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ORIGINAL ARTICLE • ELBOW - TRAUMA

Complex proximal ulna fractures: outcomes of surgical treatment

Eitan Melamed[1] · Natalie Danna[1] · Monika Debkowska[1] · Raj Karia[1] · Frank Liporace[1] · John T. Capo[1]

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Abstract
Background To review the results of plating of various fracture patterns of proximal ulna fractures including isolated olecranon fractures, olecranon fractures combined with a coronoid fracture, and olecranon fractures combined with a coronoid and radial head fracture.
Materials and methods The study included 38 patients with either an isolated olecranon fracture or combined injuries, all treated with open reduction and internal fixation of the olecranon. Other procedures were performed as needed, including radial head fixation or arthroplasty, fixation of the coronoid, and repair of the lateral collateral ligament complex. There were 27 men and 11 women with an average age of 49 years. Clinical and radiographic assessment was obtained at an average follow-up time of 15 and 8.4 months, respectively.
Results All fractures healed within 5 months. The average arc of ulnohumeral motion was 91° (range 0°–140°); average pronation–supination arc was 128° (range 0°–180°). Subgroup analysis showed a statistically significant lower rotational motion arc in patients with associated radial head (73°) or coronoid fractures (68°) compared to isolated olecranon fractures. All other parameters including ulnohumeral motion, complication rate, and revision rate were similar among the groups.
Conclusions A stable, functional elbow can be restored in most patients with proximal ulna fractures treated with open reduction and internal fixation. Loss of full flexion is likely with high-energy trauma, complex fracture patterns, and concomitant injuries. Fracture patterns involving the coronoid and/or the radial head are associated with restricted forearm rotation.
Level of evidence III

Keywords Proximal ulna · Olecranon · Elbow · Fracture · Dislocation · Plate fixation · Posterior Monteggia

Introduction

Proximal ulna fractures are a common injury, comprising 10 % of all upper-extremity fractures [1]. Sometimes classified as "olecranon fractures," these fractures are often complex and can include different injury patterns that may include the coronoid, radial head, or collateral ligaments. The term proximal ulna fractures is more descriptive as it stresses the importance of associated injuries and can be used to describe more complex injuries as well. Common mechanisms of injury include forced hyperextension, triceps overload, or direct trauma [2]. Treatment options for olecranon fractures include tension-band wiring (TBW), screw fixation, plating, and more recently IM nailing.

Non-comminuted transverse fractures with articular displacement are the most common category of fracture and can be effectively stabilized with TBW or plating following reduction [3]. Comminuted fractures of the proximal ulna, especially those involving an associated coronoid fracture and/or fracture-dislocation, often require plate fixation because TBW cannot provide enough stability to allow early postoperative motion of the elbow [4, 5]. Over the past two decades, open reduction and internal fixation have become more widely accepted as a means of achieving anatomical restoration of the articular surface

✉ Eitan Melamed
Eitanme2000@yahoo.com

[1] Division of Hand Surgery, NYU Hospital for Joint Diseases, 550 First Avenue, New York, NY 10016, USA

and facilitating early mobilization [6, 7]. Nevertheless, authors differ in their opinions with regard to the extent and type of internal fixation required [8–11]. Very few reports have specifically addressed the treatment outcomes of comminuted fractures of the proximal ulna, in isolation or with associated injuries to the coronoid, and radial head [12]. The purpose of the present study was to evaluate the mid-term functional recovery and surgical outcome of contoured plating for comminuted fractures of the proximal ulna with and without associated injuries.

Materials and methods

All human and animal studies were approved by the appropriate ethics committee and were therefore performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments; informed consent was waived and not required by our IRB. All data were collected retrospectively.

A perioperative current procedural terminology (CPT) code database identified patients who had been treated for proximal ulna fractures by two surgeons between 2004 and 2011. We included elbow fractures and fracture-dislocations involving the proximal aspect of the ulna that fulfilled the following criteria: (1) patient at skeletal maturity; (2) a fracture of the intra-articular portion of the proximal aspect of the ulna; and (3) surgical treatment of the injury. A retrospective review of patients' charts, operative reports, radiographs, and CT scans was performed to assess details of the initial injury, fixation techniques, and radiographic follow-up, joint incongruence, heterotopic ossification, complications, reoperations, and range of elbow motion postoperatively.

