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Distal humerus fractures: review of literature, tips, and tricks

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Distal humerus fractures represent 2% of all fractures with an increasing incidence of 5.7-8.3 fractures per 100,000 persons per year.[17,21] These injuries typically occur in a bimodal distribution of high energy younger male patients and low energy older female patients.[17]

Distal humerus fractures can be challenging to treat due to complex anatomy, unique biomechanical forces, poor bone quality in the elderly, and need for early range of motion. Treatment options typically include nonoperative management, open reduction internal fixation (ORIF), or total elbow arthroplasty (TEA). Nonoperative treatment is generally reserved for stable fracture patterns that are not or minimally displaced, or patients who are low demand and have high surgical risks. TEA has become an increasingly popular salvage option for severely comminuted distal humerus fractures in elderly patients. However, its use remains limited in younger patients due to high rates of complication and poor long-term survival.[24] Therefore, ORIF remains the predominant treatment of choice for a majority of these injuries.

Successful operative fixation of distal humerus fractures can be technically challenging. There are multiple considerations when choosing the best surgical strategy for ORIF including preoperative imaging, positioning, approach, fixation constructs, ulnar nerve management, and postoperative rehabilitation. The aim of this article is to review the available literature regarding these variables as well as provide technical tips for successful ORIF of distal humerus fractures.

Preoperative imaging

Initial imaging studies typically involve obtaining a standard elbow series, consisting of anterior-posterior and lateral radiographs (Fig. 1). In the setting of significant articular comminution, superimposed fragments can make these images difficult to interpret. Further imaging in the form of 2-dimensional computed tomography (2D CT), 3-dimensional CT (3D CT) scans or traction radiographs can be helpful to better define the fracture pattern and aid in preoperative planning (Fig. 2).

Traction radiographs allow for improved visualization of the fracture fragments through ligamentotaxis. In a study comparing traction radiographs to 2D CT, Galloway et al found that while traction radiographs provided similar diagnostic characteristics as 2D CT, CT improved identification of coronal fracture lines and articular comminution for less-experienced surgeons.[9] Although traction radiographs may provide helpful information, the process of obtaining them can be painful and poorly tolerated by patients. In addition to 2D CT, 3D CT reconstructions have been shown to help understand the orientation of the fracture fragments, degree of comminution, articular involvement, and to assist in preoperative planning.[4] In a comparative study of these imaging modalities, Brouwer et al found the addition of 3D CT to 2D CT and radiographs significantly improved sensitivity in the diagnosis and proposed treatment strategy and improved interobserver agreement with respect to fracture characteristics.[5] The authors prefer to use 2D CT and 3D CT reconstructions as it does not subject patients to the discomfort of traction radiographs, and it provides more information regarding the position of fragments and their spatial relationships.

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Figure 1 AP and lateral radiographs of the elbow demonstrating a comminuted, intra-articular distal humerus fracture. *AP*, anterior-posterior.

Figure 2 3D CT reconstruction of the distal humerus with subtraction of the radius and ulna can allow better characterization of the fracture pattern prior to surgery. *3D*, three dimensional; *CT*, computed tomography.

Set up and positioning

Posterior approaches remain the workhorse for distal humerus fixation. For this reason, this section will focus on set up and positioning for the posterior approaches. For ease of a posterior approach to the distal humerus, patients are typically positioned either lateral decubitus or prone with the injured extremity placed over a radiolucent support. Both prone and lateral decubitus positioning carry advantages and disadvantages that should be considered when selecting patient positioning. Prone positioning allows for improved intraoperative fluoroscopic imaging by eliminating the contralateral "down" arm which can obscure the anterior-posterior view in the lateral decubitus position. Another advantage of prone positioning is that the elbow can be positioned further away from the bed than it can in a lateral decubitus position, which allows for improved ease of access of the fluoroscopy machine for lateral views of the elbow. Disadvantages of the prone position include increased risk of blindness from pressure on the eyes, abdominal compartment syndrome, lateral femoral cutaneous neuropathy, and difficulty with the management of airway complications or cardiac arrest. In addition, prone positioning may not be permitted in polytraumatized patients with unstable abdominal, spine, or facial injuries. Lateral decubitus positioning avoids the anesthetic risks associated with prone positioning but can make obtaining adequate fluoroscopic images more difficult.

