JSES Reviews, Reports, and Techniques 1 (2021) 34–40

Contents lists available at ScienceDirect

JSES Reviews, Reports, and Techniques

journal homepage: www.jsesreviewsreportstech.org

Skinny wire and locking plate fixation for comminuted intra-articular distal humerus fractures: a technical trick and case series

Jeffrey J. Olson, MD [a,b,*], George S.M. Dyer, MD [a,b,c]

[a] Harvard Combined Orthopaedic Surgery Program, Boston, MA, USA
[b] Orthopaedic Trauma Initiative at Harvard Medical School, Boston, MA, USA
[c] Brigham and Women's Hospital, Department of Orthopaedic Surgery, Boston, MA, USA

ARTICLE INFO

Keywords:
Distal humerus fractures
Intra-articular
Locking plate fixation
Skinny wires
K-wires

Level of evidence: Technical Note

Introduction: Intra-articular distal humerus fractures present a challenge to orthopedic surgeons. Stable fixation is difficult to achieve in fractures with articular and metaphyseal comminution and osteoporotic bone. Hence, these fractures are more commonly being managed with total elbow arthroplasty. We describe a novel surgical technique that confers stable fixation, allowing for early range of motion resulting in a high rate of union, a functional range of motion, and excellent patient reported outcome scores without the activity restrictions of total elbow arthroplasty.

Methods: Retrospective case series of 30 patients with AO/OTA type B and C intra-articular distal humerus fractures who underwent ORIF from 2014-2019 utilizing a novel surgical technique that focuses on reconstructing a comminuted articular surface through meticulous, transverse fixation of the tiny articular fragments with long, thin Kirchner wires, which are then bent over and trapped under locking compression plates to create a fixed angle support to the metadiaphysis.

Results: Patient mean age of 59 (19-90) years and 61% were female. Median follow up was 1.2 years. Twenty-seven (87%) were type C fractures and 3 (13%) were type B. Five patients (16%) suffered a concurrent ipsilateral upper extremity injury and four (13%) had an open fracture. Two were polytrauma patients. All fractures healed with an average time to union of 11 weeks. Over 80% patients reported no or mild pain at final follow up. Mean arc of elbow motion was 102 degrees, mean QuickDASH score 25.2. Post-operative complications included ulnar nerve paresthesias (38%), wound infection (3.2%), heterotopic ossification (3.2%), and olecranon nonunion (3.2%). Eight patients underwent secondary procedures: 7 (23%) removal hardware, 3(9.6%) capsular release, 2 (6.4%) ulnar nerve transpositions, and 1 (3.2%) total elbow arthroplasty.

Conclusion: We describe a novel surgical technique that we believe results in strong, stable fixation of complex intra-articular distal humerus fractures irrespective of bone quality. In our series, all fractures healed and post-operatively patients reported low levels of pain, achieved excellent elbow range of motion, high patient reported outcome scores. Patients should be counseled about high rates of post-operative ulnar nerve paresthesias that can be expected to improve over time and high reoperation rates for symptomatic hardware.

Distal humerus fractures are 2%-7% of all adult fractures and 30% of elbow fractures.[4,21] Intra-articular distal humerus fractures specifically pose a challenging problem for treating orthopedic surgeons. Most commonly, these fractures result from high-energy injuries in young adults or low-energy falls in the elderly. Reconstruction of the articular surface is often technically difficult owing to poor bone quality, limited cancellous bone to support fixation, and multiple articular and metaphyseal fragments in severely comminuted fractures. The advent of locking plates placed orthogonally or in parallel have resulted in better fixation and improved clinical outcomes,[2,10,20] but there remains a small subset of patients with poor bone quality and highly comminuted, AO/OTA type C distal humerus fractures which are challenging to treat, with difficulty achieving bony union and attaining a functionally acceptable extremity. Recently, there has been a trend toward treating these patients with total elbow arthroplasty (TEA), but in practice, this solution is often

Partners Human Research approved this study (Protocol #: 1999P008705).

