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Complications and functional outcomes after transolecranon distal humerus fracture

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Background: Transolecranon distal humerus fractures are uncommon injuries. This is the first multipatient case series to describe outcomes and complications following transolecranon distal humerus fractures in the adult population.
Method: Design: retrospective; setting: single level 1 trauma center; patients/participants: 16 patients; intervention: surgical management of transolecranon distal humerus fracture; main outcome measurement: Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire after a minimum of 12 months.
Results: A total of 16 patients with open (n = 12) or closed (n = 4) transolecranon distal humerus fractures were identified. Nine female and 7 male patients with a mean age of 47 years were included. Mechanisms of injury included motor vehicle collisions (n = 3), motorcycle crashes (n = 4), ground-level falls (n = 3), falls from height (n = 4), train collision (n = 1), and an industrial accident (n = 1). Seven patients (44%) presented with nerve injury. Patients underwent open reduction with internal fixation (n = 15), external fixation (n = 6), or both (n = 5). Additional surgeries were ultimately required in 11 patients (69%), with a mean of 3 surgeries to manage each patient's elbow injuries. All patients returned for at least 3 clinical follow-up visits; mean clinical follow-up was 15.8 months and mean radiographic follow-up was 12.3 months. Complications were observed in 15 patients (94%). Eleven patients (69%) had limited range of motion with a flexion arc of less than 100° at their last clinic visit. Seven patients (44%) developed deep wound infections requiring repeat débridement and intravenous antibiotics. Implant removal was performed in 10 patients (62.5%) because of infection (n = 5), symptomatic hardware (n = 4), or device failure (n = 1). Heterotopic ossification was seen in 8 patients (50%) and post-traumatic arthrosis in 4 (25%). Two patients (12.5%) required flap reconstruction for soft tissue defects. Nonunion occurred in 7 patients (44%). DASH scores were obtained for 10 patients (62.5%) at a mean of 3.8 years after injury. The mean DASH score was 40.2, ranging from 4.2 to 76.5. Among respondents, 7 (70%) were able to resume working, with an average DASH work module score of 25.
Conclusion: Management of transolecranon distal humerus fractures remain a challenge for orthopedic surgeons. Complication rates, including deep infection and nonunion, are high, with frequent long-term functional limitations posed to the patient, as evidenced by DASH scores.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Elbow injury; transolecranon; distal humerus; functional outcomes

Surgical management of complex elbow fracture dislocations are among the most challenging procedures for orthopedic surgeons. Specifically, transolecranon distal humerus fractures have an uncommon injury pattern, where the distal humerus is driven across the olecranon process of the ulna, resulting in a fracture of both the

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humerus and the olecranon with various degrees of extension into the coronoid or the proximal ulnar shaft.[2,24] This mechanism of injury can result in severe articular injury to the humerus or ulna, or both. On the other hand, isolated distal humerus fracture, isolated olecranon fractures, and combinations of distal humerus fractures with non-articular forearm fractures in the adult population are relatively more common.

Very few cases of combined fractures of the intra-articular distal humerus and olecranon have been described in the literature. A review of the literature shows 3 published articles featuring 10 cases total describing such injuries in the pediatric population.[7,22,25] A single retrospective study of complex fractures of the distal humerus in the elderly included 2 cases of concurrent distal humerus and olecranon fractures but provided little detail on the specific injury.[6] This is the first case series to describe transolecranon distal humerus fractures in the adult population. Because of the rarity of this complex injury pattern, knowledge of managing this injury remains limited but is key to improving patient care. The aim of this study is to characterize the clinical, radiographic, and functional outcomes of patients with transolecranon distal humerus fractures using the Disabilities of the Shoulder, Hand, and Elbow (DASH) questionnaire. We hypothesized that this is a severely disabling injury with high rates of complications and poor functional results.

Materials and methods

Design and setting

This study was done in a single level 1 trauma center in the Midwest region of the United States. We performed a query of our institutional orthopedic trauma database using relevant Current Procedural Terminology (CPT), International Classification of Diseases, Ninth (ICD-9) and Tenth Revision (ICD-10) codes for all patients presenting from 2005 to 2018 with distal humerus fractures and olecranon fractures.

