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Transolecranon fracture dislocation and transolecranon basal coronoid fracture dislocation; results of standardized treatment in a retrospective cohort

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A R T I C L E I N F O

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Transolecranon fracture dislocation
Elbow fracture dislocation
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Coronoid fracture
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Elbow instability

Level of evidence: Level IV; Case Series; Treatment Study

Background: Our understanding of transolecranon fracture dislocation (TOFD) has evolved to include associated ligament, coronoid, and radial head lesions impacting stability, rather than solely bone stability. Similarly, the understanding of coronoid fracture patterns has progressed. O'Driscoll et al state that basal subtype 2 coronoid fractures correspond to a TOFD, with a fracture passing through the base of the coronoid. In the literature, there is no clear differentiation between basal coronoid TOFD (BC-TOFD) and pure-TOFD outcomes. The main objective of this study is to evaluate the functional results and complications of TOFD using a standardized surgical technique. The secondary objectives are to describe the associated injuries and to compare the results between pure-TOFD and BC-TOFD.
Methods: This retrospective study included all patients with a TOFD treated with a standardized surgical procedure and rehabilitation protocol between 2013 and 2018 in a single trauma level 1 center. The surgical procedure mainly consisted of fixing the olecranon with a plate, using the same screws for coronoid fixation and coronoid plate if necessary. Radial head management involved either arthroplasty or screw fixation, with ligament repair performed as needed. Demographic data and the associated bone and ligament injuries were reviewed. The clinical outcomes (range of motion, Mayo Elbow Performance Score (MEPS), and Broberg and Morrey (B&M) scores) were evaluated at the final follow-up, after a minimum of 2 years. Complications and reoperations were assessed.
Results: 24 patients were included, and 75.0% were men. The average follow-up was 57.9 ± 22.0 months. The mean age was 42.0 ± 15.1 years. 18 (75.0%) were BC-TOFD and 6 (25.0%) were pure-TOFD. Ligament injuries requiring repair and radial head fracture were present in 8 (33.3%) and 11 (45.8%), respectively. The average range of motion were flexion 119.0° ± 17.6, extension deficit 20.4° ± 12.6°, pronation 68.9° ± 20.4°, and supination 63.1° ± 27.4°. MEPS and B&M mean scores were 82.3 ± 16.5 and 82.0 ± 16.1, respectively. The reoperation rate was 33.3%. No significant differences were found between pure-TOFD and BC-TOFD. A significant distribution difference was found in MEPS ($P = .001$), B&M ($P = .002$), range of flexion ($P = .011$), and extension deficit ($P = .005$) between patients who had reintervention and those who did not.
Conclusion: A standardized protocol for TOFD allows good to excellent functional results. There are no significant differences between pure-TOFD and BC-TOFD. One-third underwent reintervention. Patients with reintervention presented worse outcomes.

Complex elbow dislocation is a challenging pathology, which can result in important sequelae. Its correct management requires a complete knowledge of the stability components of the elbow, as well as the mechanisms of injury. Classically, three patterns of fracture-dislocation have been described and they are as follows: posterolateral fracture-dislocation in valgus or terrible triad, posteromedial rotatory in varus, and transolecranon fracture-dislocation (TOFD).[1,2,17,19,20]

This study was reviewed and approved by the scientific ethics committee of the Hospital (Hospital Clínico Mutual de Seguridad). July 31th, 2020.

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The transolecranon pattern is described as an olecranon fracture caused by an axial force, which compromises the major sigmoid notch, causing an elbow instability of bone origin.[3,17-19] Therefore, a correct osteosynthesis of this fracture should be enough to recover stability.[4,14,18] However, as diagnostic imaging studies have evolved, our understanding of these fractures has increased. It has been published that approximately 80% of fractures are comminuted and are frequently accompanied by associated injuries, such as radial head fracture, ligaments injuries, and coronoid fractures.[3,7,9] Consequently, we might hypothesize that achieving pure reduction of the olecranon may not be the sole determinant of a positive outcome; understanding associated injuries and distinguishing fracture patterns might also be crucial in surgical planning.

Similarly, the understanding of coronoid fracture patterns has progressed. O'Driscoll et al proposed a classification according to the involvement of the tip, the anteromedial facet, or the base (body) of the coronoid.[15] Basal (body) subtype 2 corresponds to a TOFD but with the fracture passing through the base of the coronoid. In the scientific literature regarding TOFD, there is no clear differentiation between pure transolecranon fracture-dislocation (pure-TOFD) and basal coronoid subtype 2 transolecranon fracture-dislocation (BC-TOFD) outcomes.

The main objective of our study is to evaluate the functional results and complications of TOFD using a standardized surgical technique. The secondary objectives are to describe the associated injuries and to compare the results between pure-TOFD and BC-TOFD. Our hypothesis is that employing a standardized technique may result in favorable functional outcomes and that the outcomes would differ between the pure-TOFD and BC-TOFD groups.