* Corresponding author: Jeffrey J. Olson, MD, Harvard Combined Orthopaedic Residency Program, 55 Fruit Street, Boston, MA 02114, USA.
E-mail address: jeffrey.olson@mgh.harvard.edu (J.J. Olson).

https://doi.org/10.1016/j.xrrt.2020.11.007

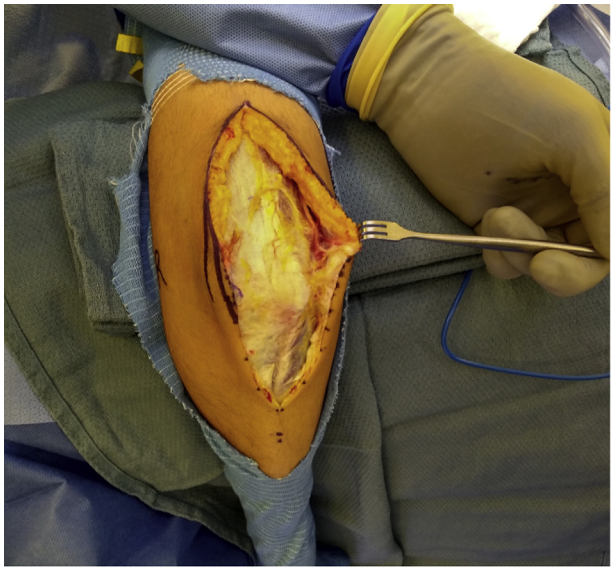

Figure 1 Posterior approach to the elbow. Medial and lateral skin flaps are created and the ulnar nerve is identified.

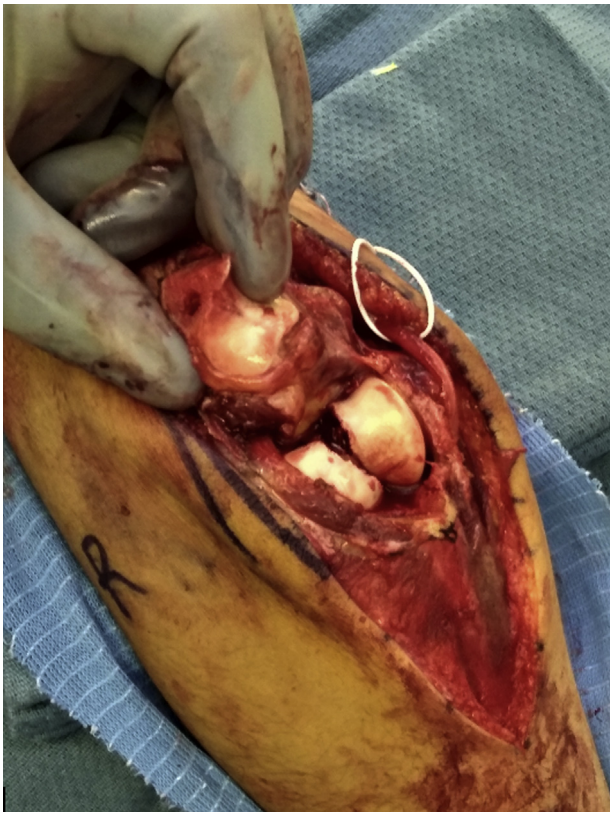

Figure 2 A Chevron olecranon osteotomy is used to gain adequate exposure to the articular surface in severely comminuted, complete articular fractures.

complicated by infection and mechanical failure. Even a successful total elbow entails strict, permanent activity restrictions which may require an active older patient to significantly change their lifestyle.[14-16] We describe a novel surgical technique which we have found produces high rates of union, functional range of motion, and excellent clinical outcomes as defined by QuickDASH and PROMIS scores in even the most fragile, comminuted distal humerus fractures.

Surgical technique

Indications

The primary indication for this operative technique were patients who presented with AO/OTA type B or C distal humerus fractures with significant articular and metaphyseal comminution and an arguably unreconstructible articular surface as determined by the treating surgeon.

