A Review Paper

Operative Treatment of Intra-Articular Distal Humerus Fractures

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Abstract

Intra-articular distal humerus fractures can be among the most challenging injuries treated by orthopedic surgeons. The goals of surgical treatment are anatomical restoration of the articular surface and stable fixation of the fracture fragments to allow for early motion. However, the bone stock of the distal humerus is limited, and stable fixation may be difficult to achieve in the case of a low fracture pattern, comminution, or osteoporosis. In this article, we provide practical recommendations for surgical management of these complex fractures.

Intra-articular distal humerus fractures can be among the most challenging injuries treated by orthopedic surgeons. The goals of surgical treatment are anatomical restoration of the articular surface and stable fixation of the fracture fragments to allow for early motion.[1-4] However, the bone stock of the distal humerus is limited, and stable fixation may be difficult to achieve in the case of a low fracture pattern, comminution, or osteoporosis. In this article, we provide practical recommendations for surgical management of these complex fractures.

Preoperative Evaluation

A focused history should assess prior trauma and function of the extremity, functional demands of the patient, and medical comorbidities. Physical examination should start with a thorough evaluation of the neurovascular status of the extremity. Vascular examination may reveal a diminished or absent pulse, which may be restored with fracture reduction. If, after reduction, the perfusion of the extremity is compromised, then angiography or exploration is warranted. Neurologic examination may reveal an associated nerve injury. Inspection of the extremity should focus on assessment of the soft-tissue envelope to detect any open fracture wounds.

Radiographic assessment includes standard anteroposterior and lateral plain films. We have found traction anteroposterior views to be helpful for assessing fracture morphology. Computed tomography provides more details about the fracture pattern, especially with 3-D reconstructions with subtraction of the proximal ulna. However, direct, intraoperative visualization of the fracture site may reveal a fracture line not well visualized during preoperative evaluation, especially in gunshot injuries.

Intra-articular fractures of the distal humerus are classified with the Mehne and Matta system as 1-column fractures (medial or lateral column), 2-column fractures (T, Y, H, or lambda), or fractures involving the capitellum or trochlea (not covered in this article).

Surgical Treatment: Open Reduction and Internal Fixation

Indications

Intra-articular distal humerus fractures should be treated surgically. The treatment of choice is open reduction and internal fixation (ORIF); restoration of articular surface congruency minimizes development of arthrosis, and stable fixation allows early motion and maximizes the functional outcome. Total elbow arthroplasty is reliable for elderly patients who have severely comminuted fractures not amenable to stable osteosynthesis.[5] Kamineni and Morrey[5] retrospectively reviewed 43 fractures in 43 patients (mean age, 69 years) who were followed for at least 2 years (mean follow-up, 7 years). At the latest follow-up, mean flexion arc was 24° to 131°, and mean Mayo Elbow Performance Score was 93 (maximum, 100 points). Fractures in high-risk surgical candidates may be treated nonoperatively.

Anesthesia, Positioning, Preparation

General endotracheal anesthesia with muscle relaxation is preferred. The patient can be in supine, lateral, or prone position based on surgeon preference. The supine position with the arm positioned over the chest, which is safe for polytrauma patients with chest or spinal injuries, allows hyperflexion of the elbow and improved visualization of the anterior part of the trochlea. However, this is a more difficult approach, and an assistant is needed to hold the extremity because gravity tends to malalign the fracture. On the other hand, the lateral position does not require an assistant, and gravity helps maintain the reduction.

The entire upper extremity is prepared and draped, and a sterile tourniquet may be applied according to surgeon preference. Use of a nonsterile tourniquet limits the proximal extension of the surgical approach and is not recommended. The contralateral iliac crest should be pre-

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Am J Orthop. 2007;36(12 suppl):8-12.