The authors prefer to use a diving board radiolucent attachment at the head of the bed, the bed turned 90°, the c-arm entering from the head parallel to the bed, and with the patient in prone positioning in the absence of anesthetic issues or other injuries that would preclude its use (Fig. 3).

Posterior approach and triceps management

Approaches to the distal humerus include direct posterior, direct medial, and direct lateral. The direct posterior approach remains the workhorse for distal humerus fracture fixation. For this reason, this section will focus on these posterior approaches with a particular emphasis on triceps management. There are multiple posterior approaches that can be used for ORIF of distal humerus fractures. These can be broadly categorized based on management of the triceps: triceps sparing and triceps off approaches. Several different techniques have been described. The most commonly used triceps sparing approaches include paratricipital approach[23] and triceps splitting, also known as the Campbell approach.[35] Triceps off approaches include olecranon osteotomy described by Jupiter et al,[12] the triceps reflecting described by Bryan and Morrey et al,[6] triceps-reflecting anconeus pedicle described by O'Driscoll et al,[18] and the anconeus flap transolecranon approach described by Athwal et al.[2]

In general, the triceps off approaches create better exposure of the articular surface but also have higher rates of complications including nonunion and delayed union of the osteotomy site, hardware prominence, and wound complications. Specifically for the olecranon osteotomy, a recent meta-analysis performed by Spierings et al found a 3.7% rate of issues with union (2% nonunion and 1.7% delayed union) and a rate of infection of 4.2% (1.4% deep and 2.8% superficial).[27]

There have been several anatomic studies performed to evaluate the extent of exposure obtained with these approaches. In the first comparative study performed, Wilkinson and Stanley found that the triceps splitting, triceps reflecting, and olecranon osteotomy exposed 35%, 46%, and 57% of the articular surface of the distal humerus, respectively.[31] More recently, Amemiya et al performed a similar study which compared anterior, posterior, and total exposures for the lateral paraolecranon, bilaterotricipital, and olecranon osteotomy approaches. They found that the bilaterotricipital

Figure 3 Preoperative patient positioning photo demonstrating the authors preferred approach of prone positioning with the arm supported by radiolucent popsicle sticks and a stack of several blankets.

exposed 25.3% of the articular surface compared to 46.4% for the lateral paraolecranon approach, and 58.5% for the olecranon osteotomy approach. In addition, the olecranon osteotomy allowed for the best visualization of the anterior aspect of the articular surface which can be helpful in fracture patterns with significant anterior comminution or central depression.[1]

The authors use the following algorithm for the surgical approach to bicolumnar distal humerus fractures. For extra-articular fractures, the author uses a standard paratricipital approach with medial and lateral windows. For simple intra-articular fracture patterns, an anconeus flap is created in a manner similar to that described by Athwal et al. In these cases, the lateral paratricipital window is extended distally, dividing the fascia overlying the anconeus muscle at the interval with the extensor carpi ulnaris. The anconeus is kept in continuity with the triceps, for preservation of the neurovascular supply to the anconeus from the terminal branch of the radial nerve.[2] The anconeus muscle is elevated medially toward the ulna, off the posterolateral elbow capsule, which is then excised for direct visualization of the capitellum, radiocapitellar joint, and lateral trochlea (Fig. 4). The anconeus flap, combined with a standard medial paratricipital window, can often provide sufficient access and visualization to anatomically reduce simple intra-articular fractures, including patterns with fractures through the central trochlea. In the setting of complex intra-articular fracture patterns with central trochlea comminution, the authors prefer to extend the anconeus flap elevation off the proximal ulna and include an olecranon osteotomy as described by Atwal et al[2] (Fig. 4).