Selection criteria

From our database query, 234 charts were reviewed to identify all patients with the combined injury of interest. Inclusion criteria included adult patients with fracture of the distal humerus and concomitant fracture of the olecranon or intra-articular proximal ulna fractures (AO/OTA type 13 and type 2U1B1 injuries). Patients younger than 18 years, patients with gunshot-inflicted injuries, and patients with extra-articular proximal ulna fractures were excluded. We identified 17 patients who met all the criteria. Of these 17 patients, all were treated surgically, and all but 1 patient, who was from out-of-state, returned for at least 3 clinical follow-up visits over the course of 3 months. Ultimately these 16 patients were selected for study inclusion.

Data collection

Patient charts were reviewed for demographic and baseline health data, injury characteristics, clinical notes and radiographic data. AO/OTA fracture classifications and determination of fracture union were determined by a Board-certified orthopedic surgeon with fellowship training in hand and upper extremity. Complications included nerve injury, infection, post-traumatic arthrosis, hardware removal, heterotopic ossification (HO), reduced range of motion less than a functional arc of 100°, and nonunion. Clinically relevant HO was defined as HO causing functional limitation, that is, Hastings and Graham classification[14] class 2 or 3. No HO prophylaxis was undertaken in any of our patients.

After a minimum of 1 year from initial injury, patients were contacted by a researcher not involved in their care to administer the DASH questionnaire on functional elbow use. The DASH questionnaire consists of a 30-item disability/ symptom scale scored from 0 (no disability) to 100 (most severe disability), with an optional work module to assess work-related disability, and has been previously evaluated for its reliability and validity.[1,16,26,27]

Results

Sixteen patients, 9 female and 7 male, with a mean age of 47 years (range, 20-92) were included. The dominant extremity was fractured in 6 patients and the nondominant in 10. Mechanisms of injury included motor vehicle collisions (n = 3), motorcycle crashes (n = 4), ground-level falls (n = 3), falls from height (n = 4), 1 train collision in a suicide attempt, and 1 industrial accident involving a rock crusher. Seven patients were polytrauma patients, 2 of whom presented initially with Glasgow Coma Scale scores of 3 and 3T. The remaining patients all had Glasgow Coma Scale scores of 15.

Four of the fractures were closed and 12 were open. Of the open fractures, 3 were type I, 4 type II, and 5 type III. Of the grade 3 injuries, 2 were IIIa, 2 IIIb, and 1 IIIc (Table I) per Gustilo classifications.[13] Fractures were classified using the Orthopaedic Trauma Association's Fracture and Dislocation Compendium.[19] Twelve patients had C-type fractures, all of which were classified as C3 (OTA type 13C3); 6 had B-type fractures (5 B1, 1 B2); and 3 had A1 fractures (Table I). Patients underwent open reduction with internal fixation (n = 15), external fixation (n = 6), or both (n = 5).

The average time from injury to surgery was 1.5 days (range, 0-10). Surgeries were performed by 7 different surgeons—3 orthopedic trauma specialists and 4 orthopedic hand and upper extremity specialists—with 13 of 16 patients being treated solely by the hand and upper extremity specialist. All patients returned for at least 3 clinical follow-up visits; the mean clinical follow-up was 15.8 months (range, 3.4-52.4) and the mean radiographic follow-up was 12.3 months (range, 3.4-41.6).

Table I Demographic and injury characteristics

Patient	Age	Sex	Open vs. closed	Classification (AO/OTA)	Mechanism	Other injuries
1	38	F	Open (type IIIb)	13C3.3	MVC	TBI and subarachnoid hemorrhage, fractures of bilateral femur fractures and acetabulum
2	92	F	Open (type I)	13B1.2	Fall from standing	
3	20	M	Open (type I)	13B1.3	MCC	
4	28	M	Open (type IIIa)	13C3.3	MCC	Fractures of rib and scaphoid; lung injuries
5	40	M	Open (type II)	13B3.1	MCC	Fractures of thoracic and lumbar vertebrae, first metacarpal, femur, tibia, fibula, metatarsals, ribs
6	23	M	Open (type II)	13C3.3	Fall from standing	
7	50	F	Closed	13C*	MVC	
8	52	M	Open (type II)	13B1.3	Fall from height	TBI; fractures of pelvis, ribs, lung injuries, humerus shaft
9	50	F	Closed	13A1.1	Fall from standing	
10	62	F	Open (type I)	13C3.3	Train collision (suicide attempt)	Scaphoid fracture
11	54	F	Open (type II)	13C3.2	Fall down stairs	Bilateral olecranon fractures
12	54	F	Closed	13B1.3	Fall down stairs	
13	26	F	Open (type IIIa)	13C3.2	MVC	Fractures of coracoid and ankle
14	53	M	Open (type IIIc)	13A1.1	Industrial (fell into rock crusher)	Injuries to aorta, knee dislocation, brachial artery, brachial plexus, abdomen; fractures of scapula, ribs
15	33	M	Open (type IIIb)	13B1.1	MCC	TBI, abdominal and urologic injuries; fractures of femur, pelvic ring, distal radius and first metacarpal
16	46	F	Closed	13A1.1	Fall from height	Fractures of ulnar shaft, distal radius, scaphoid