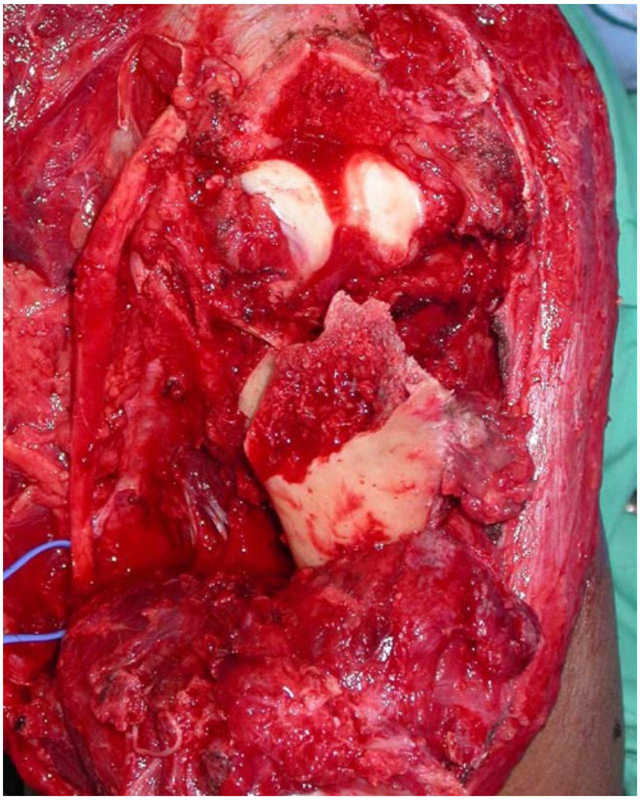

Figure 1. Exposure of fracture site after olecranon osteotomy.

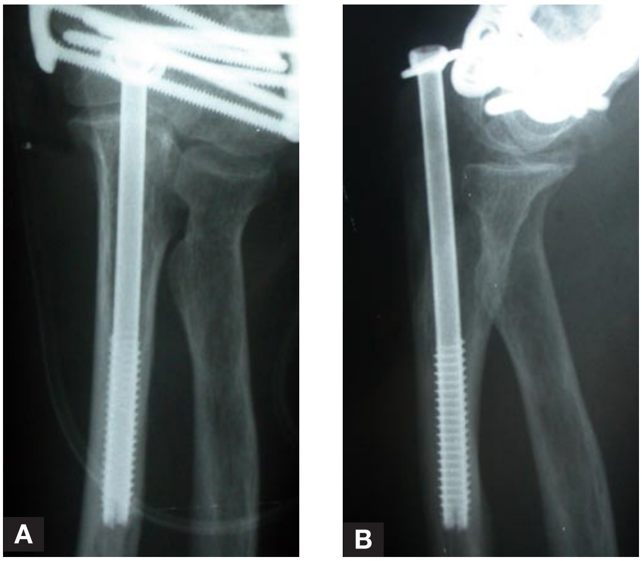

Figure 2. Fixation of olecranon osteotomy with a 6.5-mm cannulated screw and a washer. As noted in both the anteroposterior **(A)** and lateral views **(B)**, the treaded part of the screw engages the isthmus of the ulna, resulting in compression of the osteotomy site and stable fixation.

pared and draped so that, if bone graft is needed, a second surgeon can harvest the graft simultaneously.

Surgical Approach

The surgical approach may be performed through an olecranon osteotomy or reflection of the triceps (Bryan-Morrey or triceps-reflecting anconeus pedicle approach).[3,6] The