Several fixation methods of the olecranon osteotomy have been described including tension band, single intramedullary screw, plate and screw constructs, and a combination of a tension band and intramedullary screw. When selecting a method of fixation, risk of complications including infection, nonunion, loss of reduction, and hardware irritation should be considered. The literature regarding olecranon osteotomy fixation is limited to retrospective reviews. Previous literature has found tension band constructs have the highest overall complication rate. Reported implant removal rates vary considerably. In a review of olecranon osteotomy fixation, Meldrum et al found the rate of hardware removal to be highest in tension band constructs (44%), followed by plate fixation (33.3%), and lowest with intramedullary screw fixation (0%).[14] Woods et al published a similar retrospective review which found similar implant removal rates other than a slightly higher rate of intramedullary screw removal (15.4%).[32]

Rates of nonunion after olecranon osteotomy have been reported between 3.3% and 13.3%.[14,32] Woods et al reported the odds of nonunion to be 10.06 times higher for tension band constructs when compared to screw fixation. There was no significant difference in nonunion rates when screw fixation was compared to plate construct or a combination tension band and screw construct. Regardless of fixation construct, more comorbid patients were found to be at higher risk of nonunion.[32]

The author prefers to fix the osteotomy with a self-contoured 2.7 mm minifragment plate and screw construct because it provides secure fixation, maintains the reduction, and is low profile with a low rate of hardware removal and soft tissue irritation. Regardless of the method of fixation chosen, placing and removing the hardware, including screws, prior to making the osteotomy allows for improved ease of reduction of the osteotomy site at the conclusion of the case (Fig. 5). The author prefers to position the plate and only insert the screws that cross the osteotomy site. The holes distal to the osteotomy site are not predrilled as the bone loss from the kerf of the saw blade when making the osteotomy may shift the plate distally. All the hardware is then removed prior to completion of the osteotomy.

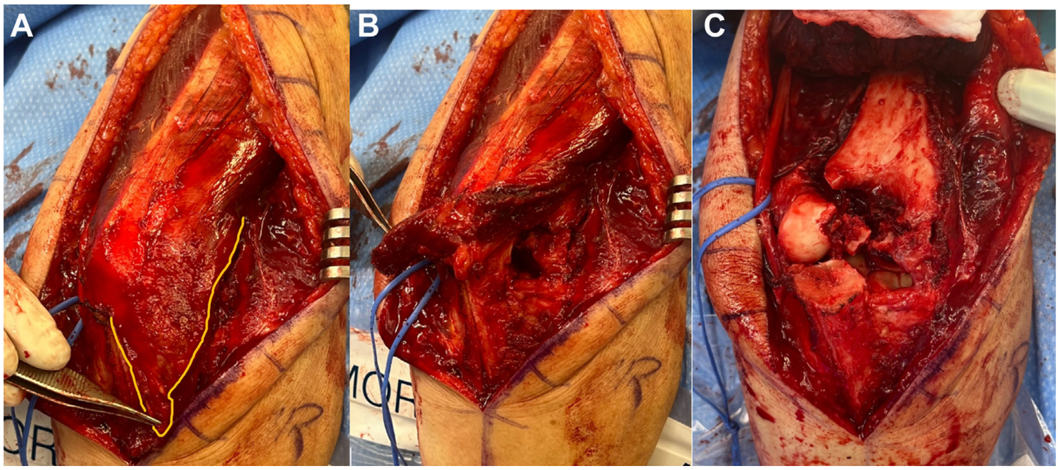

Figure 4 Intraoperative photo demonstrating visualization (**A**) before elevation of the anconeus flap, with the anconeus outlined in ▬▬, (**B**) after elevation of the anconeus flap, and (**C**) after an olecranon osteotomy.

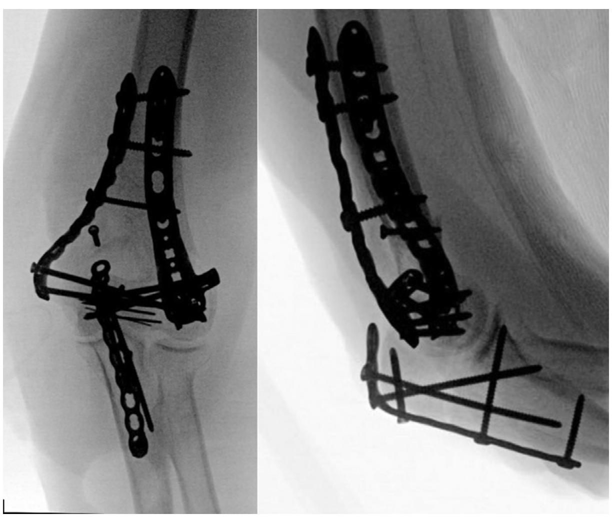

Figure 5 AP and lateral radiographs demonstrating the authors preferred olecranon osteotomy fixation using a self-contoured 2.7 mm minifragment plate and screw construct. *AP*, anterior-posterior.