Materials and methods

Study design

Case Series; Treatment Study

Ethical approval

This study was approved by our institutional ethics committee.

Inclusion and exclusion criteria

All patients with a TOFD surgically treated between 2013 and 2018 in a single level 1 trauma center (worker-related hospital) were identified and reviewed retrospectively. The exclusion criteria were patients with previous traumatic elbow injuries, osteoarthritis, and sequelae of joint infections. In addition, Monteggia and Monteggia-like fractures were also excluded since the mechanism and structures injured differ.

Demographic data and initial evaluation

A total of twenty-four patients were included in the study. The mean age at the time of surgery was 42.0 ± 15.0 years (range 21-75 years), with 75.0% of the patients being male. The average follow-up period was 57.9 ± 22.0 months (range 26-98 months), with no losses to follow-up.

All patients were radiologically examined with an anteroposterior- and lateral-view x-ray and a computed tomography scan with 3-dimensional (3D) reconstruction after elbow reduction in the emergency room. The presence of a coronoid and/or radius head fracture was evaluated and classified according to the O'Driscoll and Mason classifications, respectively.[8,15]

Surgical technique

Anesthesia protocol included general anesthesia and ultrasound-guided interscalenic regional block with 15 ml of 0.25% bupivacaine. Patients were in supine position using a tourniquet with a pressure of 250 mmHg.

Surgeries were performed by four shoulder and elbow surgeons within the first 2 weeks after the accident. As we described in a recent publication, in our center we use a standardized surgical procedure for all elbow fracture-dislocations according to its pattern.[17]

Through a universal posterior elbow approach, olecranon fracture was fixed with an anatomic plate (Acumed LLC, Hillsboro, OR, USA).

For coronoid fractures, fixation was achieved using the same screws of the plate. If fracture stability was insufficient, a coronoid anatomic plate (Acumed LLC, Hillsboro, OR, USA) was added through a medial flexor carpi ulnaris split approach (Fig. 1, *A-H*).

In case of a radial head fracture, fixation or arthroplasty was accomplished through the olecranon fracture. In the presence of comminution with more than three fragments, radial head arthroplasty (Evolve; Wright Medical Technology, Inc., Memphis, TN, USA) was performed; otherwise, the fracture was fixated with screws. If injured, the annular ligament was repaired with absorbable sutures.

Lateral ulnar collateral ligament (LUCL) was repaired when injured through a Kocher approach using a corkscrew 5.5 (Arthrex, Naples, FL, USA) or through a transosseous tunnel. The anterior band of the medial collateral ligament (MCL) was repaired only in case of significant valgus instability despite a correct fixation of the coronoid. The ulnar nerve was transposed whenever a medial approach was used.

A deep drain was used for 24 hours. An anterior cast at 90° flexion and neutral position was applied until discharge from the hospital, after which an articulated elbow splint was installed with free flexion and extension locked at 90°. Heterotopic ossification (HO) prophylaxis was reserved for revision surgeries.

Rehabilitation protocol

For the first two weeks, the use of the articulated splint was strict, allowing free flexion but preventing extension beyond 90° to protect bony fixation and ligament repair. Patients were encouraged to perform hand, wrist, and elbow exercises from the first postoperative day. Active assisted exercises and overhead rehabilitation were allowed after being discharged from the hospital. Assisted physical therapy was initiated from week three, with a goal of progressive extension of 10° per week. In cases of stiffness at the 6th week, a fixed extension brace was indicated at night for extension stiffness and a dynamic (elastic band) flexion orthosis during the day for flexion stiffness.

Functional evaluation and complications

Patients were evaluated clinically and radiologically by an independent observer at the final follow-up. Range of motion (ROM) (flexion, extension, supination, and pronation) was measured with a goniometer. Functional evaluation was performed using Mayo Elbow Performance Score (MEPS) and Broberg and Morrey score (B&M).[11] Complications and reoperations were assessed.

Statistical analysis

Statistical analysis was performed using STATA V.14 program (StataCorp, College Station, TX, USA), defining a 95% confidence