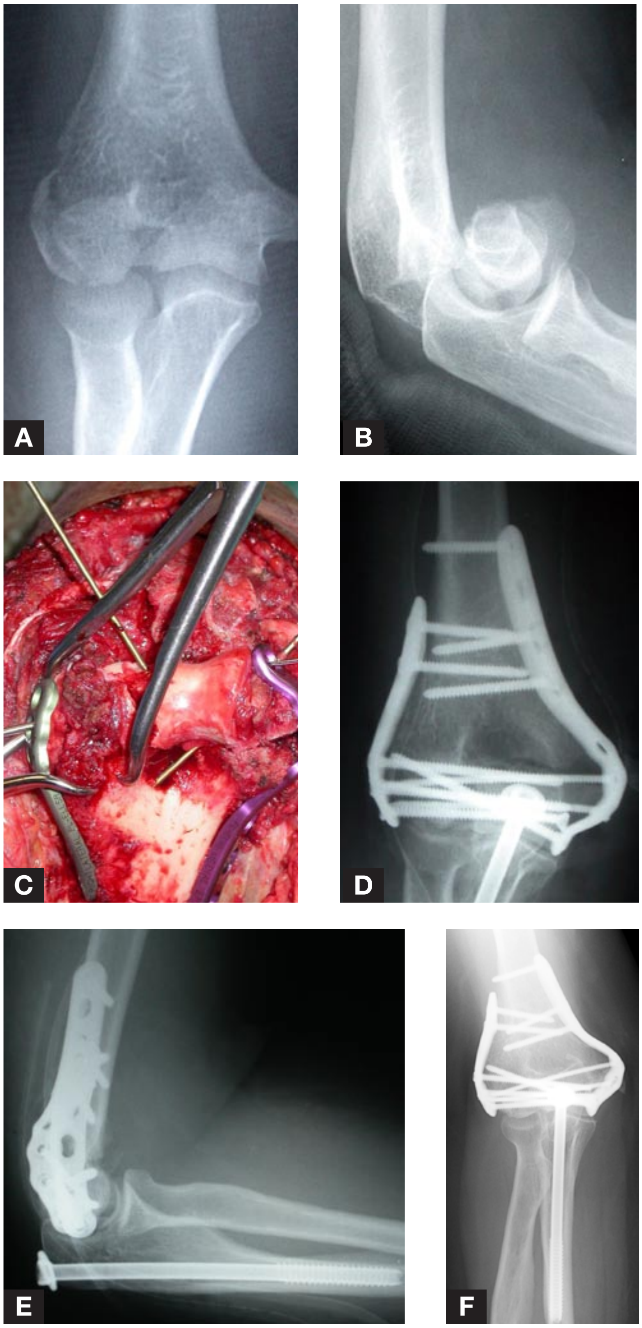

Figure 3. A very low intra-articular fracture of the distal humerus as seen in the preoperative anteroposterior **(A)** and lateral radiographs **(B)** is an especially challenging injury because of the limited distal bone stock available for fixation. The bone fragments are reduced and provisionally stabilized using reduction clamps and Kirschner wires (K-wires). Note that positioning of the K-wires does not interfere with plate application. **(C)** The implants should be applied so as to maximize fixation of the distal fragments to the metaphysis/diaphysis of the humerus. As many screws as possible should be placed through the plates into the distal fragments (6 such screws in this case), and each distal screw should be long and engage as many articular fragments as possible **(D)**. Both plates should be applied with compression at the supracondylar level. Note the isthmic fit of the screw used for fixation of the osteotomy as noted in the lateral view **(E)**. Following these principles will ensure that the fracture site is stabilized enough to allow early motion of the elbow, and uncompromised fracture healing **(F)** with a satisfactory outcome.

olecranon osteotomy provides excellent visualization of the fracture (Figure 1), but there are concerns regarding nonunion of the osteotomy site and prominence of the hardware placed at the olecranon. If elbow arthroplasty is considered, the olecranon should not be osteotomized. Triceps reflection avoids the complications of the olecranon osteotomy (but may result in triceps rupture) and provides satisfactory exposure but not to the same extent as the osteotomy. Most osteotomy nonunions are attributable to inadequate fixation of the osteotomy site and thus can be prevented with stable fixation. Also, treating a nonunion of the olecranon is easier than treating an intra-articular malunion of the distal humerus.

Incision

After perioperative antibiotics are administered, a posterior midline skin incision is made. This incision allows wide exposure, protects cutaneous nerves, and can be reused for revision procedures. The incision extends from approximately 15 cm proximal to 7 cm distal to the tip of the olecranon and is placed slightly lateral or medial to the tip. Full-thickness subcutaneous flaps are raised both medially and laterally.

Ulnar Nerve Dissection

The ulnar nerve is identified and carefully dissected and mobilized. It is important to release the ulnar nerve from the arcade of Struthers proximally to the first motor branch to the flexor carpi ulnaris distally to allow anterior transposition of the nerve without tension. For the same reason, the medial intermuscular septum is excised. Mobilization of the ulnar nerve protects it during the case and facilitates plate application along the medial epicondyle. Depending on how proximally fixation is needed on the lateral column, the radial nerve may also need to be identified and mobilized.

Olecranon Osteotomy

If a screw and washer will be used to fix the olecranon osteotomy, then the olecranon and proximal ulna should be drilled and tapped beforehand to facilitate anatomical reduction of the osteotomy site. Preoperative templating helps in selecting the diameter and length of the olecranon screw that will provide the best fit in the isthmus of the ulna (Figures 2A, 2B). In most cases, a 6.5- or 7.3-mm cannulated screw is appropriate. Based on templating, the correct-diameter guide pin, drill, and tap are used. The starting point should be slightly radial to the midline of the olecranon so that a long screw can negotiate the varus bow of the proximal ulna, gain purchase at the narrowest part of the diaphysis, and compress the osteotomy site, thereby increasing stability of the fixation and preventing the complication of nonunion.

The olecranon osteotomy is performed at the bare spot of the olecranon, which is located at the center of the olecranon sulcus and is identified by elevating the anconeus muscle. A sponge is placed transversely underneath the olecranon to protect the articular cartilage and to allow an assistant to provide countertraction while the osteotomy is made. An apex distal chevron-type osteotomy helps with anatomical reduction and improves stability. A thin oscillating saw is used initially, but the final portion of the osteotomy is made with an osteotome to facilitate interdigitation of the bone ends and reduction of the osteotomy. After the osteotomy, the olecranon tip is reflected proximally with the triceps, and the articular surface of the distal humerus can now be directly visualized. An olecranon osteotomy should be avoided if primary arthroplasty is being considered.