A total of 49 elbow fractures and fracture-dislocations involving the proximal aspect of the ulna had been treated surgically. Eleven patients were lost to follow-up. The remaining 38 elbows formed the basis of this study. Twenty-seven of the patients were male, and eleven were female. The mean patient age at the time of surgery was 49 years (range 19–85 years), and 19 patients injured their dominant arm. Clinical and radiographic follow-up assessment was obtained at an average time of 15 and 8.4 months, respectively. The patients were divided into three groups according to the variants of proximal ulna fractures (Fig. 1): group 1–Olecranon (25 patients); group 2–olecranon + coronoid (5 patients); group 3–olecranon + coronoid + radial head (8 patients).

The Mayo classification was used to describe the fracture pattern [6]. Type I fractures are nondisplaced. Type II olecranon fractures are displaced, but the ulnohumeral joint is stable. Type III fractures have a concomitant subluxation or dislocation of the elbow. Each fracture type is subdivided into non-comminuted (A) or comminuted (B) subtypes. There were one comminuted type I fracture; 23 type II fractures, 12 of which were comminuted; and two type III fractures, one of these being comminuted. Eight patients had concomitant radial head fractures, and five patients had an associated coronoid fracture. According to the Jupiter classification of Bado type 2 or posterior Monteggia injuries [13], three fractures in group 3 were 2B, 2A, and 2D. Two fractures, one in group 2 and one in group 3, were considered to be anterior olecranon fracture-dislocations (trans-olecranon fracture-dislocations), with preserved radial head and fractured coronoid. A scheme describing elbow stability as related to the proximal ulna fracture pattern is presented in Fig. 2.

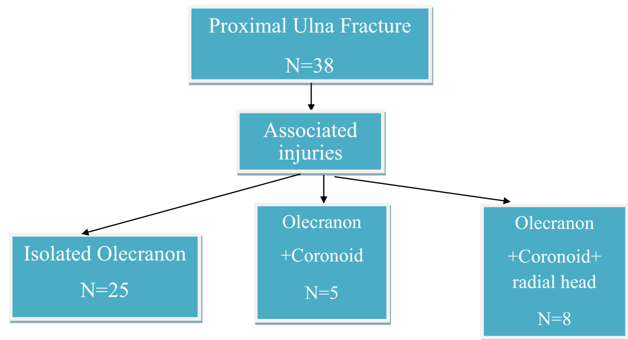

Fig. 1 Scheme describing the types of fractures based on associated injuries

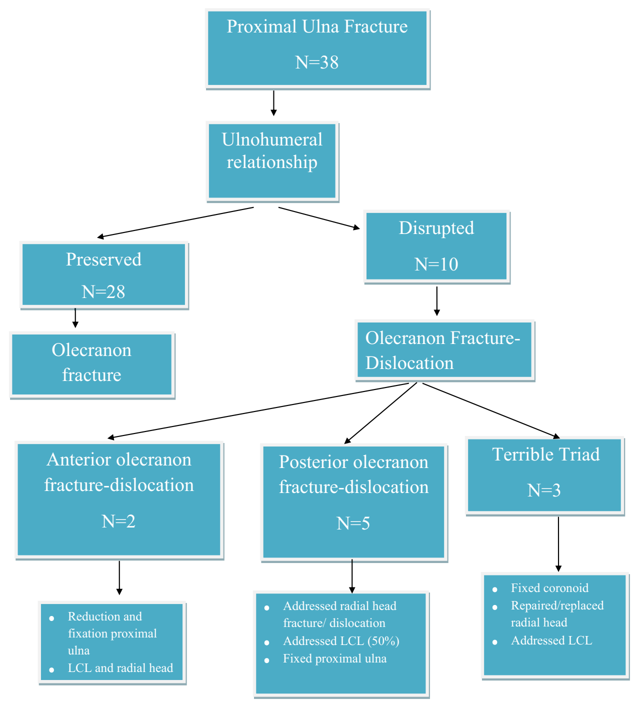

Fig. 2 Scheme describing elbow stability of the different fracture patterns, and treatment elected for each subgroup