Operative technique

Patients are positioned in the lateral decubitus position with the operative arm at 90 degrees of shoulder abduction and elbow at 90 degrees flexion, supported by a firm bump. A sterile, self-contained low-profile tourniquet (HemaClear, OHK Medical Devices, Grandville, MI) is used to limit blood loss. All patients receive perioperative antibiotics (cephalexin or appropriate alternative) before incision. A direct posterior incision is used and dissection is carried out down to the triceps fascia (Fig. 1). Medial and lateral skin flaps are elevated and the ulnar nerve is identified medially and released along the cubital tunnel from the proximal mid-arm down to the two heads of the flexor carpi ulnaris and is tagged with a vessel loop for protection and handling (Fig. 2). In most cases, an olecranon Chevron osteotomy is used to obtain adequate exposure to the articular surface of the distal humerus (Fig. 2). A paratricipital approach may be used if adequate exposure of the articular surface can be achieved without osteotomy. The articular fragments are then identified, aligned anatomically and clamped in compression with reduction forceps. The fragments are then secured utilizing numerous 1.25-mm Kirschner wires passing transversely from the lateral to medial column, creating a rigid articular block with a reconstructed joint surface (Fig. 3). Rather than cutting them off, the long wires are bent 90 degrees proximally and molded to the shaft so they become a critical part of the definitive fixation. The metaphyseal fragments are realigned and fixed provisionally, thereby linking the articular segment and distal humeral shaft (Fig. 3). Polyaxial locking, anatomically contoured distal humerus plate(s) are subsequently utilized to create the final construct (Table I). Before plate application, the long, skinny wires used for the articular block are cut flush along the medial column, bent over the lateral column, and trapped beneath the lateral column plate to prevent migration and effectively to unify them into a fixed-angle fixation device (Fig. 4). If the sharp ends poke out medially, they are cut flush. The plate(s) are then fixed first proximally to the humeral shaft, clamped in compression from medial to lateral to the articular block, and then fixed to the articular segment distally with combination of locking and nonlocking screws. Polyaxial distal locking screws allow for intentional interference placement of screws with the wires, maximizing fixation in the distal articular segment. In no case was there difficulty placing screws due to the existing presence of the wires. Attention is then turned back to the olecranon osteotomy, which is repaired by any appropriate method (tension band wire, an intramedullary screw, or a plate). In our series, a 7.3-mm cannulated screw was used for fixation most often (Table I). Before closure, in 19 (61%) of the previous cases, the ulnar nerve was transposed subcutaneously to avoid contact with the medial plate;

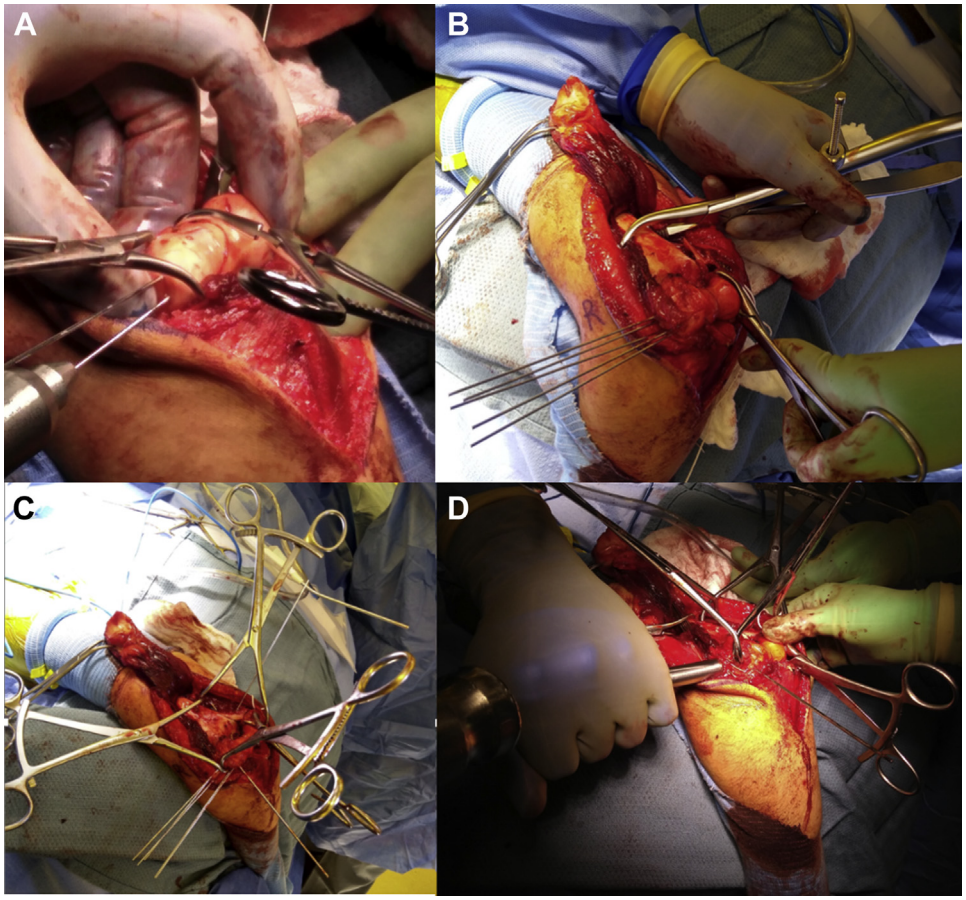

Figure 3 (**A**) Articular fragments are clamped in compression, then transversely fixed utilizing small, nonthreaded K-wires. (**B**) The metadiaphysis is then clamped to the reconstructed articular block. (**C**) Multiple reduction clamps are used for reduction of metaphyseal comminution. (**D**) A wire bender is used to bend the long K-wires over the lateral column.

