes	4
	Anteromedial.1	0	Pullout	-	OTS screws	12 (3)	Ulna plate	92	No	66	No	96
	Anteromedial.2	0	Screws	-	Prosthesis	34 (9)	Ulna + Coronoid Plate	8				
	Anteromedial.3	7	Anatomic plate	-	Radial head fracture	50 (13)						
	Basal.1	0										
	Basal.2	93										

Table 2
Description of the results of each injury pattern, regarding the arc of mobility and functional scores.

Groups	Cases	Flexion		Extension		Pronation		Supination		MEPS		B&M	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
All cases	89	124	20	−12	11	76	16	73	20	89	12	87	12
Terrible triad	42	128	13	−9	10	77	15	78	12	90	11	89	10
Posteromedial	21	124	10	−9	9	82	11	78	12	92	9	88	11
Transulnar (basal coronoid)	26	122	14	−19	12	68	20	62	20	83	16	82	15

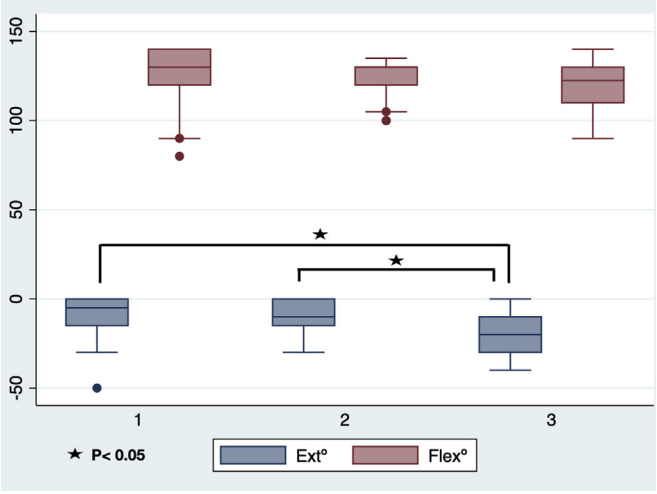

Figure 6 Comparative analysis of degree of Flexion and extension according to the classification pattern. (1) PLRV, (2) PMRV, (3) TUFD.

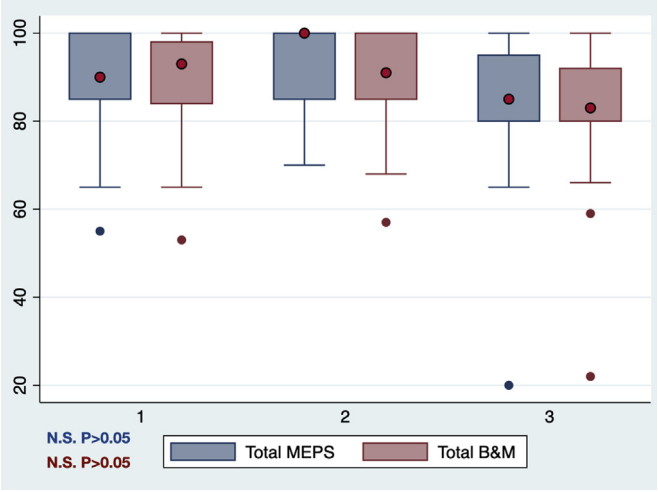

Figure 8 Comparative analysis Mayo elbow performance and Broberg & Morrey Scores according to the classification pattern. (1) PLRV, (2) PMRV, (3) TUFD. *N.S.*, Not Significant.