MVC, motor vehicle collision; *MCC*, motorcycle crash; *TBI*, traumatic brain injury.

* Determined using operative note and postoperative images; this patient's preoperative images were not available to us, as her original fixation was done at an outside hospital.

Complications were ultimately observed in 15 patients (94%). Limited range of motion, defined as flexion arc of less than 100° noted at last clinical visit, was the most common complication, seen in 11 patients (69%). Three patients underwent contracture release with subsequent improvement in total arc of elbow flexion, but still were not able to gain a functional arc of 100°. Average flexion arc was 74° (range, 0°-125°), and average forearm pronation supination arc was 156° (range, 120°-180°).

Seven patients (44%) developed deep infections requiring surgical débridement and intravenous antibiotics, and wound dehiscence was observed in 4 (25%). Organisms identified included methicillin-sensitive *Staphylococcus aureus*, *Enterobacter cloacae*, methicillin-resistant *Staphylococcus aureus*, and *Proteus mirabalis*. Each wound infection was successfully treated with surgical débridement and antibiotics, with removal of hardware. Two patients required flap reconstruction with a bipedicle flap and a posterior interosseous island flap.

Nine patients (56%) returned with nerve dysfunction at follow-up visits. All involved the ulnar nerve except for 1 patient (patient 1) with radial nerve dysfunction; however, the etiology of his neuropathy remains unclear and is possibly attributable to brain injury of stroke. Two patients underwent additional surgery for ulnar neuropathy with subsequent improvement of their symptoms. The remaining 6 ulnar nerve palsies resolved with conservative management.

HO was identified on the radiographs of 8 patients (50%), with 7 (44%) graded as clinically relevant HO, that is, class II or III (Table II). Two patients with class IIA HO underwent additional surgery to remove heterotopic bone with the goal of improving motion. One of these patients experienced HO recurrence after excision. Another patient with class IIIA HO had complete bridging ankylosis at 90° flexion.

Four patients (25%) developed post-traumatic arthrosis. Three of these patients had a minimum of 15 months of

Table II Patient outcomes

Patient	Nerve injury	Infection	Arthrosis	Hardware removal	Heterotopic ossification	Flexion arc <100°	Final ROM (degrees extension-flexion)	Radiographic outcome	Clinical follow-up (mo)	Radiographic follow-up (mo)	DASH score
1	Yes	Yes		Yes	Class IIA	Yes	50-90	Union	3.6	3.6	
2					Class I		15-120	Union	3.5	3.5	
3	Yes		Yes	Yes	Class IIA	Yes	25-105	Union	15.5	15.5	
4	Yes	Yes		Yes		Yes	45-90	Infected nonunion of distal humerus	4.6	4.6	
5		Yes				Yes	30-100	Nonunion of olecranon	11.9	11.9	76.5
6		Yes		Yes		Yes	35-130	Nonunion of olecranon	8.0	8.0	4.2
7	Yes		Yes	Yes	Class IIA	Yes	45-95	Union	20.5	17.7	23.3
8	Yes	Yes		Yes			0-125	Infected nonunion of olecranon	41.3	28.4	65
9	Yes						30-135	Nonunion of olecranon	12.0	7.8	37.5
10				Yes			15-125	Union	9.4	2.7	14.7
11	Yes					Yes	60-100	Nonunion of olecranon; Malunion of distal humerus	26.6	15.3	
12					Class IIA	Yes	20-115	Union	5.4	5.4	45.8
13			Yes		Class IIA	Yes	35-115	Nonunion of distal humerus	5.3	5.3	36.7
14	Yes		Yes	Yes	Class IIA	Yes	15-100	Union	45.6	32.0	75.8
15		Yes		Yes	Class IIIA	Yes	0 (fused at 90°flexion)	Union	33.1	31.5	
16	Yes	Yes		Yes			Not documented	Union	6.1	4.5	22.4