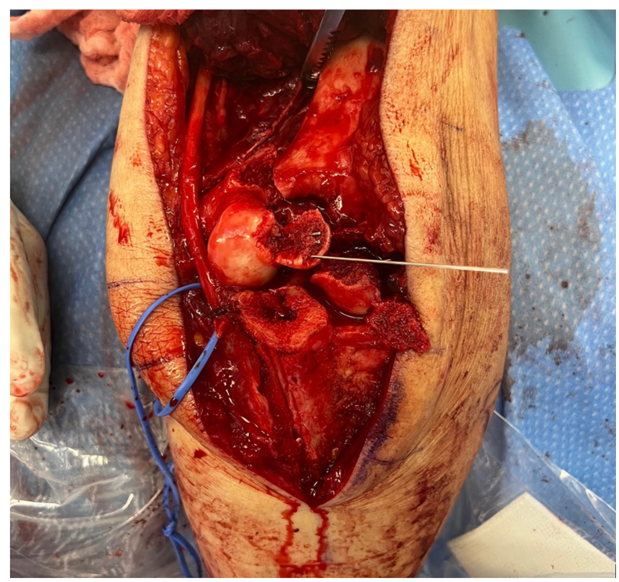

Figure 6 Intraoperative photo demonstrating use of threaded k-wires to piece back complex intra-articular fracture fragments.

Fixation construct

The goal of distal humerus fracture internal fixation is to achieve an anatomic reduction of the articular surface and to secure the articular segment to the humeral shaft with anatomic alignment. Provisional fixation may be achieved in numerous ways. The authors typically use a combination of point-to-point clamps, k-wires, and sometimes minifragment plates in cases of severe comminution to provisionally hold the reduction once achieved. In cases with significant comminution or bone loss, the authors prefer to start with fixation of the column with a simpler fracture pattern, which provides a more accurate foundation to which the more complicated segment can be reduced to. A useful technique for securing multiple articular fragments is using fully threaded wires, either 0.9 or 1.1 mm diameter. Placed subchondral, these can then be cut flush with the bone and be used to hold free articular fragments together (Fig. 6). Additionally, for articular fragments without substantial subchondral bone, bioabsorbable k-wires may be placed through the articular surface of the fragment to obtain fixation and cut flush to the articular surface. Another technique for reconstruction of multifragmentary articular fractures described by Olson and Dyer rebuilds the articular surface using many k-wires passed transversely through small fragments from the lateral to the medial column. These k-wires are then bent over the lateral column and trapped under the lateral column plate to theoretically create a fixed angle construct to support the metadiaphysis.[19]

Additionally, fixation of the medial and lateral columns must be stable enough to allow for early elbow range of motion. Fixation constructs have been described by the positioning of the medial and lateral plates including parallel plating, which refers to a direct medial plate and direct lateral plate, and orthogonal plating (also described as 90-90 plating or perpendicular plating), which refers to a direct medial plate and posterior plate along the lateral column (Fig. 7). Previous biomechanical studies have demonstrated superior stiffness in bending, rotational stability, and axial load strength for parallel plating when compared to orthogonal plating.[13,25,29] Clinically, this has translated to a lower rate of fixation failure requiring revision for parallel plating compared to orthogonal plating (1% vs. 6%). Despite this, parallel plating has been found to