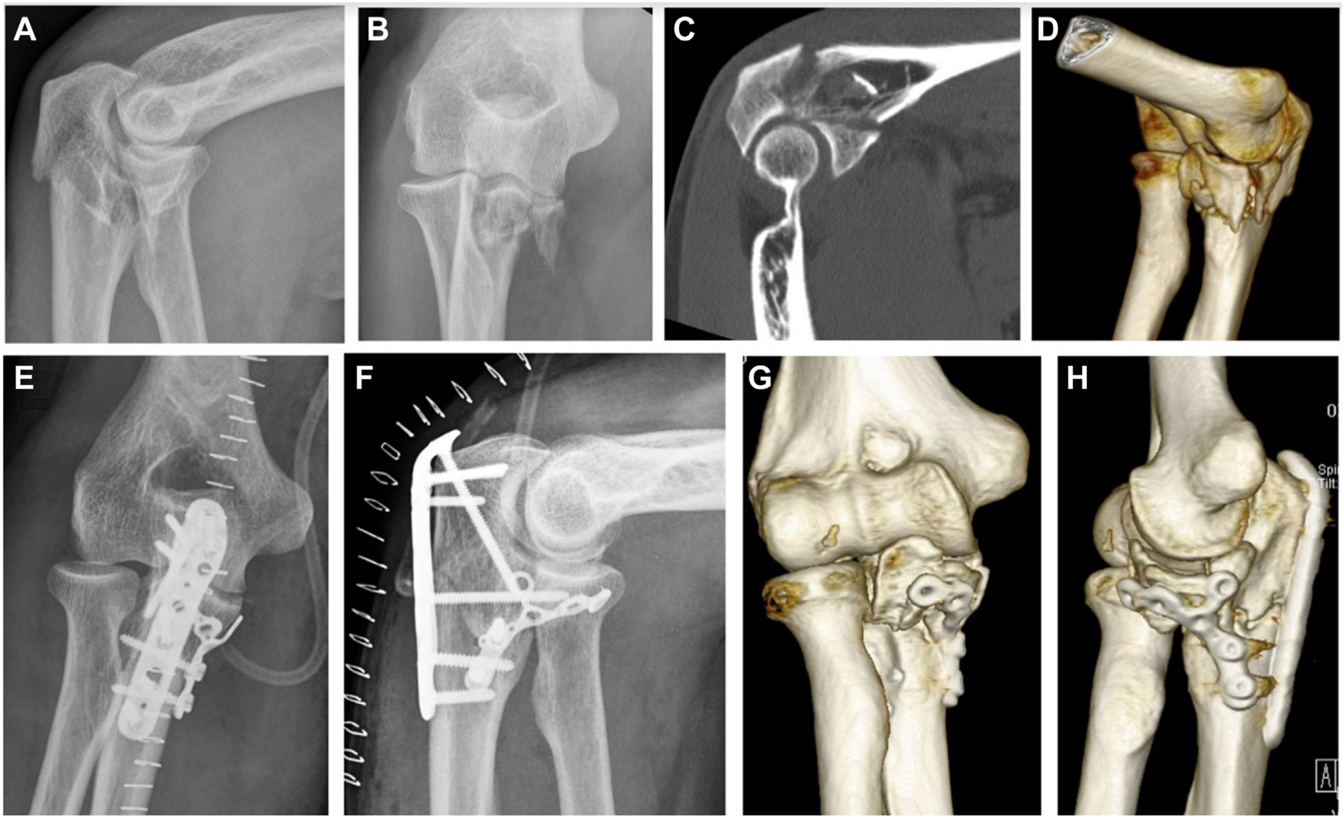

Figure 1 Case 9 TOFD with a basal subtype 2 coronoid fracture treated with olecranon and coronoid anatomic plates. (**A**-**D**) preoperative after reduction left elbow fracture-dislocations (**A**) AP view X-ray, (**B**) lateral view X-ray, (**C**) CT scan 2D sagittal view, (**D**) CT scan 3D reconstruction. (**E** and **F**) postoperative X-ray (**E**) AP view, (**F**) lateral view. (**G** and **H**) 3D reconstruction of the 3rd month CT scan, advance healing process. *AP*, anteroposterior; *CT*, computed tomography; *TOFD*, transolecranon fracture-dislocation.

interval and a level of statistical significance of $P < .05$. Descriptive statistics (mean with standard deviation and range for continuous variables, and frequencies with proportions for categorical data) were used to summarize recorded variables. The Shapiro–Wilk test was applied to assess the normality of the distribution for quantitative variables. Due to the nonparametric nature of the data, the Mann–Whitney U test was used to evaluate differences in distribution, and Fisher's exact test was applied to analyze the association between qualitative variables.

Results

Associated injuries and procedures

A coronoid fracture was observed in 19 cases (79.2%), with 2 cases (8.3%) requiring a coronoid plate. According to the O'Driscoll classification, 18 cases (75.0%) were classified as basal subtype 2, and one case as an anteromedial subtype 3 coronoid fracture. Radial head fractures were identified in 11 patients (45.8%). Radial head arthroplasty was performed in 7 cases (29.2%), osteosynthesis was preferred in 3 cases (12.5%), and one case was managed orthopedically (4.2%). Ligament injuries requiring repair were present in 7 patients (29.2%) for LUCL injuries and in only 1 patient (4.2%) for MCL injuries. Associated injuries and procedures are better detailed in Table I.

Outcomes: range of motion, functional scores, and complications

The average ROMs were flexion 119.0° ± 17.6°, extension deficit 20.4° ± 12.6°, pronation 68.9° ± 20.4°, and supination 63.1° ± 27.4°.

Table I
Associated injuries and procedures.