ROM, range of motion; *DASH*, Disabilities of the Arm, Shoulder, and Hand questionnaire.

radiographic follow-up, whereas 1 patient had his (or her) last follow-up at 5 months. One patient underwent additional surgery for excision of osteophytes and symptomatic keloid scar formation.

Ultimately, 7 patients (44%) went on to nonunion: 5 (31%) had nonunion of the olecranon, whereas 2 (12.5%) had nonunion of the distal humerus. Revision surgeries were performed in 2 patients (12.5%; patients 5 and 8, see Figure 1); however, both fractures remained in nonunion. Of the 7 patients with nonunion, 1 had functional nonunion (patient 6, see Figure 2), 2 were not interested in further surgery, 2 were lost to follow-up, and 2 are still being followed in clinic with consideration for future revision or arthroplasty. Eleven patients (69%) underwent more than 1 surgery to manage their injuries, with each patient requiring an average of 3 (range, 1-6) surgeries. Common reasons for additional surgeries included revision open reduction internal fraction (ORIF), implant removal, infection washout, wound dehiscence, adjustment of external fixator, HO excision, soft tissue release, nerve decompression, and flap reconstruction performed by a plastic surgeon. In most cases, additional surgeries were performed for variable combinations of the previously mentioned reasons.

Functional outcome questionnaires using the DASH questionnaire were obtained for 10 patients (62.5%). DASH scores were unable to be obtained for 1 patient with advanced dementia, 1 patient in jail, and others lost to follow-up. Respondents completed the questionnaire at a mean of 3.8 years from their injury dates. Among the 10 respondents, the average DASH score was 40.2, with a range of 4.2 to 76.5. The highest disability component of the DASH questionnaire among respondents was in doing heavy household chores (eg washing walls, floors, etc) with an average score of 3.3 of 5, correlating to moderate disability. The work module portion of the DASH was completed by 7 of 10 who had resumed work, with an average work-DASH score of 25 (range, 0-62.5). Positions held by these patients included 2 medical clerks, a secretary, a retail employee, a babysitter, and a nurse. The patient working as a nurse scored a 62.5 on her work module.

Discussion

Transolecranon distal humerus fractures are complex and challenging injuries. Clinical and functional outcomes of this rare injury have not previously been described. Orthopedic surgeons face considerable challenge when counseling patients with complex high-energy injuries such as the transolecranon distal humerus fracture; thus, it is important for surgeons to be familiar with the potential clinical and functional outcomes of this injury. To our knowledge, this study represents the largest single cohort of patients with transolecranon distal humerus fractures. We evaluated the complications and assessed functional outcomes of patients with transolecranon distal humerus fractures seen at our level 1 trauma center.

Among our cohort of patients, 75% had open injuries, attesting to the high amount of energy required to produce this kind of traumatic injury, and making this injury more difficult to treat because of the bone and soft tissue injuries. Six of our patients (37.5%) were managed using external fixation. One patient (patient 11) was treated using only external fixation, who later progressed to malunion of the distal humerus fracture and nonunion of the proximal ulna. The magnitude of the soft tissue injury associated with this fracture pattern cannot be overstated as it may dictate treatment options and ultimate outcome.