The elbow injury was the result of a fall from a standing height in 12 elbows (31 %), high-energy trauma (motor vehicle accident or fall from a height of >15 ft) in 23 (60 %), gunshot wound in two (6 %), and correction of nascent malunion in one case (3 %). Three patients had an intracranial injury. Two patients had a spine injury but no spinal cord injuries in either case. Nine patients had associated lower extremity fractures. The injury was open in 16 cases, in which patients underwent irrigation and debridement of open injuries before the definitive surgery.

Continuous variables were analyzed between the three groups using one-way analysis of variance (ANOVA), and categorical comparisons were made using Fisher's exact test. Post hoc analysis included Tukey pairwise comparisons to look at individual differences between the groups. All statistical tests were performed using SPSS 20 (IMB, Chicago, IL) with a significance level of $p = 0.05$.

Results

Post-surgically, reduction was maintained and the fractures achieved union in all cases. The mean radiographic follow-up duration was 8.4 months (range 3 months–2.4 years). The mean interval between injury and primary surgical treatment was 1.9 days (range 0–26). The initial treatment of all olecranon fractures was ORIF with plating. The plates used were reconstruction plates ($N = 4$), 3.5-mm dynamic compression plates ($N = 3$), and proximal ulna-specific plates ($N = 31$) (DePuy-Synthes, Paoli, Pennsylvania, or Evolve EPS, Wright Medical, Memphis TN). Third tubular plates were used for supplemental fixation in three cases. Olecranon-specific locking plates were utilized in 21 cases (55 %) and standard non-locking plates in 17 cases (45 %). Fractures of the coronoid were repaired in a stepwise fashion and incorporated into the fixation. Radial head fractures (group 3) were either treated with metallic radial head arthroplasty in six cases (Evolve Radial Head System, Wright Medical, Arlington TN) or fixed with plates and screws in two cases. Reattachment of the lateral collateral ligament was performed in two cases. Mean time to radiographic union was 22 weeks (155 days, range 75–190), for all patients. There was no statistically significant difference in time to radiographic union among the subgroups.

Patient demographics and postoperative results are presented for the three patient subgroups, respectively (Tables 1, 2, and 3). The postoperative ulnohumeral motion at last follow-up was from a mean flexion of 110° (range 101°–118°) to a mean extension deficit of 19° (range 13°–25°). There was no significant difference in ulnohumeral motion between the isolated and more complex fracture patterns (group 1: 15°–113°; group 2: 28°–91°; group 3: 25°–112°, $p = 0.201$). However, for rotational movements, our data showed a statistically significant difference in pronation and supination between the isolated olecranon fractures (pronation 79°, supination 79°) and those who had olecranon and coronoid (pronation 29°, supination 39°) and olecranon, coronoid, and radial head fracture (pronation 44°, supination 29°) ($p = 0.007$ and 0.012, respectively, for pronation, and $p = 0.054$ and 0.001, respectively, for supination). A comparison between groups 2 and 3 showed no statistically significant difference in forearm rotation.

Augmentation of plate fixation was performed with lag screws outside the plate in 10 cases (26 %) and with a medial plate in 11 cases (29 %). Adding a medial plate was more common in the combined patterns (60 %; 75 %) versus olecranon only fractures (7 %) (Table 4).

Corner screws (the proximal-most screws in the proximal fragment screw cluster) were utilized in 19 cases (50 %) and were all well seated within the plate (Fig. 3). Irregularity of contour of the plate versus the proximal ulna, defined as mismatch of plate and bone surface leaving "any space" under the plate, was recorded in seven cases (18 %). Screw prominence defined as displacement of the screw head from the plate surface at least one screw diameter was evident in 16 cases (42 %). There was no correlation between the above-mentioned fixation features, or the use of locking or non-locking plates and the complication rate, hardware removal rate, or lower motion scores.