Table I
Details of procedure and surgical fixation.

Mean time to ORIF (range)	3.5 (0-29) days
ASA score	
2	17 (55%)
3	14 (45%)
Mean (range) operative time (min)	162 (55-390)*
Mean (range) EBL (cc)	108 (10-400)*
Mean (range) length of stay (days)	2.2 (0-8)
Olecranon osteotomy + fixation	26 (84%)
7.3 mm partially threaded screw	21 (81%)
Olecranon plate	4 (15%)
Tension band wiring	1 (4%)
ORIF construct (+ skinny wires)	
Lateral column plate	3 (10%)
Bicolumnar plate	24 (81%)
Bicolumnar + posterolateral plate	2 (9%)

ORIF, open reduction internal fixation; *ASA*, American Society of Anesthesiologists; *EBL*, estimated blood loss.
* One case combined with ORIF proximal humerus.

the remainder were left decompressed in situ. The wound is then irrigated and closed in standard fashion.

Postoperative protocol and follow-up

Patients are splinted in a posterior slab splint postoperatively allowing for 10-14 days of soft tissue rest. Patients do not routinely receive radiation therapy or nonsteroidal anti-inflammatory medication for heterotopic ossification prophylaxis postoperatively. At their two-week visit, early, unlimited range of motion with limited weight-bearing is initiated. No splint, sling, or other orthosis is used beyond two weeks. Range of motion is measured at occupational therapy sessions or postoperative visits using a goniometer. Postoperative radiographs are used to assess healing of the fracture and the osteotomy site. Fig. 5 shows an example of a typical type C distal humerus fracture with significant articular comminution fixed with this technique. Fig. 6 shows the fracture healing with a reconstructed joint surface at three months postoperatively. Fracture healing is assessed by appearance of bridging callus or resolution of radiolucent fracture line combined with clinical assessment of functional pain at the site of the fracture. Patient-reported outcomes (QuickDASH and PROMIS Global 10 Mental and Physical Health scores) are collected prospectively in during clinic visits.

Results

Thirty-two patients with intra-articular distal humerus fractures treated with this novel surgical technique between 2014 and 2019 were retrospectively reviewed. Patients with minimum one year of follow-up were included. Two patients were excluded: one for inadequate follow-up (<3 months) and one for a devastating open injury with significant articular bone loss requiring trochlear interposition arthroplasty. Thirty patients were included in the final analysis. Results are presented as mean (range) or median