Stiffness is a known common complication of distal humerus fractures and can arise from a variety of causes, including soft tissue contractures, HO, articular incongruity from nonunion, malunion, or loss of cartilage.[20] Previously, the functional arc of elbow motion for activities of daily living has been found to be 100° for both flexion-extension (30°-130°) and pronation-supination (50° in either direction).[21] Eleven of the patients (69%) in our study lacked a functional flexion arc of 100°, with 25% of patients requiring contracture release with subsequent improvement in stiffness and range of motion. The average flexion-extension arc of our patients at their last clinical visit was 74°, lower than the averages of 98°-126° currently reported in the literature for patients after ORIF of isolated distal humerus fractures.[29]

Distal humerus fractures and elbow fracture-dislocations are also known to be a common source of post-traumatic elbow arthrosis due to greater severity of articular surface injury, while isolated fractures of the olecranon are less prone to the development of arthrosis.[12] In our cohort, 4 patients (25%) exhibited post-traumatic radiographic arthrosis, with only 1 patient receiving surgery for management of painful arthrosis. Considering that 9 of our patients (56%) had less than 1 year of radiographic follow-up, this is likely an underestimate of the true incidence of post-traumatic arthrosis in transolecranon distal humerus fractures. Long-term radiograph analysis and larger cohort studies would be needed to determine the true incidence rate.

The prevalence of HO after elbow fractures in various studies has varied widely, from 0% to 49%.[10,18] Such variability may be due to differences in patient demographics, use of HO prophylaxis, fixation methods, injury characteristics (open vs. closed, fracture patterns), and reporting (all grades of HO vs. clinically relevant HO), making it difficult to make a true comparison between case series. Previous studies have suggested male gender, fracture dislocation or subluxation, open fractures, central nervous system injury, severe chest injury, and longer time to surgery as risk factors for clinically relevant HO.[8,15,28] In our cohort, 8 of 16 (50%) patients developed HO, where 7 (44%) were clinically relevant. Of these were 2 traumatic brain injury patients, 3 patients with fracture dislocations, and 6 with open fractures. The reason for our high rate of HO may be related to the severity of the injuries, associated head injuries, fracture dislocations, and a high open injury rate. Use of radiation and NSAIDs for HO prophylaxis may be considered for all patients without contraindications, or selectively in patients with elevated risk such as those with open fractures and traumatic brain injury.

Our study demonstrates higher rates of complications and nonunion than what is currently reported in the literature for intra-articular distal humerus fractures. Previous studies on overall complications following ORIF of distal humerus fractures report variable complication rates of 11% to 48%.[4,9] Differences in fixation methods, fracture patterns, and patient demographics likely account for such wide variability in these numbers. Reported nonunion rates after ORIF of distal humerus fractures range from 0% to 20%, whereas nonunion after ORIF of displaced olecranon fractures is even more uncommon around 1% and associated with complex injury patterns.[3,23] Eleven of our patients (69%) required additional surgeries for management of their complications. Our nonunion rate of olecranon and/or distal humerus fracture was 44% (7 of 16), which was unchanged even after revision ORIF of 2 patients with nonunion (patients 5 and 8; see Figure 1). Six of the 7 (86%) nonunions were open fractures, with 5 of the 7 (71%) classified as type II or type III. Both distal humerus nonunions were complete articular (AO/OTA type C) fractures, suggesting that risk factors for nonunion may include open fracture, higher severity of open fracture, and articular injury. Of course, patient-specific risk factors including medical comorbidities may also play a significant role in healing. Nevertheless, with a nonunion rate of 44%, our study attests to the added challenges of treating patients with transolecranon distal humerus fractures compared to isolated intra-articular distal humerus fractures.

Transolecranon distal humerus fractures are devastating injuries that require a multidisciplinary approach. As demonstrated in our series, 2 of our 16 (12.5%) of patients required additional soft tissue procedures, including skin grafts and complex reconstruction with muscle flaps. It is likely that for some of our patients, the soft tissue injuries contributed to the final outcome as much as the osseous

injuries. We are fortunate to have plastic surgery colleagues with a specific interest in post-traumatic reconstruction. Orthopedic surgeons confronted with these injuries should feel comfortable referring these patients to tertiary care centers if the necessary reconstructive services are not available at their facility.

We obtained functional outcome data on more than half of our patients at a mean of 3.8 years after date of injury. In the current literature, functional DASH scores from various cohort studies of patients with complex intra-articular distal humerus fractures range from 7-23.[4,5,11,17] Our study cohort had a mean DASH score of 40.2. The higher functional disability suggested by our mean DASH score of 40.2 emphasizes the everyday impairment patients may experience as a result of this injury. Figures 1 and 2 demonstrate the courses of 2 patients (patients 5 and 6), both with persistent olecranon nonunion, who report drastically different functional scores of 76.5 and 4.2, respectively. We recognize that DASH scores in some of our patients may be affected by polytrauma and/or concurrent ipsilateral upper extremity injuries.