Complications occurred in 11 patients. Heterotopic ossification occurred in 10, requiring surgical excision in four cases due to restricted motion. Three patients presented with ulnar neuropathy, which resolved within the first 2 months. Residual subluxation was present in one patient, which was subsequently treated with by revision open reduction internal fixation (ORIF) and radial head arthroplasty. There was no significant difference between the groups regarding complication rate ($p = 0.78$).

Additional surgery was performed on ten patients (26 %) and included hardware removal in nine cases, excision of heterotopic ossification in four cases, ulnar nerve transposition in three cases, triceps release in two cases, and collateral ligament repair in one case. There was no statistically significant difference between the three subgroups with regard to additional surgery ($p = 0.75$).

Discussion

Fractures of the proximal ulna can appear complicated, and identification of basic injury patterns can facilitate their management. An apparent simple fracture pattern of the olecranon can have associated injuries that create complex instability patterns in the elbow. It is crucial that the

Table 1 Details of olecranon fractures without associated injuries

Age	Sex	Postop flexion (degrees)	Postop extension (degrees)	Postop pronation (degrees)	Postop supination (degrees)	Mayo classification	Ulnar fixation	Revision surgery
42	M	75	−25	90	90	IIB	ORIF	Hardware removal
42	M	130	−5	90	90	IIA	ORIF	
85	M	130	0	90	90	IIA	ORIF	
69	F	100	−30	70	70	IIA	ORIF	
22	M	110	−10	90	90	IIA	ORIF	
54	M	130	0	90	90	IIB	ORIF	
40	M	105	−20	90	90	IB	ORIF	
22	F	130	0	90	90	IIA	ORIF	Hardware removal
28	F	130	0	90	90	IIB	ORIF	
27	M	95	−5	90	90	IIA	ORIF	
25	M	140	−20	90	90	IIA	ORIF	
65	F	60	−30	90	45	IIB	ORIF	
34	M	135	0	90	90	IIA	ORIF	
81	F	130	0	90	90	IIA	ORIF	
58	F	130	−15	90	90	IIB	ORIF	
42	M	130	−15	80	80	IIA	ORIF	Hardware removal
39	M	Locked at 100				IIB	ORIF	
31	M	110	−30	50	90	IIB	ORIF	
39	M	130	0	90	90	IIB	ORIF	
19	M	120	−30	90	90	IIA	ORIF	
Average motion (°)		113	15	79	79			

M male, *F* female, *ORIF* open reduction internal fixation

Table 2 Details of olecranon fractures with associated coronoid

Age	Sex	Postop flexion (degrees)	Postop extension (degrees)	Postop pronation (degrees)	Postop supination (degrees)	Classification	Radial fixation	Soft tissue repair	Revision surgery
38	M	70	−20			Mayo type IIB			
55	M	Locked 90		5	5	Anterior fracture-dislocation of olecranon	ORIF, ex-fix	LCL repair	
31	M	105	−10	80	80	Mayo type IIIB	ORIF	LCL repair	Hardware removal
29	M	80	−30	0	50	Mayo type IIB	ORIF		
36	M	90	20	30	20	Mayo type IIB	ORIF		
Average motion (°)		91	28	29	39				

M male, *F* female, *ORIF* open reduction internal fixation, *Ex-fix* external fixator, *LCL* lateral collateral ligament

operating surgeon addresses all of these issues in the fixation construct (Fig. 4).

The goal of treatment of proximal ulna fractures is complete fracture union with a functional range of motion and preservation of ulnar nerve function. As the elbow does not tolerate immobilization well, stable fixation must be ensured to allow early mobilization and prevent stiffness and heterotopic ossification [14]. However, even well-treated complex injuries can result in stiffness, ulnar neuropraxia, heterotopic bone, or nonunion.