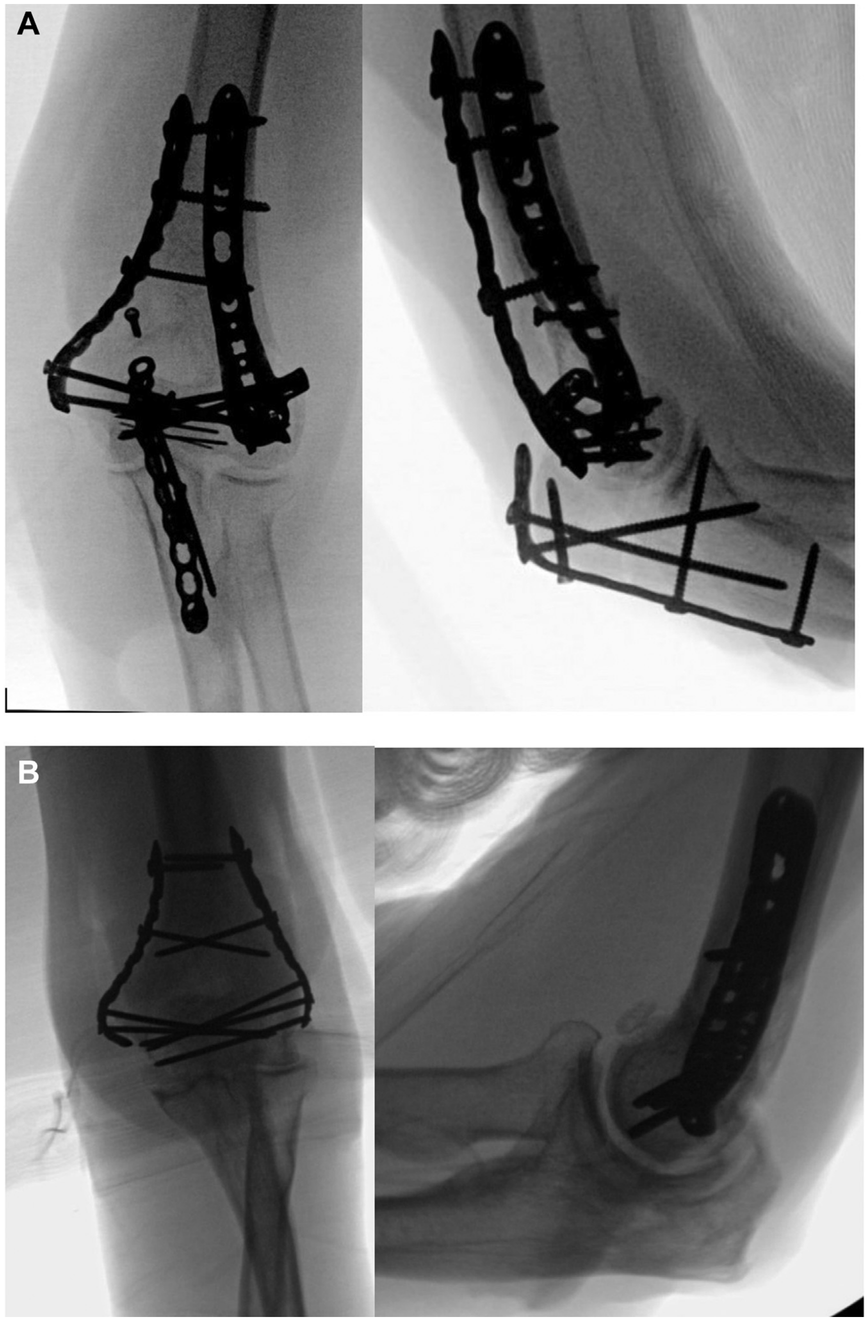

Figure 7 AP and lateral radiographs of the elbow demonstrating (**A**) an orthogonal plating construct with additional lateral support to allow for transcondylar screw placement into the medial condyle and (**B**) a parallel plating construct.

have a higher overall complication rate (54% vs. 45%) and higher overall reoperation rate (24% vs. 16.5%) when compared with perpendicular plating. The higher complication rate in parallel plating is driven by higher rates of ulnar neuritis (13% vs. 9%), implant prominence (7% vs. 3%), wound dehiscence (5% vs. 0.1%), and removal of hardware (17% vs. 7%).[33]

More recently, an orthogonally based plate configuration with an additional lateral tab for screw placement has been developed which allows for a transcondylar screw placed through the lateral epicondyle in the lateral to medial direction to achieve increased fixation. In a biomechanical analysis comparing an orthogonal plating system with and without a transcondylar screw through the support of the dorsolateral plate, Hara et al found no differences in regards to stability with ulnar or radial compression.[11] When using either a direct medial or direct lateral plate, the authors will not disrupt overlying the soft tissue and tendon attachments on the epicondyles and will place the plates over top of them.