We acknowledge that limitations of our study exist. Given the relative rarity of this injury, our study is not powered to assess significant differences between variables. We also recognize that follow-up on our patients was inconsistent. Several of our patients lacked long-term follow-up; therefore, conclusions regarding long-term complications such as HO and post-traumatic arthrosis are limited. Poorer follow-up rates of our patients can be attributed to a variety of factors. As a tertiary trauma center, many of our patients were admitted to our hospital from outside hospitals; thus, it is possible that patients from out of the Cleveland area may have chosen to pursue follow-up at a hospital closer to their homes. To address this, the electronic health record for each patient was thoroughly searched for any record of visits at outside hospitals, and

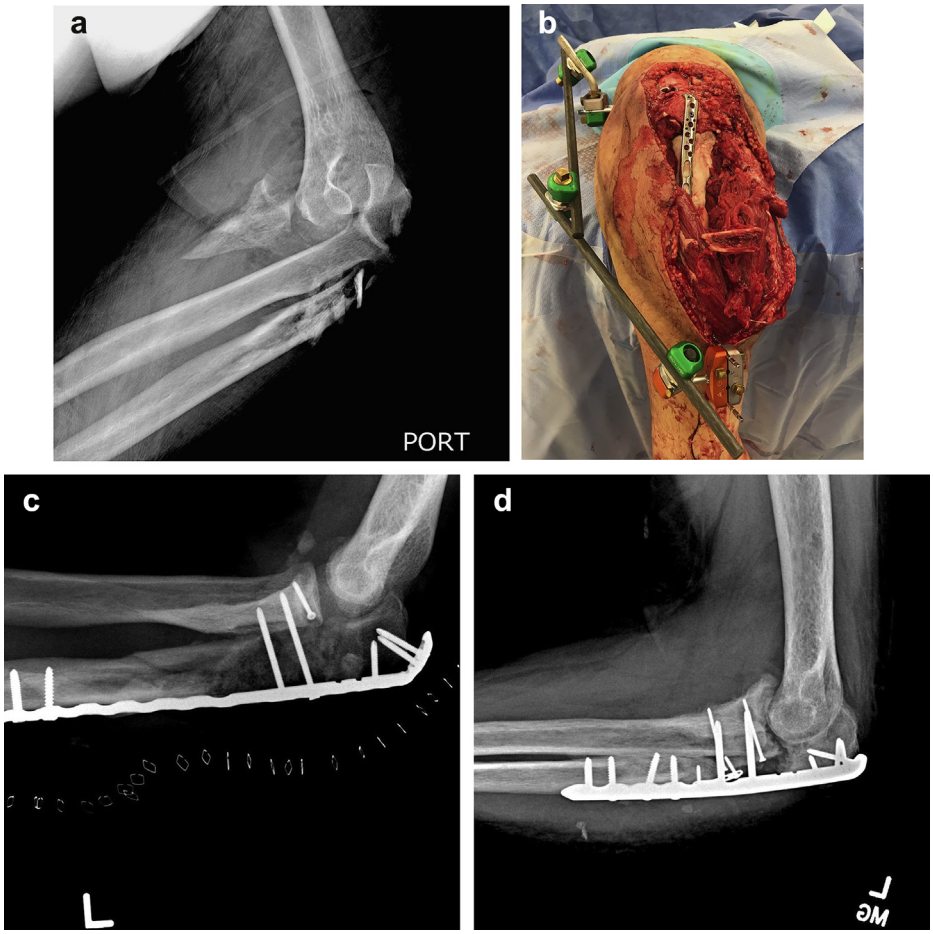

Figure 1 (**a**) Radiograph of a 40-year-old man (patient 5) with an open (type II) left elbow transolecranon fracture-dislocation with 3 cm of segmental bone loss, as well as fractures of the radial head, capitellum, coronoid, and olecranon. (**b**) Intraoperative image taken 2 weeks after the injury. ORIF of the proximal ulna with application of external fixator for stabilization, and antibiotic cement spacer in place of the bone defect. (**c**) One month after the injury. In addition to previously mentioned procedures, patient is post-revision ORIF of proximal ulna, bone graft of proximal ulna defect using Masquelet technique, and removal of previous hardware. Patient later goes on to nonunion and receives another revision ORIF with iliac crest bone graft of proximal ulna and ulna shaft with resection of the radial head. (**d**) Radiograph from 1 year after the original injury showing persistent nonunion, with lucency around the screws. *ORIF*, open reduction internal fixation.