Fracture-dislocations of the proximal ulna can have various injury patterns. They may be associated with

Table 3 Details of olecranon fractures with associated coronoid and radial head fractures

Age	Sex	Postop flexion (degrees)	Postop extension (degrees)	Postop pronation (degrees)	Postop supination (degrees)	Classification	Ulnar fixation	Radial fixation	Revision surgery
37	M	100	−40	40	30	Posterior Monteggia type B	ORIF	RHA	
39	F	120	−10	30	0	Anterior (trans-olecranon) fracture-dislocation	ORIF		Hardware removal
77	F	120	−10	50	15	Posterior Monteggia 2B	ORIF	RHA	Hardware removal
34	M	130	−5	80	90	Posterior Monteggia 2D	ORIF	RHA	
24	M	120	0	0	0	Open fx prox radius and ulna	ORIF		
37	M	100	−55	30	5	Posterior Monteggia 2B	ORIF	RHA	
52	F	110	−20	90	90	?	ORIF	RHA	Revision ORIF for residual subluxation
42	F	100	−40	40	30	Posterior Monteggia type B	ORIF	RHA	
Average motion (°)		112	25	44	29				

M male, *F* female, *ORIF* open reduction internal fixation, *RHA* radial head arthroplasty

Table 4 Rate of additional olecranon fixation with a medial plate

Group	Number
Olecranon only	2/27 (7 %)
Olecranon + coronoid	3/5 (60 %)
Olecranon + coronoid + radial head	6/8 (75 %)

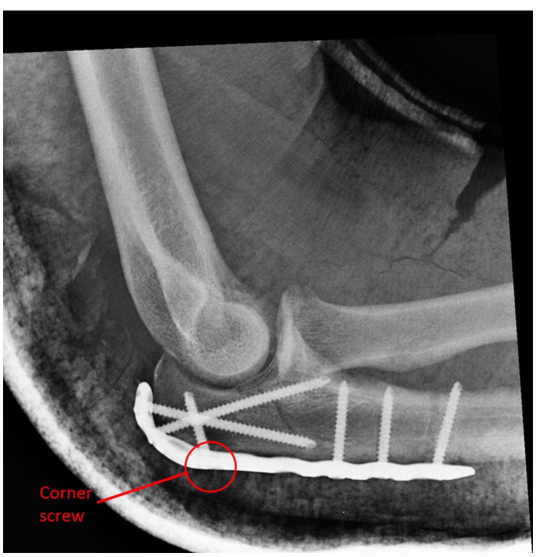

Fig. 3 Corner screws inserted at the point of plate angulation can be bothersome

anterior displacement of the forearm (trans-olecranon fracture-dislocation) or have posterior angulation of the proximal ulna and anterior displacement of the radial head (Monteggia fracture-dislocation) [13]. The olecranon