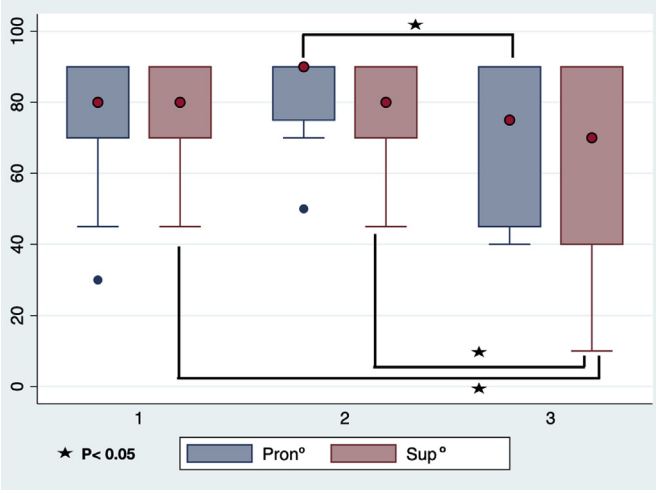

Figure 7 Comparative analysis of degree of Pronation and Supination according to the classification pattern. (1) PLRV, (2) PMRV, (3) TUFD.

term study has compared clinical results of these fixation types. In a study of 27 patients with PMVR, 90% of coronoid fractures were fixed with plates, reporting good results, with no loss of reduction and no reoperations owing to prominent osteosynthesis.[12] In this study from McLean et al,[12] only 1 patient had a marginal fracture of the radial head, unlike the 9 patients (43%) reported in our series. Among these 9 patients in our study, two were solved with arthroplasty, 1 with screws, and the six other patients had minor fracture that did not need any specific treatment. This high incidence of radial head fractures was probably related to the prevalence of high-energy injuries. In another study reporting 8 patients with PMRV, all anteromedial coronoid fractures were fixed using a 1.5- or 2.0-mm "T" buttress plate.[10] They report an average flexion-extension arc of 130° and a MEPS evaluation of 75 points without reoperations or persistent instability at a short-term follow-up. These previous studies and ours shows the importance of performing an anatomic reduction and stable fixation of the anteromedial facet of the coronoid, allowing to recover the stabilizer role against posterior translation and posteromedial rotation.[21]

In TUFD, we obtained an average functional arc of 122° of flexion with −19° of extension. In our comparative analysis, this injury reported statistically worst range of motion than the other injury types; however, functional outcome were comparable. A study Mortazavu et al[17] report 8 patients with TUFD, fixed in seven cases with a reconstruction plate and in 1 case with a tension band, which failed and was reoperated using a plate. In this study, they obtained a mean flexion, extension, pronation, and supination of 115°, −20°, 75°, 83°, respectively, with an average score of 88 points in the B&M functional evaluation. Based on their results, they always recommend open reduction and internal fixation with plate in this type of injury, as reported by Doornberg et al.[3] In our study, we used a locked olecranon plate in all cases and an associated coronoid plate was used in 8% of the cases, to have an anatomic and stable reduction to the coronoid. The significant difference in ROM, when compared with the other injury patterns, may be secondary to the involvement of a larger area of the articular surface. In relation to complications, 19% of patients with posteromedial pattern (4 patients) had a transient ulnar neuritis that did not need a specific management. Reoperation was performed in 23% owing to stiffness. In a study by Muñoz et al,[18] the complication rate was 27%, with only 6 patients (9.7%) being subjected to reoperations, where 2 of them were reoperated because of postsurgical stiffness.

In another study, Lor et al[10] reported only 1 case of infection and 1 case of heterotopic ossification.

The rate of reoperation of our study is higher than the one reported in the literature. This could be explained by more demanding patients owing to our worker compensation hospital type. Despite this, reoperations did not modify the good functional resulted at the final follow-up.

We present the results of a standardized surgery for elbow fracture dislocation with a good outcome at least a short follow-up. However, our study has several limitations; first, this is a retrospective study. Second, surgeries were performed in a worker's compensation hospital, making the rehabilitation and results less predictable than in general population. Finally, surgeries were performed by 4 different surgeons, and although surgery is planned and protocolized, experience may lead to different results.

Conclusions

A standardized and protocolized treatment of elbow fracture dislocations, as per the injury pattern, allows us to obtain predictable clinical and functional results in these injuries despite a significant reoperation rate. Although TUFDs had worse results in range of motion, functional scores were comparable with other injuries patterns.

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