	N (%)
Coronoid fracture	19 (79.2)
Coronoid classification	
Anteromedial subtype 3	1
Basal subtype 2	18
Coronoid plate	2
Radial head fracture	11 (45.8)
Radial head osteosynthesis	3
Radial head arthroplasty	7
Orthopedic treatment	5
Repaired LUCL	7 (29.2)
Repaired MCL	1 (4.2)

LUCL, Lateral ulnar collateral ligament; *MCL*, Medial collateral ligament.

The MEPS and B&M mean scores were 82.3 ± 16.5 and 82.0 ± 16.1, respectively. Categorizing the B&M score, 3/24 (12.7%) of patients scored as excellent, 15/24 (62.5%) as good, 4/24 (16.7%) as fair, and 2/24 (8.3%) as poor

Eight patients (33.3%) had a complication, and all of them had at least one revision surgery. 5 cases had persistent stiffness (20.8%), for which an open fibroarthrolysis was performed. Two cases (8.3%) had a nonunion of the ulna. The first one was managed with a bone autograft and a medial plate to the ulna, evolving with satisfactory consolidation. The second one had a collapse of the coronoid, necessitating another surgery with a bone autograft for coronoid reconstruction and a temporary external fixator. Finally, one patient (4.2%) underwent early reoperation due to subluxation; in the revision surgery, additional screws were utilized to enhance fixation of the coronoid, and the MCL was repaired. He developed

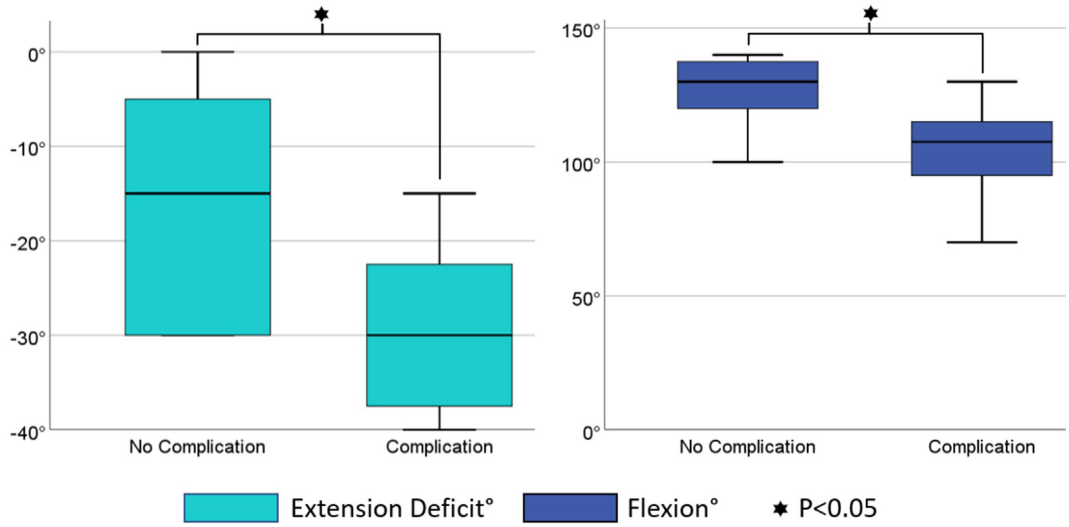

Figure 2 Range of motion based on complications.

subluxation and nonunion of the coronoid, so he was reoperated with a coronoid plate, a bone autograft, and a temporary external fixator.

No statistically significant difference of distribution was found in functional scores or ROMs according to associated injuries (coronoid or radial head fracture or LUCL or MCL injury) or procedures performed. A significant difference was found in the range of flexion ($P = .011$), extension deficit ($P = .005$) (Fig. 2), MEPS ($P = .001$), and B&M scores ($P = .002$) (Fig. 3) between patients who had complications and those who did not (Table II).

Patients with BC-TOFD had a reintervention rate of 38.9% (7/18) vs. those with a pure-TOFD 16.7% (1/6). Using the Fisher's exact test, it was found that none of these differences was statistically significant. Similarly, between BC-TOFD and pure-TOFD, there were no significant differences in associated injuries (see Table III) and no significant differences of distribution in functional scores or ROMs.