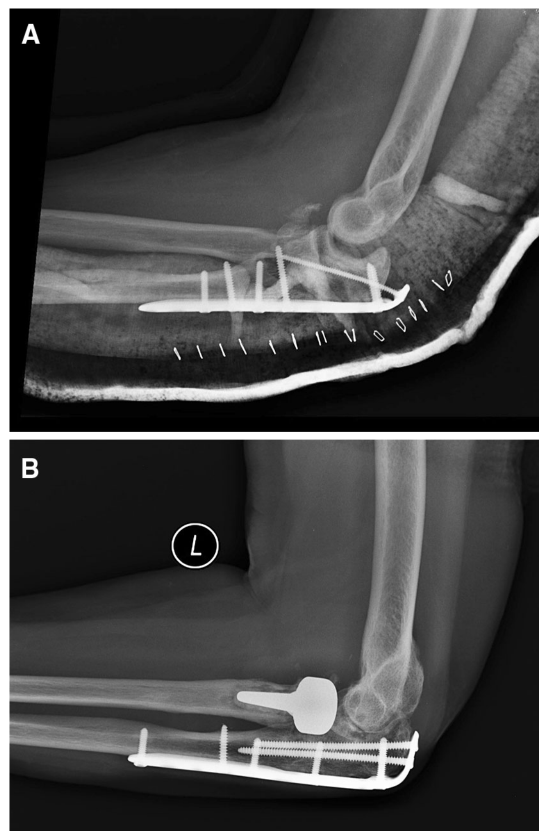

Fig. 4 a Postoperative radiograph demonstrating two common pitfalls in the treatment of olecranon fracture-dislocations. 1. Failure of fixation secondary to the use of a small 2.7 mm screw used as a "home run screw" instead of a 3.5 mm screw. 2. Poor visualization of the radial head results in a failure to recognize a radial head fracture. **b** Postoperative radiograph following revision fixation and radial head replacement

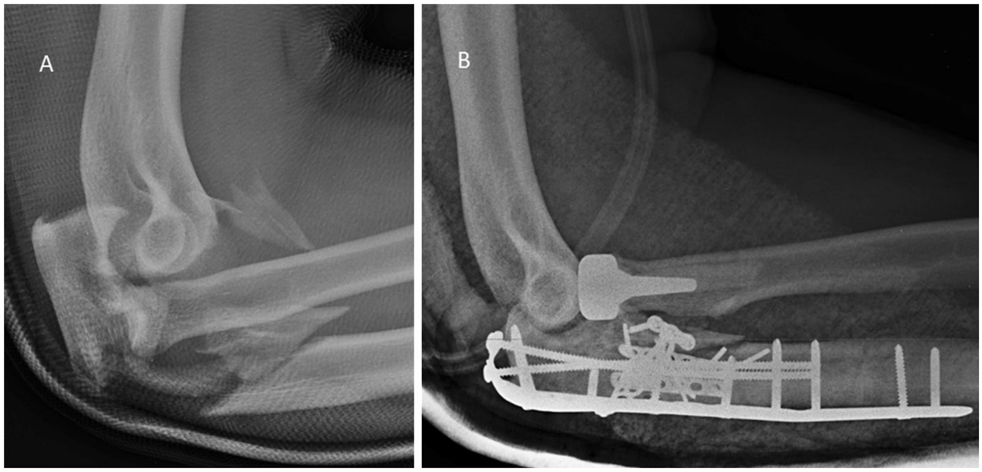

Fig. 5 **a** Posterior fracture-dislocation. In this case, the radial head is comminuted and the coronoid fracture is displaced. **b** For definitive treatment, the radial head and olecranon fracture must both be addressed. The radial head is usually addressed first, and in this case, the radial head was replaced. The coronoid was reduced and plated. Another option is to place a lag screw perpendicular to the fracture line. Final fixation required the application of a pre-contoured dorsal plate and two supplemental medial plates

Table 5 Summary of recent studies for reported hardware removal rate following plate fixation of olecranon fractures

Study	Implant	Number of patients	Hardware removal rate (%)
Chen W [19]	Central tension plate with sharp hook	26	0
Wang YH [20]	Reconstruction plate, LC-DCP, LCP	28	60
Erturer RE [21]	Locking plate	18	11
Siebenlist S [22]	3.5-mm LCP olecranon plate	15	26
Munoz-Mahamud E [23]	LC-DCP, LCP	10	40
Kloen P [24]	Reconstruction plate, LC-DCP, LCP	26	38
Anderson ML [2]	Mayo Congruent Elbow Plate System (Acumed, Hillsborough, California)	32	12.5
De Giacomo A [25]	Region-specific plates	182	15

component of the fracture can be combined with proximal ulnar shaft extension or combined with a coronoid fracture. In addition, any of these proximal ulna fracture patterns can be associated with a radial head fracture, which further increases the complexity of the injury. Treatment of these injuries (groups 2 and 3 in our series) requires attention to the coronoid, radial head, and the lateral collateral ligament complex (Fig. 5).