Ultimately, the final fixation construct is driven by multiple factors including fracture complexity, morphology, and bone quality. In situations where patients have segmental column injuries, bone loss, or poor bone quality, augmented stability of the medial and lateral columns can be beneficial. Strategies to achieve this are medial and/or lateral column screws or minifragment plating in addition to standard plating (Fig. 8). Minifragment plates are particularly helpful for smaller fracture fragments that require additional fixation by allowing for a higher density of screws placed in these pieces. When possible, the authors advocate to place screws through the plates; however, there are times this is not

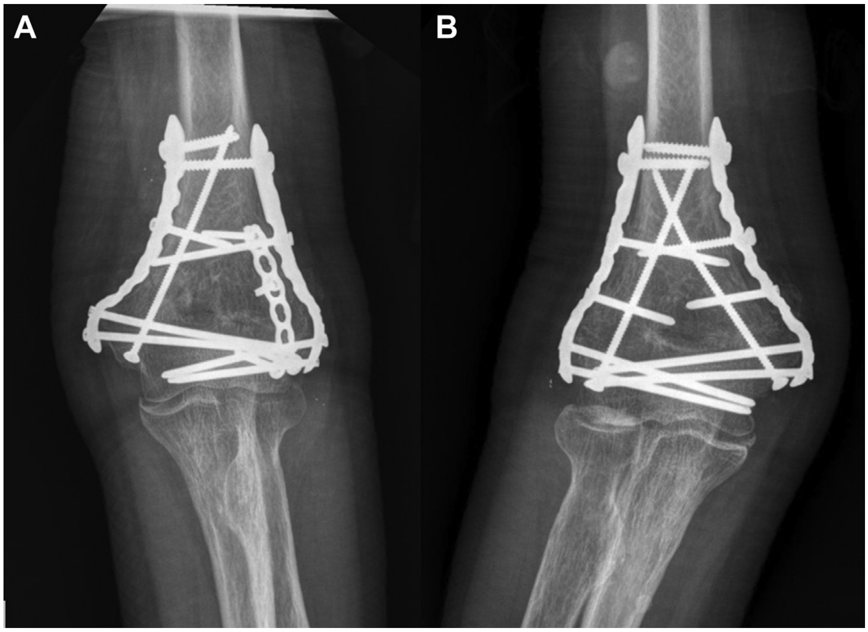

Figure 8 AP radiographs of the elbow demonstrating addition of (**A**) minifragment plates and a medial column screw and (**B**) medial and lateral column screws to augment fixation of the medial and lateral columns.

possible or necessary. Examples of this include independent lag screws to compress the articular surface, oblique fracture patterns in the metadiaphyseal region, or independent column screws. One tip for placing independent column screws in noncomminuted fracture patterns is to reduce the column and provisionally secure this with a bicortical 2.0 k-wire along the column. After plates and screws have been placed, the column wire can then be exchanged for a 2.7 mm cortical screw with an unblocked pathway.

Management of the ulnar nerve

Management of the ulnar nerve after ORIF of distal humerus fractures remains debated. There is not a consensus whether to leave the decompressed ulnar nerve in situ or to transpose the nerve anteriorly. A meta-analysis performed by Shearin et al found an incidence of ulnar neuropathy to be 15.3% in the in-situ decompression group and 23% in the decompression and transposition group.[26] However, this meta-analysis was limited by the retrospective nature of the studies included. In addition, the nonrandomized design of the studies included allows for introduction of selection bias. For example, it is possible that patients with preoperative ulnar nerve symptoms were more often selected for transposition. In contrast to these results, a randomized control trial of 58 patients performed by Dehghan et al found no significant difference in ulnar nerve entrapment score, Mayo Elbow Performance Score, Visual Analog Scale, and 2-point discrimination at any time point between patients who underwent anterior transposition and those who did not.[7] In the absence of preoperative ulnar nerve paresthesia or ulnar nerve subluxation, the author prefers to leave the nerve decompressed in situ and prevent subluxation by eliminating the anterior space and suturing the medial soft tissues to the medial epicondyle.