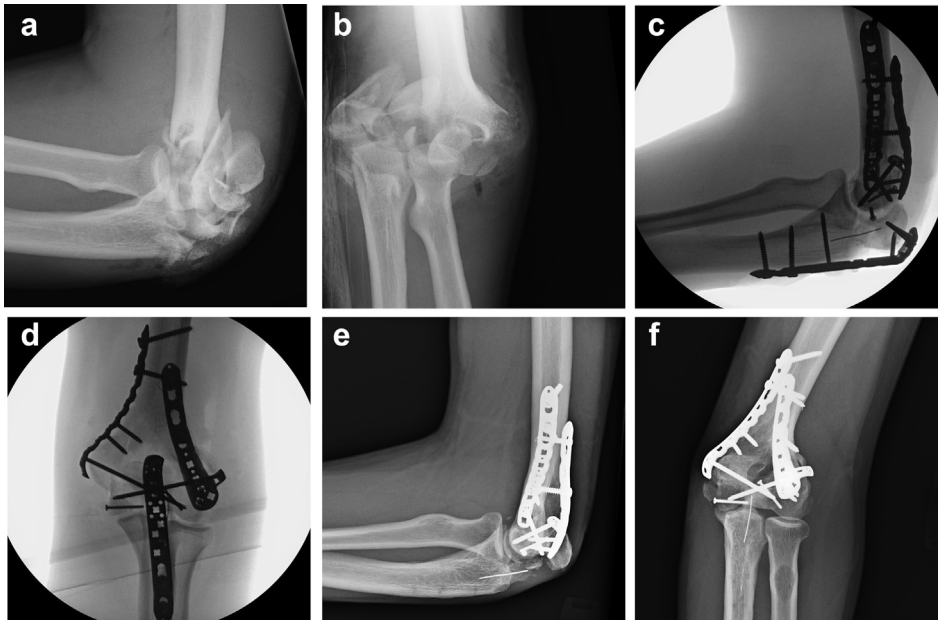

Figure 2 (**a, b**) Radiograph of a 23-year-old man (patient 6) with an open (type II) left intra-articular distal humerus transolecranon fracture. (**c, d**) Intraoperative images taken after ORIF with local bone grafting. (**e, f**) Image from 7 months after the injury showing union of the humerus and nonunion of the olecranon. Previous to this, the patient was taken to the operating room twice for washout after developing postoperative infection (5 weeks post-ORIF) and wound dehiscence (7 weeks post-ORIF). At 7 months out, he is noted to be doing quite well despite olecranon nonunion, with a DASH score of 4.2 and a work score of 0. *ORIF*, open reduction internal fixation.

outside hospital images and records were requested when necessary. Still, we recognize that higher follow-up rates and higher DASH response rates would have enhanced our study results. It is also possible that varying experience levels, specialties, and backgrounds of surgeons may have influenced outcomes among patients. Our 16 patients were operated on by 7 different fellowship-trained orthopaedic surgeons, 3 of whom were trauma specialists and 4 of whom were hand and upper extremity specialists, all with a focus on upper extremity trauma. The number of surgeons involved in the care of our 16 patients may further limit reliability when comparing and interpreting results. Because much of our data were collected from chart review of the electronic health record, variability in documentation among different surgeons must also be considered.

Conclusion

Transolecranon distal humerus fractures are complex and challenging injuries associated with high rates of infection, nonunion, stiffness with loss of motion, and poor functional scores. The extensive articular damage and soft tissue injury caused by this injury put patients at increased risk for complications such as infection, post-traumatic arthrosis, HO, and nonunion. Surgeons and patients should be made aware of the high rates of complications that occur with transolecranon distal humerus fractures, as well as the subsequent loss of elbow function patients are likely to experience, which can have significant implications on their ability to use the injured extremity for everyday tasks, and to return to the same level of work.

Disclaimer

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