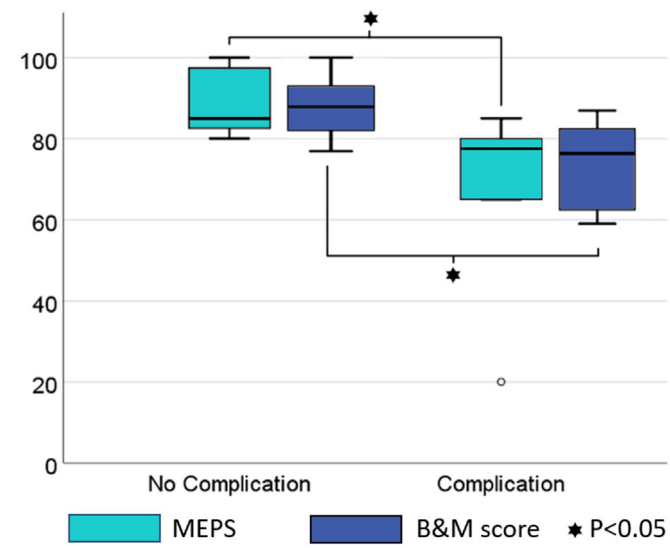

Figure 3 Functional scores based on complications. *MEPS*, Mayo elbow performance; *B&M* score, Broberg and Morrey score.

Discussion

The management of elbow fracture-dislocations is complex, and understanding the pattern of injury is essential for planning surgery. The classic patterns are posterolateral in valgus or terrible triad, posteromedial rotatory in varus, and TOFD.[17,19] Regarding this last group, several publications have shown good functional results and variable rates of the complications.[4,5,7,9,10,13,14,16,18] In a systematic review, Cho et al established that in 6 studies, in which the B&M score was used and 35.7% of patients scored as excellent, 47.1% as good, 10% as fair, and 7.1% as poor.[3] Similarly, in our study, most of the patients achieved excellent or good results (75% according to the B&M score). The slightly lower functional outcomes may be since this is a workers' compensation group. A systematic review by Fujihara et al showed worse upper extremity surgery outcomes in this type of patients.[6]

Treating elbow fracture-dislocations effectively demands a thorough comprehension of the complex interaction of all structures involved in elbow stability.[19] Classically, it has been hypothesized that in TOFD, instability depends only on the bone injury and that osteosynthesis of the olecranon is sufficient to restore a stable elbow.[4,18] This does not explain why some olecranon fractures result in a stable elbow while others lead to ulnohumeral instability. More recent publications have emphasized the importance of associated ligament injuries.[19] A biomechanical study by Midtgaard et al demonstrated that an olecranon osteotomy alone was insufficient to destabilize the elbow; instability occurred when at least one of the collateral ligaments was disrupted.[12] Therefore, ligament instability may result from either injury to the collateral ligament complexes or fractures in the ligament insertion areas.

In this fracture-dislocation pattern, coronoid fractures are common, being present in 53.3% of cases in published reports[3] and in 79.2% in our series. These fractures can compromise the insertion zones of collateral ligaments, especially when comminution is present. Therefore, it is crucial to achieve precise reduction and fixation of the coronoid, using a coronoid plate if necessary, to ensure ulnohumeral stability. In addition to bone injuries, ligament injuries can also occur. In our patients, ligament injuries requiring repair occurred in 29.2% of cases for LUCL and 4.2% for MCL. These injuries should be suspected and repaired, particularly when the coronoid remains intact.

Table II
Comparison of range of motion and clinical outcomes between pure TOFD, BC2 TOFD, and patients with and without complications.

	Pure TOFD	BC2 TOFD	*P* value	Without complication	With complication	*P* value	Total
Flexion	117.5 ± 8.8 (105.0-130.0)	119.4 ± 19.9 (70.0-140.0)	.496	126.3 ± 12.2 (100.0-140.0)	104.4 ± 18.4 (70.0-130.0)	.005	119.0 ± 17.6 (70.0-140.0)
Extension deficit	19.2 ± 12.0 (5.0-40.0)	20.8 ± 13.1 (0.0-40.0)	.770	15.9 ± 11.6 (0.0-30.0)	29.4 ± 9.8 (15.0-40.0)	.011	20.4 ± 12.6 (0.0-40.0)
Pronation	62.5 ± 19.4 (40.0-90.0)	71.1 ± 20.8 (40.0-90.0)	.378	71.6 ± 19.1 (40.0-90.0)	63.8 ± 23.1 (40.0-90.0)	.291	68.9 ± 20.4 (40.0-90.0)
Supination	61.7 ± 18.4 (40.0-90.0)	63.6 ± 30.3 (10.0-90.0)	.626	70.6 ± 23.5 (10.0-90.0)	48.1 ± 30.0 (10.0-90.0)	.061	63.1 ± 27.4 (10.0-90.0)
MEPS	84.2 ± 7.4 (75.0-95.0)	81.7 ± 18.7 (20.0-100.0)	.871	89.1 ± 8.0 (80.0-100.0)	68.8 ± 21.0 (20.0-85.0)	.001	82.3 ± 16.5 (20.0-100.0)
B&M score	84.8 ± 5.7 (79.0-93.0)	81.0 ± 18.3 (22.0-100.0)	1.000	88.4 ± 7.2 (77.0-100.0)	69.0 ± 21.2 (22.0-87.0)	.002	82.0 ± 16.1 (22.0-100.0)

Pure-TOFD, Pure-transolecranon fracture-dislocation; *BC2-TOFD*, Basal coronoid transolecranon fracture dislocation; *MEPS*, Mayo Elbow Performance Score; *B&M*, Broberg and Morrey score.
Results are presented as mean ± standard deviation (minimum–maximum).