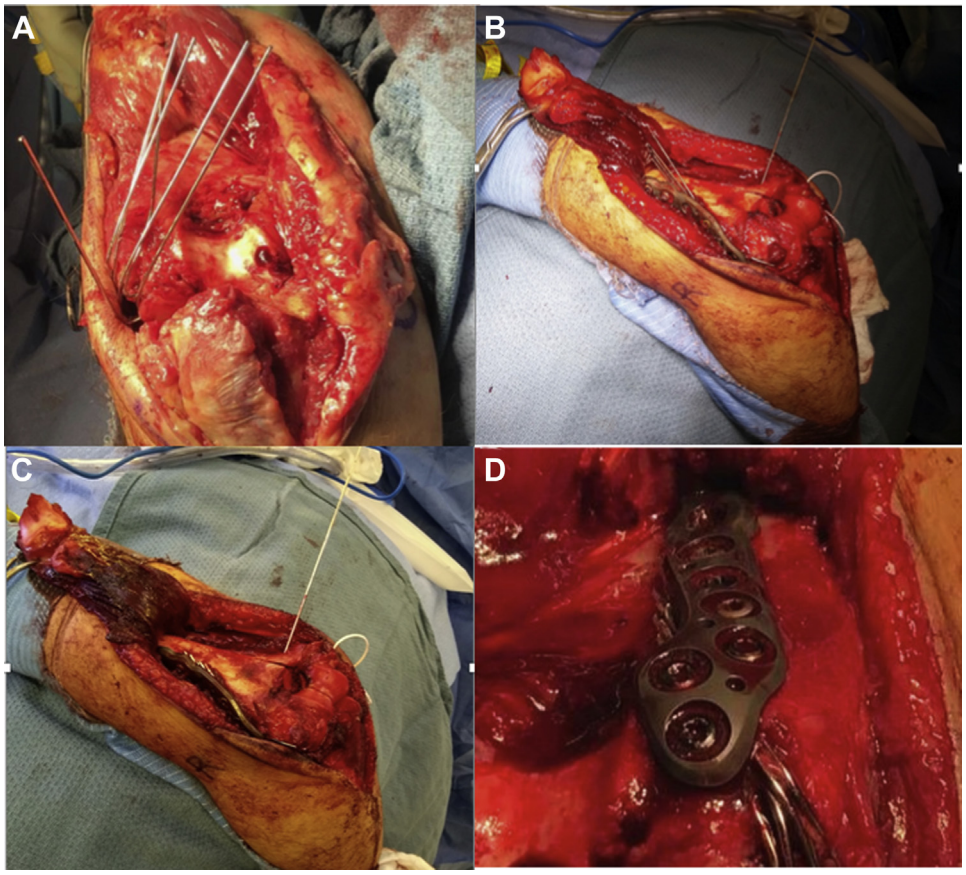

Figure 4 (**A**) K-wires bent over lateral column are shown. (**B**) Lateral column plate is applied, trapping the K-wires deep to the plate, preventing retrograde wire migration. (**C**) The wires are cut flush along the lateral column, avoiding prominent hardware. (**D**) Upclose view of final construct demonstrating wires secured deep to plate.

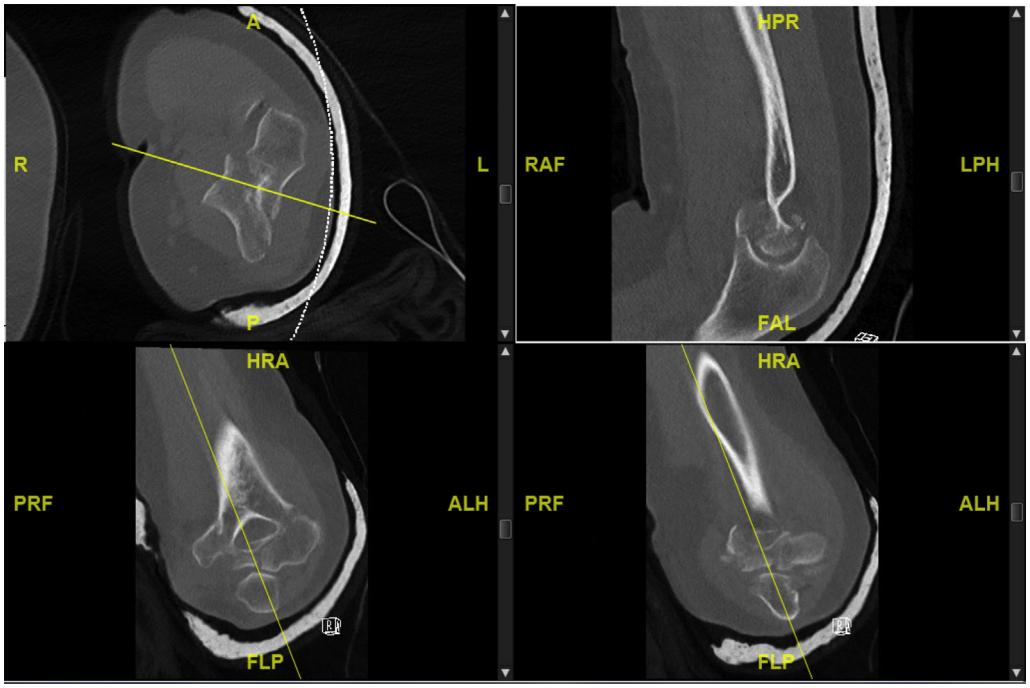

Figure 5 Midsagittal CT scan of a typical type C distal humerus fracture with significant articular comminution.