Fracture Reduction

The hematoma is removed by irrigating the fracture site, and the fracture fragments are identified. The surgeon and assistants should preserve all existing soft-tissue attachments of bone fragments and should be careful at this point to avoid inadvertently dropping an articular fragment completely devoid of soft-tissue attachments. After direct visualization of the fracture site, preoperative assessment of the fracture is confirmed, or new fracture lines may be discovered, thus changing the preoperative plan.

Fracture reduction may start at 1 of the 2 columns or at the articular surface. The order and method of reduction must be tailored to the individual fracture pattern. When a column is not comminuted, we prefer to start the reduction there to use the accurate read present. When there is comminution at the metaphyseal level, we reduce the articular surface first and then attach it to the diaphysis, aiming to restore rotation and valgus orientation of the joint. Bone-to-bone contact across the columns is essential, and any gaps must be filled, preferably with autogenous bone graft. Alternatively, synthetic bone graft may be used as a void filler to avoid donor site complications from harvesting iliac crest bone graft. In cases of severe comminution and bone loss, supracondylar shortening, which maximizes bone contact and improves stability at the fracture site, is a viable option.[7] Any defect in the articular surface should be filled with autogenous bone graft, because shortening of the trochlea will lead to incongruency and arthrosis of the ulnohumeral joint. Also, a fully threaded screw should be used so as not to lag the condyles together and shorten the distal humerus articular segment.

The reduced bone fragments are held in place with fracture reduction clamps and are provisionally fixed using Kirschner wires (K-wires) with a diameter of 1.2 to 2.0 mm, depending on fragment size (Figures 3A–3C). The K-wires are positioned so they do not interfere with plate application. The reduction is then checked both visually and fluoroscopically.

Fixation Technique

Unicolumnar fractures may be stabilized with 1 plate, but intra-articular distal humerus fractures involving both columns require 2 plates. Although there is universal agreement on the necessity of stable fixation, the optimal tech-

Figure 4. Hardware failure at the supracondylar level.

nique for stable fixation remains controversial. One fixation technique uses 2 plates applied at a right angle to each other (ie, a medial plate on the medial column combined with a posterior plate on the lateral column of the distal humerus).[3,4,8] An alternative technique uses 2 parallel plates (ie, a medial plate on the medial column combined with a lateral plate on the lateral column).[1,9,10] To our knowledge, no clinical studies have compared these 2 techniques, and biomechanical studies of distal humerus fixation have had conflicting results.

Orthopedic surgeons should have several technical objectives. They should: apply plates so compression is achieved at the supracondylar level for both columns, place as many screws as possible through the plates into the distal fragments, use the longest distal screws possible, and make them engage as many articular fragments as possible (Figures 3D–3F).[10] Achieving these objectives maximizes fixation of the distal fragments to the metaphysis/diaphysis of the humerus, which is critical because most failures occur at the supracondylar level (Figure 4).

A free intra-articular 3.5-mm cortical screw or 4.0-mm cancellous screw can also be used to stabilize a sagittal split of the articular surface. In such a case, the screw should be strategically placed so it will not block application of distal screws through the plates, and, if there is comminution in the sagittal plane, the screw should not be inserted in compressive mode, so as to avoid shortening of the distal humerus articular segment.

Free articular fragments, usually secondary to coronal fractures, should be fixed with compression screws countersunk underneath the articular cartilage. Headless screws, such as Herbert (Zimmer, Warsaw, Ind.) and Acutrak (Acumed, Hillsborough, Ore.) screws, are helpful. Very small articular fragments can be fixed definitively with threaded 0.9- or 1.2-mm K-wires placed in the subchondral bone.

A variety of plates can be used, depending on fracture configuration and surgeon preference. The 3.5-mm LC-DCP plates provide sufficient strength, but their ability to be contoured is limited. They can be placed on the posterior aspect of the lateral column. The 3.5-mm reconstruction plates can be easily contoured so that they are placed more distally around the medial epicondyle or around the posterior surface of the capitellum to improve fixation in low fracture patterns. Lack of articular cartilage at the posterior distal surface of the lateral column facilitates distal positioning of the plate. A 3.5-mm reconstruction plate can also be bent in a J-shape and placed on the lateral surface of the lateral column. Precontoured anatomical elbow plates are easily and accurately applied, decrease operative time, and facilitate insertion of a maximum number of screws in the distal fragments. Our preference is to use parallel precontoured plates, placed on the medial and lateral columns (Figures 3C–3F). Locking plates, both standard and precontoured, are available. Application of locking screws distally increases stability in the presence of osteoporotic bone, comminution, and short distal segments.