Table III
Comparison of associated injuries and complications between pure-TOFD and BC-TOFD.

	Pure-TOFD (=6)	BC-TOFD (=18)	*P* value
Repaired LUCL injury	2 (33.3%)	5 (27.8%)	.800
Repaired MCL injury	0 (0.0%)	1 (5.6%)	.560
RH fracture	2 (33.3%)	9 (50.0%)	.480
Complications	1 (16.7%)	7 (38.9%)	.320

Pure-TOFD, Pure-transolecranon fracture dislocation; *BC-TOFD*, Basal coronoid transolecranon fracture-dislocation; *RH*, radial head; *LUCL*, Lateral ulnar collateral ligament; *MCL*, Medial collateral ligament.

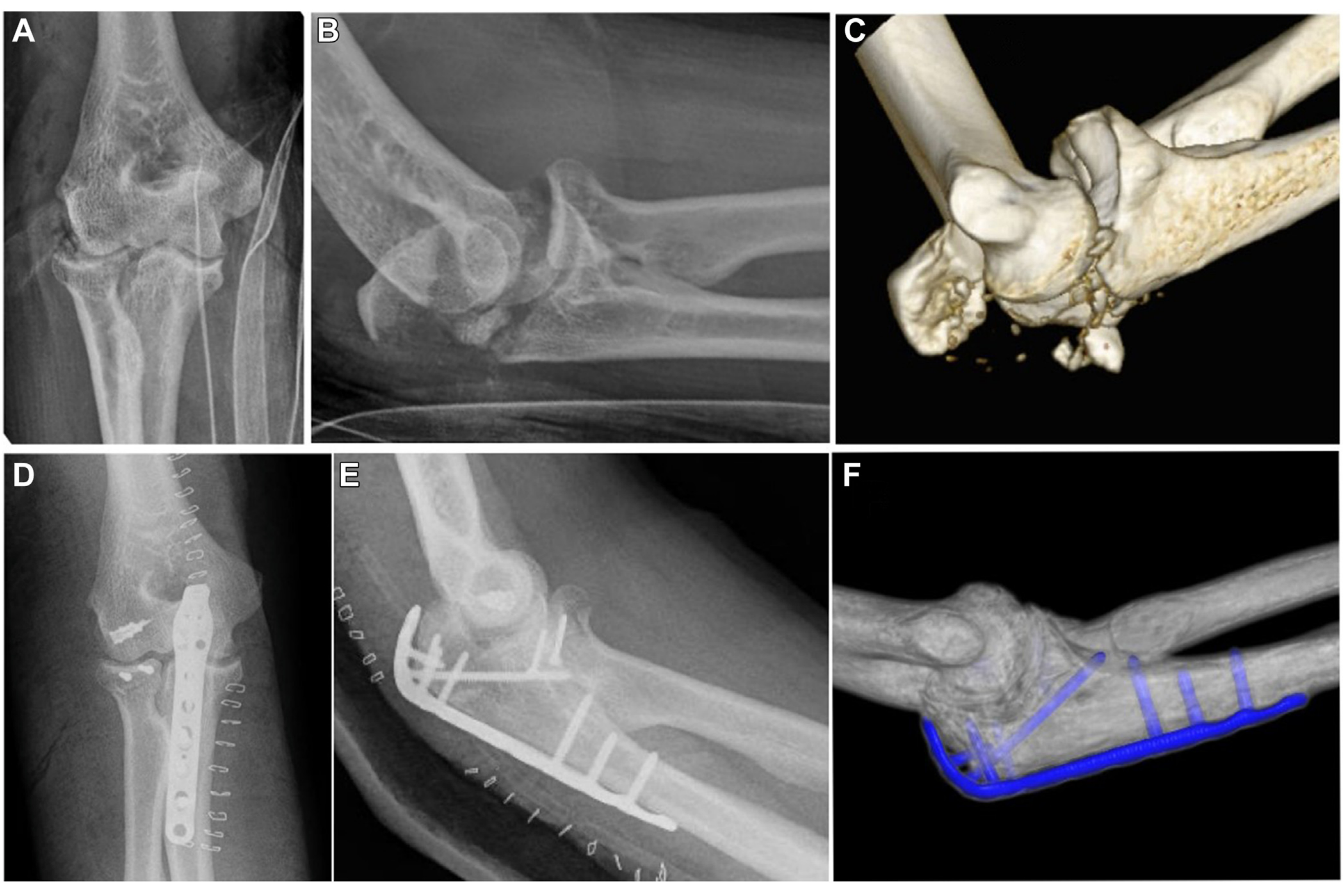

Figure 4 Case 17 example of pure-TOFD. (**A**-**C**) preoperative left elbow fracture-dislocations, (**A**) AP view X-Ray, (**B**) lateral view X-ray, (**C**) CT scan 3D reconstruction. (**D** and **E**) postoperative X-ray (**D**) AP view, (**E**) lateral view. (**F**) 3D reconstruction of the 6th month CT scan, complete healing. *CT*, computed tomography; *TOFD*, transolecranon fracture-dislocation.