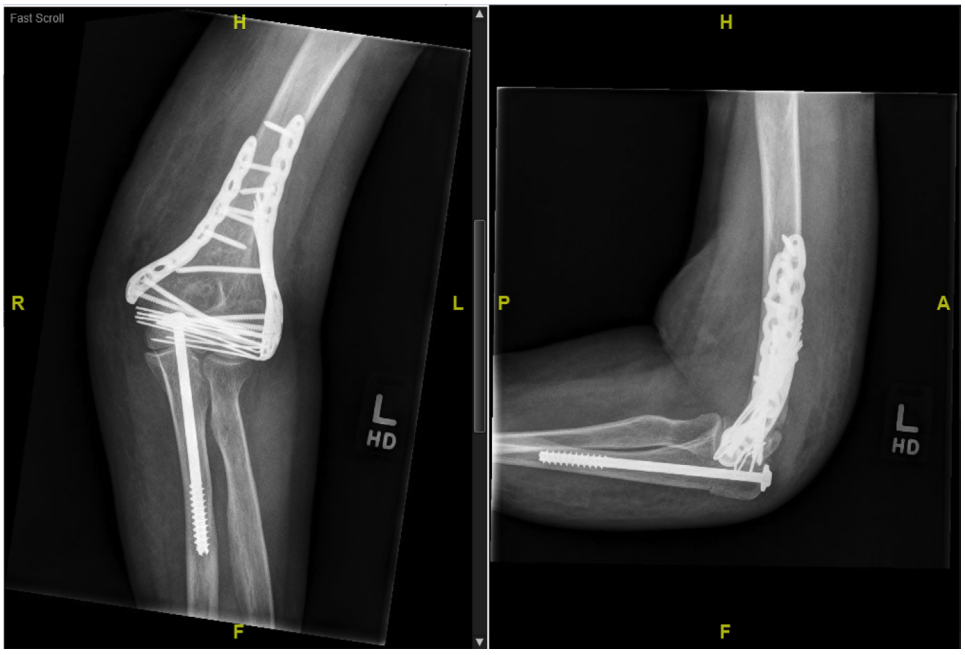

Figure 6 Three month postoperative radiographs demonstrating a healing fracture after utilizing multiple small K-wires to reconstruct the comminuted articular surface and locking plate fixation.

Table II
Injury and fracture characteristics.

Mechanism of injury	
Fall—standing	21 (70%)
Fall—height	5 (17%)
Motorcycle crash	3 (10%)
Gunshot wound	1 (3%)
High energy	10 (33%)
Polytrauma	2 (7%)
Ipsilateral upper extremity injury	5 (16%)
AO/OTA classification	
A type	0 (0%)
B type	3 (10%)
C type	27 (90%)
Affected extremity (% left)	21 (68%)
Open fracture (Gustilo-Anderson)	4 (13%)
1	3 (10%)
2	1 (3%)
3A	0
3B	0
3C	0
Primary nerve palsy	2 (7%)
Brachial plexopathy*	1 (3%)
Ulnar nerve	1 (3%)
Arterial injury	0 (0%)
Compartment syndrome	1 (4%)

* Patient sustained an ipsilateral proximal humerus fracture/dislocation.

(interquartile range) for continuous variables and as percentages for categorical data. Statistical analysis was performed using SPSS software (version 22.0; IBM, Armonk, NY, USA). The patient cohort had a mean age of 59 (19-90) years and a median follow-up of 1.5 (1.1-2.5) years. Sixty-one percent of patients were women and patients had an average BMI of 27.4 (19-49). Smoking and alcohol use were documented in 9.7% and 16.1% of patients, respectively. Medical comorbidities were reported in 74% of patients with osteoporosis (26%), diabetes mellitus (16.1%), chronic immunosuppression (12.9%), coronary artery disease (6.5%), and chronic liver disease (6.5%) the most common. Sixty-four percent of

Table III
Summary of postoperative outcomes and reported complications.

Fracture union	30 (100%)
Mean time to union	11.1 weeks
Ulnar nerve neuropraxia	12 (38%)
Paresthesias	12 (38%)
Motor deficit	1 (4%)
Nerve recovery	10 (83%)
Wound infection	1 (3%)
Heterotopic ossification	1 (3%)
Olecranon nonunion	1 (3%)
Secondary procedures	11 (35%)
Removal hardware	8 (26%)
Capsular release	3 (10%)
Ulnar nerve transposition	2 (6%)
Excision heterotopic ossification	2 (6%)
Total elbow arthroplasty	1 (3%)

Table IV
Functional and patient-reported outcomes.