The average ulnohumeral motion was moderately impaired. The average flexion arc of our patients was 92°, as compared to Flinterman et al. [15] (143°) and Karlsson et al. [16] (134°). However, these studies report on the results of isolated olecranon fractures, resulting in one study from low-energy trauma in 59 % [16] compared to 40 % in our patients. We observed an unequal loss of motion, with a greater degree of flexion loss than extension loss. Most activities of daily living can be performed using an arc of motion between 30° and 130° [17], but we observed a limitation in flexion to an average of 110°, which has marked functional implications. Our results revealed that the average arc of forearm rotation was substantially restricted in group 2 (68°) and group 3 (73°). This is below the 100° degrees of forearm rotation (equally divided between supination and pronation) needed for daily activities [17]. The reason for the lower mean arc of motion in the current cohort remains unclear but may be a consequence of one of the several attributes of the patient group. These may be due to the high-energy injury patterns seen in our patients, as all of these cases were seen at an urban level 1 trauma center. Also the average age (49) of our patient was higher than the other studies (35, range 18–73 [15]; 36, range 17–66 for men and 54, range 20–77 for women [16]). The presence of associated injuries may also contribute to the limited motion of our patients. Since no severe osseous malalignment was present in any of the cases, soft tissue contracture and scarring are the most likely cause for loss of rotation.

Most fractures in our series were displaced oblique fractures not amenable to treatment by tension-band wiring alone, as the compression achieved by this technique is along the axis of the ulna and will displace an oblique fracture. Also, the tension-band concept at the elbow has recently been challenged [18], as the premise that distraction forces on the outer cortex are converted to compression between the fracture fragments does not hold in a biomechanical model. Since most fractures in our series were type IIb and comminuted, we elected to treat them with a dorsally applied standard or specialized plate, locking or non-locking with the focus on restoring the greater sigmoid notch.

In our series, nine cases required hardware removal (23 %). Given the superficial location of the olecranon, removal of symptomatic hardware is not uncommon and ranges from 0 to 60 % [19–25] (Table 5). In 50 % of the cases, we used corner screws, to reinforce the proximal fixation. Recently, it has been cited that hardware complaints are more common with corner screws [25]. Our cohort did not demonstrate such an association. Also, other fixation features (including the use of lag screws outside the plate, irregularity of plate contour versus bone contour, use of lateral plates, screw prominence) did not affect outcomes in terms of lower motion scores, hardware removal, or presence of complications. Hardware removal is not to be considered a complication, and this should be communicated to the patient before surgery. Our study did not find an advantage for olecranon-specific plates over other plates, in terms of motion, hardware symptoms, and complications. However, modern plating systems with proximal screw holes, as well as splitting of the triceps for more proximal plate placement, maximize the number of screws in the proximal fragment, thereby better capturing small proximal fragments and improving fixation, especially with comminuted fractures.

Our data should be interpreted with caution in light of the fact that only 38 (77 %) patients out of 49 were available for follow-up. Therefore, only a subset of patients, possibly younger and healthier, returned to follow-up, and we might have lost patients who, possibly, were doing well with minimal complaints. Another drawback of the study is the lack of a patient-reported outcome measures. This prevents us from measuring the impact of surgery on function and quality of life, and correlating our clinical assessment with the patients' subjective outcome. The subgroups were disproportionate in size and underpowered to assess differences in reoperation and complication rate between the three subgroups. If we had a higher number of patients in groups 2 and 3, we may have seen a significant difference in extension deficit as compared to simple olecranon fractures.

In conclusion, complex proximal ulna fractures can be difficult problems to treat, especially when associated with concomitant trauma to the coronoid and radial head. Although healing was achieved in all cases, restricted motion was common, even in the isolated olecranon fracture group. Complex associated fracture patterns were associated with poorer rotational forearm motion well below the functional range as compared to isolated olecranon fractures.

Conflict of interest Eitan Melamed MD, Natalie Danna MD, Monika Debkowska, Raj Karia MPH, and Frank Liporace MD declare that they have no conflict of interest. John T Capo MD declares that he has received research support and consultant for Synthes Corporation, and Wright Medical Technology. He is also consultant and member of Speakers Panel Integra Life Sciences.

Ethical standards This study has been approved by the local ethics committee and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

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