As previously mentioned, coronoid fractures are common in this pattern. In our series, this fracture was present in 19 out of 24 patients (79.2%), with the majority (18 cases, 75.0%) corresponding to a basal fracture subtype 2, according to the O'Driscoll classification.[15] The presence of this fracture will determine the difficulty of the surgery. In cases where only the olecranon is fractured, proper osteosynthesis and potential ligament repair are usually adequate for restoring stability.[19] On the other hand, when

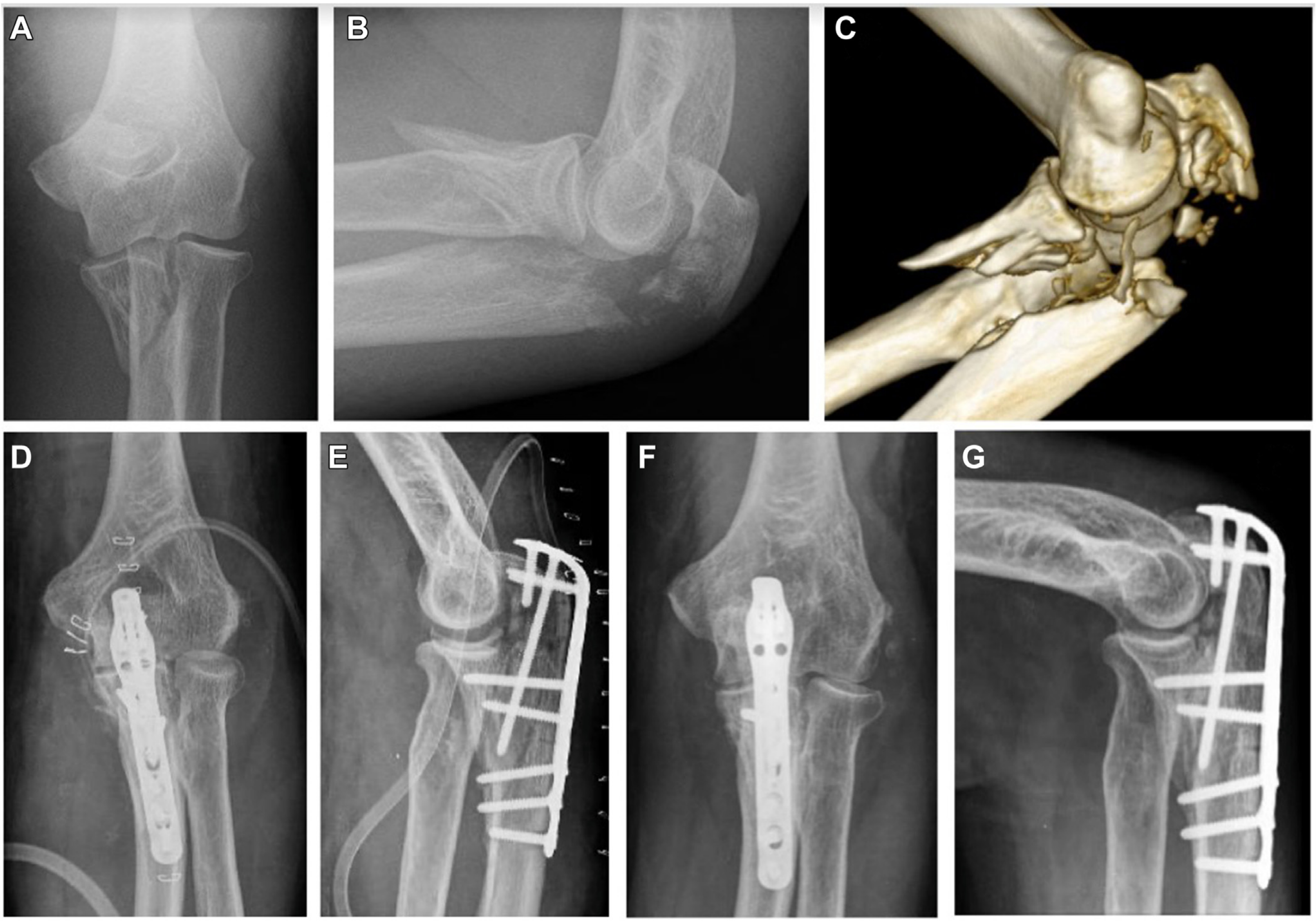

Figure 5 Case 21 example of TOFD with a basal subtype 2 coronoid fracture. (**A**-**C**) preoperative right elbow fracture-dislocations (**A**) AP view X-ray, (**B**) lateral view X-ray, (**C**) CT scan 3D reconstruction. (**D** and **E**) postoperative X-ray, (**D**) AP view and (**E**) lateral view. (**F** and **G**) postoperative 3rd month X-ray; (**F**) AP view and (**G**) lateral view. *CT*, computed tomography; *TOFD*, transolecranon fracture-dislocation.

the fracture compromises the coronoid, we must pay attention to the fixation of the fragments that could be influencing stability.