Pain (NRS)	
None (0)	17 (54.8%)
Mild (1-3)	10 (32.3%)
Moderate (4-6)	4 (12.9%)
Severe (7-10)	0 (0%)
Range of motion	
Arc of motion	104 (45-140) degrees
Flexion	125 (90-160) degrees
Extension	−18 (−45 to 0)
Mean (SD) QuickDASH	24.0 (20.2)
Mean (SD) PROMIS (Global 10)	
Mental	53.8 (8.9)
Physical	49.6 (7.8)
Return to work/activity	
Retired—ADLs only (n = 9)	9 (100%)
Laboring occupation (n = 12)	10 (83%)
Office worker (n = 8)	8 (100%)
Physical activity (n = 2)	2 (100%)

NRS, numerical rating scale; *SD*, standard deviation; *ADLs*, activities of daily living.

patients were working at the time of injury, 38% in laboring professions. The remainder were retired or unemployed.

Most patients fractured their distal humerus as a result of a ground level fall. The remainder were high-energy mechanisms of injury. Table II presents details on fracture classification, injury mechanisms, concurrent injuries, classification of open fractures, and relevant nerve and vascular injuries. Three patients had extraordinary circumstances. One patient sustained severe polytrauma as a result of a motorcycle crash. His injury burden included renal contusion, transverse process fractures, contralateral intertrochanteric femur and distal radius fractures, an ipsilateral tibial plateau fracture, and an ipsilateral proximal humerus fracture-dislocation resulting in a brachial plexus injury. A second patient sustained a Gustilo-Anderson grade 3A open fracture which required three irrigation and débridement procedures before definitive fixation, which involved interposition arthroplasty of the trochlea using triceps tendon autograft due to significant bone loss. Finally, a third patient sustained an ipsilateral both bone forearm fracture and underwent fasciotomy for evolving symptoms of compartment syndrome. In all 31 cases, fractures healed at mean time of 11 weeks. At final follow-up, most patients reported low levels of pain, a functional arc of motion, excellent PROMs, and high rate of return to work or activity in both laboring (ie, fire fighter, security guard, operating room technician, construction, gymnastics coach) work and activities (ie, kayaking, yoga, weightlifting) as detailed in Table III. There was a 38% postoperative complication rate and 35% reoperation rate, details of which are presented in Table IV. Transient ulnar neuropathy occurred at a rate of 38.7% and was higher when the ulnar nerve was transposed (52.6 vs. 16.7%, $P = .045$).

Discussion

For extra-articular or simple intra-articular distal humerus fractures in patients with good bone mineral density, conventional plating techniques alone are a good option. Union rates of 92%-100% with good to excellent range of motion, low pain, and good functional outcome scores have been achieved in multiple studies looking at modern techniques with both parallel and orthogonal configurations of plates and screws—precontoured, locking, or nonlocking.[1,2,4-7,9,10,12,20]

However, in low intercondylar fractures with a high degree of comminution in osteoporotic bone, engaging the small articular fragments with distal screws is challenging. More recently, surgeons have foregone fixation for total elbow arthroplasty (TEA) given the challenging nature of reconstructing the articular surface in these fragile, comminuted fractures. Frankle et al demonstrated superior clinical outcomes and significantly less revision surgery with total elbow arthroplasty compared to ORIF in women older than 65 with intra-articular distal humerus fractures.[3] However, there is a high-rate infection and revision with total elbow arthroplasty. Prasad et al reported a 31% rate of aseptic loosening, although only two patients were symptomatic and required revision surgery[16] and Peretta et al reported a 57% revision rate when total elbow was indicated for trauma. Survival was 75% at five years and 55% at 10 years for all total elbows.[15] TEA is far from the perfect solution for low, comminuted intra-articular distal humerus fractures. It serves most appropriately for low-demand patients who can better tolerate the activity restrictions imposed on them by a total elbow arthroplasty procedure.

Here, we describe a technique that offers patients with highly comminuted fractures and poor bone quality a potentially better option than TEA. In our study, 100% of fractures healed at mean time of 11 weeks. This construct withstood an early active range of motion protocol, resulting in a functional mean arc of motion of 102 degrees. Our surgical technique focuses on first achieving direct anatomic reduction of the articular surface, clamping the spool in compression, and capturing the small articular fragments using multiple Kirschner wires. This first creates a solid articular block, and by bending these wires and unifying them to the shaft, it effectively makes them into a fixed angle construct. Pin pull out is nearly impossible as our wires are left long, bent over the lateral column, and secured deep to the lateral column plate. Although we developed this independently, we note that in 2012, Kamrani et al described a similar “pin and plate” technique using articular wires. However, they secured their wires proximally in one spot with a 3-hole recon plate, risking wire migration distally at the bone/wire interface.[8] They reported a high union rate with good ROM and DASH scores. However, they could not attribute all of their success to their technique as it was used in combination with Herbert screws and tension band wiring in multiple cases. In our study, the same technique was used in all patients. We report a mean arc of motion of 104 degrees, low pain score, and excellent QuickDASH and PROMIS scores. Even the oldest and most osteoporotic patients have been able to return to their normal activities of daily living. Younger ones have returned to laboring and physically demanding jobs, and activities they enjoy, without restriction.