On completion of the fixation, the joint should be carefully evaluated both visually and fluoroscopically to ensure that there is no protrusion of hardware through the articular cartilage, olecranon fossa, or coronoid fossa. The elbow is ranged, and the stability of the fixation is assessed.

The olecranon is then reduced, and the osteotomy is fixed according to the surgeon's preferred technique (screw, tension band, or plate). We prefer to use a screw, as already described (Figures 2A, 2B, 3D, 3E). In the widely used tension band technique, two 1.2-mm parallel K-wires go through the osteotomy site and engage the anterior cortex of the proximal ulna just distal to the coronoid. Two wires of small diameter (20 to 22 gauge) are used to minimize hardware prominence.

Ulnar Nerve Transposition and Wound Closure

The ulnar nerve is anteriorly transposed into a subcutaneous location to avoid impingement from hardware over the medial epicondyle or entrapment into scar tissue at the fracture site. If a tourniquet was used, it is deflated and hemostasis obtained. One or 2 large suction drains are placed, and the wound is closed in layers. A bulky elbow dressing is placed with the arm in extension.

Postoperative Management

Hand and wrist range-of-motion exercises are begun immediately after surgery, and, along with elevation of the extremity, they help limit soft-tissue swelling in the early postoperative period. Heterotopic ossification prophylaxis is not routinely used, so as to avoid interfering with bone and soft-tissue healing. Prophylaxis (with either indomethacin or irradiation) may be considered for a patient with head injury. Early elbow mobilization, which is essential, starts 24 to 48 hours after surgery with active and active-assisted exercises. A night splint is applied to keep the elbow extended. If fracture healing progresses satisfactorily, muscle-strengthening exercises are started 12 weeks after surgery. Rehabilitation should continue for at least 6 months, because improvement in elbow range of motion may occur for up to 6 or even 12 months. Range of motion of 30° to 130° is considered sufficient for activities of daily living.[11]

Open Fractures

Treatment of open intra-articular distal humerus fractures starts with early antibiotic administration in the emergency department, followed by surgical débridement and irrigation of the open fracture. Primary internal fixation can usually be performed at the same time. However, in cases of severe contamination or soft-tissue damage, the fracture can be provisionally stabilized in a splint (if gross alignment can be maintained) or external fixator, and a repeat débridement should be performed at 24 to 48 hours. If a repeat procedure is planned, antibiotic beads are placed at the fracture site to enhance local antibiotic delivery.

Outcome

A satisfactory outcome can be achieved in most patients when anatomical ORIF is performed according to the principles described in this article. However, complications may occur, and reoperations may be required.

Jupiter and colleagues[4] reported on a series of 34 patients with intra-articular distal humerus fractures followed up for a mean of 5.8 years. Twenty-seven (79%) of the 34 patients had a good or excellent outcome. Slight to moderate narrowing of the joint space developed in 19 patients (56%) and extensive arthrosis in 4 (12%). Complications included 2 nonunions of the fracture site, 1 nonunion of the olecranon osteotomy, 1 deep infection, 1 clinically significant heterotopic ossification, and 4 cases of ulnar nerve compression.

In a series reported by Sanchez-Sotelo and colleagues,[1] a good or excellent outcome was achieved in 27 (84%) of 32 patients followed up for a mean of 2 years. Mean elbow extension and flexion were 26° and 125°, respectively. Wound healing complications developed in 2 patients, deep infection in 1, nonunion in 1, heterotopic ossification requiring excision in 5, arthrosis in 2, and permanent ulnar neuropathy in 2.

Doornberg and colleagues,[2] who evaluated a series of 30 patients at a mean of 19 years after ORIF of intra-articular fractures of the distal humerus, found that durable results can be achieved: There were 26 good or excellent results (87%); mean ASES (American Shoulder and Elbow Surgeons) score was 96 points; and mean DASH (Disabilities of the Arm, Shoulder, and Hand) score was 7 points. Mean elbow extension and flexion were 23° and 129°, respectively. Twenty-four patients (80%) developed arthrosis; of these, 11 had slight joint-space narrowing, 11 had moderate narrowing, and 2 had severe arthrosis. However, arthrosis did not correlate with impairment or disability.

Conclusions

The principles of surgical management of intra-articular fractures of the distal humerus are anatomical restoration of the articular surface and stable fixation of the fracture fragments to allow for early motion. Careful preoperative planning, surgical expertise, and aggressive postoperative rehabilitation are essential for optimizing outcome.

Authors' Disclosure Statement

The authors report no actual or potential conflicts of interest in relation to this article.

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