Due to this difference in biomechanics and surgical complexity, we prefer to classify them differently; pure-TOFD when the fracture passes through the trochlear notch (Fig. 4, *A-F*) and BC-TOFD when there is also an associated fracture through the base of the coronoid (Figs. 1, *A-H* and 5, *A-G*). This last group would be the most frequent according to our results (18/24 cases, 75.0%). Recently, other authors have also emphasized the coronoid. Barlow et al published a very similar classification system for proximal trans-ulnar fracture-dislocations based on the coronoid. They categorized them into trans-olecranon fracture-dislocations (where the coronoid is still attached to the ulnar metaphysis); Monteggia variant fracture-dislocations (where the coronoid is still attached to the olecranon); and ulnar basal coronoid fracture-dislocations (where the coronoid is not attached to either the olecranon or the ulnar metaphysis). This demonstrated almost perfect intraobserver and interobserver agreement.[1]

In our study, we did not find statistically significant differences in reintervention rates, associated injuries requiring repair, or functional outcomes between BC-TOFD and pure-TOFD cases. Additional research with a larger sample size could provide further information and potentially reveal differences between both groups.

Regarding reinterventions, in the previously mentioned systematic review by Cho et al,[3] the reoperation rate was 29.5% (31/105), and the main causes were elective hardware removal in 9 cases (8.6%), failed tension band in 6 (5.7%), failed 1/3 tubular plate fixation in 3 (2.6%), capsular release in 3 (2.6%), ulnar nerve transposition in one (1.0%), and ulnar nonunion in one (1%). In our study, the reintervention rate was 33.3% (8/24), and joint stiffness was the main cause in 5/24 cases (20.8%).

Nonunion (2 cases, 8.3%) and subluxation (1 case, 4.2%) were infrequent; and if we analyze in detail, 2 of these complications occurred in cases in which the surgical protocol was not strictly followed. One patient presented with persistent subluxation on postoperative radiographs. During the revision surgery, the fixation of the coronoid appeared insufficient and unstable, because the coronoid fragment was secured with only one screw from the olecranon plate. This lack of stability likely contributed to the subluxation. The fixation was subsequently reinforced with additional screws; however, the patient later experienced further subluxation and nonunion of the coronoid. Ultimately, it was managed with a coronoid plate, bone autograft, and a temporary external fixator. Although it is not strict, we believe that if the olecranon plate screws do not achieve adequate fixation of the coronoid; a medial coronoid plate works better than adding more screws.

It should be emphasized that patients with reintervention presented worse functional results and ranges of motion. Though these results may seem reasonable, we did not find other publications reporting this statistically significant difference. This is useful information for physicians when estimating the prognosis of patients.

Other complications, such as HO and ulnar nerve injury, have been reported with rates of up to 42.9% and 70%, respectively.[7,10] Interestingly, in our series, there were none of these complications. No HO prophylaxis protocol was used, except in reinterventions. The ulnar nerve was always transposed in medial approaches.

Our study has several limitations. Firstly, the retrospective design led to increased data loss and potential bias. Secondly, the surgeries were performed within a worker's compensation hospital, which may yield outcomes different from those observed in the general population. Thirdly, the limited statistical power may have hindered our ability to detect smaller yet clinically significant differences, particularly due to the small sample size in the TOFD group. Furthermore, there was a lack of long-term follow-up, which is essential for evaluating the durability of outcomes. The absence of magnetic resonance imaging also limited our ability to fully assess the correlation between preoperative ligament imaging and intraoperative findings. Finally, the surgeries were conducted by four different surgeons. Although the surgical approach was standardized and protocolized, the variations in experience and technique among these surgeons may have contributed to differing outcomes. Moreover, there were several potential contributors to complications or functional outcomes that we were unable to assess.

Future studies regarding the differences between the BC-TOFD and pure-TOFD patterns would be interesting. We believe that thinking about them as different, helps the surgeon to have a better surgical approach as well as a better estimation of the future prognosis.

Conclusions

A standardized protocol for pure-TOFD and BC-TOFD cases results in good to excellent functional outcomes. The BC-TOFD pattern was the most prevalent, accounting for 75.0% of cases, with no significant differences in reintervention rates, associated injuries, or functional outcomes between the two groups. Approximately, one-third of the patients required reintervention, primarily due to joint release, while nonunion and persistent subluxation were rare and linked to nonadherence to the surgical protocol.

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