This technique has its complications, as does any way of managing these challenging injuries. Rates of postoperative complications after distal humerus fixation are reported as high as 44-53%.[12,17-20] Nonunion, hardware failure, heterotopic ossification, ulnar nerve paresthesias, and symptomatic hardware are the most common. Olecranon nonunion is a potential problem when osteotomy is used to access the articular surface. Nonunion rates following ORIF of distal humerus fractures are reported to be between 2 and 10%.[18,21] In the present study, there were zero nonunions of the distal humerus, similar to results of more recent published series of simpler fractures.[21] Heterotopic ossification (7-9%) is a significant problem after ORIF of distal humerus fractures, causing stiffness and pain which calls for reoperation.[5,12,18,19,21,23] In our series, one patient formed heterotopic bone requiring excision with subsequent improvement in motion. Infection rates are reported from 6 to 15% based on two large systematic reviews of distal humerus fractures.[18,21] Ulnar nerve paresthesias are very common after ORIF with rates ranging from 0 to 51%.[2,11,13,18,21,22] A recent meta-analysis published in 2018 found the rate ulnar nerve injury after distal humerus fixation to be 19.3%.[19] In our study, we report a 38% rate of postoperative ulnar nerve paresthesias although 10 of 12 (83%) experience improvement by the final follow-up. There was a higher rate of postoperative paresthesias when ulnar nerve transposition was used (53% vs. 17%, $P = .045$). One patient developed ulnar nerve motor weakness and intrinsic wasting which did not recover. Symptomatic hardware was also common in our practice with 26% of patients undergoing hardware removal. Recent studies have reported similar rates of hardware removal between 12 and 31%.[2,10,20]

We acknowledge the limitations to our study and surgical technique. All these surgeries were performed by a single orthopedic surgeon whose practice is mostly complex upper limb trauma, and thus it may not be generalizable to all treating orthopedic surgeons. The surgical technique is associated with a high rate of secondary procedure, particularly removal of hardware. Elbow range of motion was functional, but still limited. There was a high rate of ulnar paresthesias, particularly when the ulnar nerve was transposed. It is unclear how much is attributable to initial nerve injury in the setting of severe soft tissue trauma, and how much from the technique itself. Our study is retrospective and some data are inconsistently reported or incomplete in the electronic

medical records. Physical examinations were not standardized with the goal of collecting data for research purposes. However, the most important clinical data were captured consistently including elbow ROM, functional scores, and patient-reported outcome scores. As with most trauma studies, follow-up is short. It is our practice to obtain radiographs only until the fracture unites, unless there is a clinical reason for more. Because 100% of fractures healed, this leaves the possibility of missing radiographic evidence of asymptomatic post-traumatic arthritis. Furthermore, given the short duration of follow-up, it is possible more patients will request hardware removal at a later date. It is also possible that patients who later develop post-traumatic arthritis would report greater pain and lower functional outcome score. QuickDASH and PROMIS scores could worsen with longer follow-up.

Conclusion

We describe a novel surgical technique that addresses the problem of achieving adequate fixation in very distal articular humerus fractures with significant comminution and poor bone quality. We believe our method of fixation may spare patients the need for a total elbow arthroplasty, providing good to excellent clinical outcomes without activity restriction. Further comparative study comparing the two groups directly would be helpful in drawing a more substantiative conclusion. In our series, we achieved 100% union rate in all patients with minimum one year of follow-up. Patients reported low levels of postoperative pain, achieved reasonable elbow range of motion, and had excellent patient-reported outcome scores at the final follow-up. They were permitted any degree of motion and weight-bearing after healing and many returned to physical work (eg, construction, fire-fighting, demolitions), or high-demand leisure activity (eg, kayaking, yoga, rock-climbing). Complication and reoperation rates remain high but comparable with other techniques used to treat these injuries. Patients should be counseled preoperatively about the risk of ulnar nerve paresthesias that should be expected to recover and symptomatic hardware that may warrant a second procedure.

Conflicts of interest

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Funding

No funding was disclosed by the authors.

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