Postoperative plan

Post-traumatic elbow stiffness is a major cause of functional impairment following elbow trauma and surgery. Morrey et al described a functional 100° arc of elbow flexion and extension from 30° of flexion to 130° of extension and 100° arc of rotation from 50° of supination to 50° of pronation which allows completion of most activities of daily living.[15] More severe elbow stiffness following surgery is associated with higher energy trauma, more complex fracture patterns, injury-surgery interval more than 7 days, and prolonged immobilization.[30,34] In a retrospective review of 75 patients who underwent ORIF distal humerus, Tunali et al found improved functional scores in patients with more than 100° of flexion and extension after surgery when compared to those with less than 100°.[30] Similarly, in a retrospective review of 18 patients undergoing ORIF type C intra-articular distal humerus fractures, Pajarinen et al found immobilization exceeding 3 weeks associated with elbow stiffness and worse outcomes.[20]

The authors use a short period of immobilization for wound healing with early range of motion protocols to reduce the complication of postoperative stiffness. The authors follow a standard postoperative protocol with the patient's elbow splinted in approximately 30° flexion and neutral rotation. Strict elevation is encouraged to help with edema control. Shoulder, wrist, and finger range of motion are encouraged immediately postoperatively. The immobilization period lasts for 7-10 days to allow the incision to heal. This period is followed by passive, active-assisted, and passive gravity-assisted range of motion. Resistance exercises are started when there is radiographic evidence of fracture healing, which typically occurs between 8 and 12 weeks.

Another postoperative consideration is heterotopic ossification (HO), which is a well-described complication of distal humerus fractures following operative fixation. In a retrospective review performed by Foruria et al, HO occurred in 42% of patients with operatively managed fractures distal humerus fractures. These patients had significantly less extension and more limited flexion than those without HO. Risk fractures for HO formation include concomitant head injury, longer time to surgery, dual plating fixation constructs, and use of bone graft.[8] Options for HO prophylaxis include postoperative nonsteroidal anti-inflammatory drugs (NSAIDs) and single-dose radiation therapy. There remains debate in the literature whether HO prophylaxis after operative management of distal humerus fractures is effective with these modalities.

Additionally, there is concern both modalities may inhibit fracture healing.[10,16]

A prospective randomized control trial performed by Hamid et al evaluating the use of radiation therapy as prophylaxis for HO following elbow trauma found no difference in prevalence of HO between the treatment group and control group. However, this study was terminated early due to unacceptably high nonunion rates.[10] Conversely, a retrospective review evaluating the efficacy of a single-dose radiation therapy after ORIF distal humerus for HO prophylaxis performed by Robinson et al found it to be safe and effective.[22]

While use of NSAIDs for HO prophylaxis following hip surgery is well described, the evidence for its use following elbow trauma and surgery is lacking. In a retrospective review of 152 patients, Sun et al found a course of celecoxib after open arthrolysis for elbow stiffness due to HO was associated with lower rates of HO recurrence and lower severity of recurrence.[28] In contrast, in a retrospective review of patients undergoing operatively managed elbow trauma, Bochat et al found use of NSAIDs postoperatively did not affect the incidence of HO.[3]

The authors do not routinely use either radiation therapy or NSAIDs for HO prophylaxis.

Conclusion

Distal humerus fractures are a debilitating injury for patients and a complex treatment challenge for orthopedic surgeons. Although some cases can be managed nonoperatively or with TEA, these options are only suitable for a small subset of patients. Successful operative fixation can be technically challenging, and the preoperative plan often varies based on fracture morphology and patient characteristics. The authors have identified techniques for improving patient positioning, developing appropriate exposure, reducing and fixing the fracture, and guiding postoperative rehabilitation to optimize patient outcomes.

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