Distal Humeral Fractures in Adults

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Abstract

Distal humeral fractures in adults often pose a challenge to the orthopaedic surgeon. Preoperative planning, minimal devitalization of bone and soft tissue, and adherence to the prerequisites of biomechanical fixation are all important elements in effecting the desired end result. The chevron modification of the olecranon osteotomy affords excellent surgical exposure of the joint surface for fractures with an intra-articular component. When two plates are used to fix the lateral and medial distal humeral columns, it is best to orient them so that, when looked at in cross section, they are at right angles to each other. The achievement and maintenance of an anatomic reduction secure enough to permit early functional, pain-free motion of the elbow can be best ensured by open reduction and internal fixation with careful attention to detail.

J Am Acad Orthop Surg 1996;4:336-344

The diagnosis of a distal humeral fracture is easily made on the basis of clinical examination and plain radiographs. Associated neurovascular injury should be carefully sought and documented. If there is a question of vascular injury (e.g., if there is diminished or absent pulse despite traction or splinting of the fracture) on physical examination, angiography should be performed expeditiously. At my institution, this study can be completed within 1 hour. If the limb is ischemic and has been so for 4 to 6 hours, strong consideration should be given to immediate operative exploration of the vessels in the region of the fracture (without angiography) so as to diminish warm ischemia time. The simultaneous or sequential address of the skeletal injury depends on the specifics of the vascular injury and the fracture pattern. A coordinated plan must be arrived at by both the vascular surgeon and the orthopaedic surgeon.

For the purpose of this discussion, distal humeral fractures are defined as shown in Figure 1. These fractures have been classified by Müller[1] into three general categories: type A, nonarticular; type B, articular with one articular fragment being continuous with the shaft; and type C, articular with all the articular fragments separated from the shaft (Fig. 2).

Nonoperative Management

Stable type A distal humeral fractures can be treated nonoperatively. After gentle closed reduction (usually consisting of axial traction in neutral rotation), nonoperative management can consist of a short period (2 weeks) of splinting or casting, followed by use of a hinged cast or a hinged functional brace with initiation of early elbow motion.[2] The use of olecranon Kirschner-wire traction with later conversion to a hinged cast or hinged brace may be an option, depending on the patient's overall status, the fracture pattern, and local soft-tissue requirements. In general, nonoperative methods necessitate frequent radiographic assessment and may entail multiple adjustments of the splinted fracture, particularly early in treatment.

In addition to fracture type, there are other factors that may make nonoperative management advisable. There may be a systemic or local contraindication to operative treatment. Patients who present significant operative risks or who have severe osteoporosis such that there is insufficient bone stock to anchor internal fixation are other examples.

Although the end result after nonoperative treatment of a suitably stable type A fracture is often characterized by a less-than-perfect restoration of axial alignment, as visualized radiographically (usually slight varus angulation unless the fracture was initially nondisplaced and/or incomplete), and callus formation (sometimes palpable), there is generally good elbow

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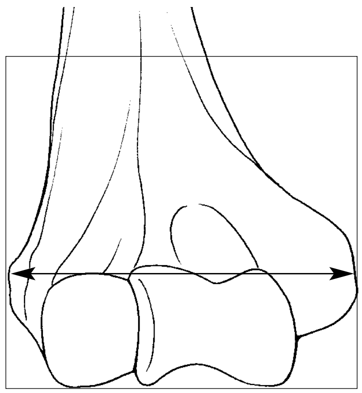


Fig. 1 Method of defining a distal humeral fracture, according to the Müller classification.[1] A square is drawn on an anteroposterior radiograph of the distal humerus, with the width being the distance from epicondyle to epicondyle. If the epicenter of the fracture falls within the square, the fracture is considered a distal humeral fracture.

function. Unstable (comminuted or significantly displaced) type A fractures are not well suited to nonoperative management. The result is more likely to be malalignment with compromised elbow function and/or delayed healing.

Nonoperatively managed type B and C fractures are likely to have compromised functional outcomes due to residual articular incongruity, elbow stiffness, and arthritis.

Principles of Operative Management

In general, distal humeral fractures in adults are best managed by open anatomic reduction and stable fixation, with the objective of early restoration of the anatomy and function of the brachium. Although certain type A fractures may be amenable to nonoperative treatment, operative stabilization of the distal humerus provides a platform for restoration of early pain-free elbow motion and thereby diminishes the development of elbow stiffness while the fracture is healing.

In type B and type C fractures, even minor offsets in the articular portion can significantly interfere with function and predispose the joint to early arthritic sequelae. Therefore, for articular fractures with displacement, operative management with direct visualization of the joint surface and anatomic reduction and stabilization of the fracture provides all the benefits discussed for operatively managed type A fractures and also prevents the accelerated arthritis associated with articular malreduction.[3-5] In a series of 33 operatively managed type C fractures (14 of which were open), Henley[6] reported good or excellent results in 92% followed for an average of 1½ years. Other authors have reported similarly good results with use of the principles of operative stabilization.[4,5,7]

Preoperative Planning

For the best delineation of the detail of the fracture fragments, anteroposterior and lateral traction films of the injured side are recommended (Fig. 3, A). Distal humeral fractures lend themselves well to formal preoperative planning.[8] A radiograph of the contralateral noninjured distal humerus (Fig. 3, B) can be taken for that purpose and then "flipped" (turned left to right) (Fig. 3, C) in order to make a paper tracing on a view box. The fracture lines are drawn on the tracing so as to depict the reassembled, anatomically reduced fracture (Fig. 3, D). Overlays of the intended implants can then be used to illustrate the final position of the plates and screws that will be used.

Although type B fractures can be managed with appropriately positioned lag screws and a single plate, most type A and type C fractures call for a combination of medial and lateral plates with the plates situated (in cross section) at right angles to each other. Recent studies have shown that this arrangement provides the most stable biomechanical construct.[9,10]

The final aspect of a preoperative plan calls for writing down the steps in accomplishing the procedure, including the position of the patient on the operating table, the surgical incision, placement of any aids to reduction, and the details of both provisional and definitive fixation. This then serves as the blueprint for conducting the procedure and allows the surgeon to focus on the technical aspects of carrying it

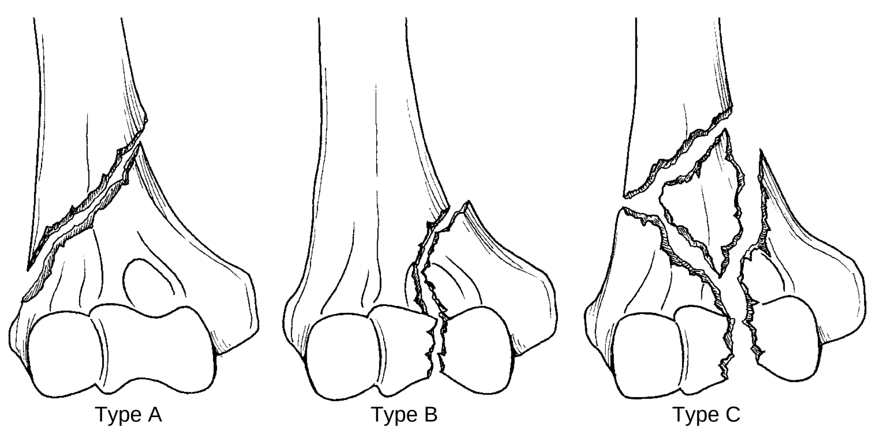


Fig. 2 Müller's classification of distal humeral fractures: type A is nonarticular; type B is articular with one articular fragment being continuous with the shaft; and type C is articular with the shaft separate from the articular fragments.

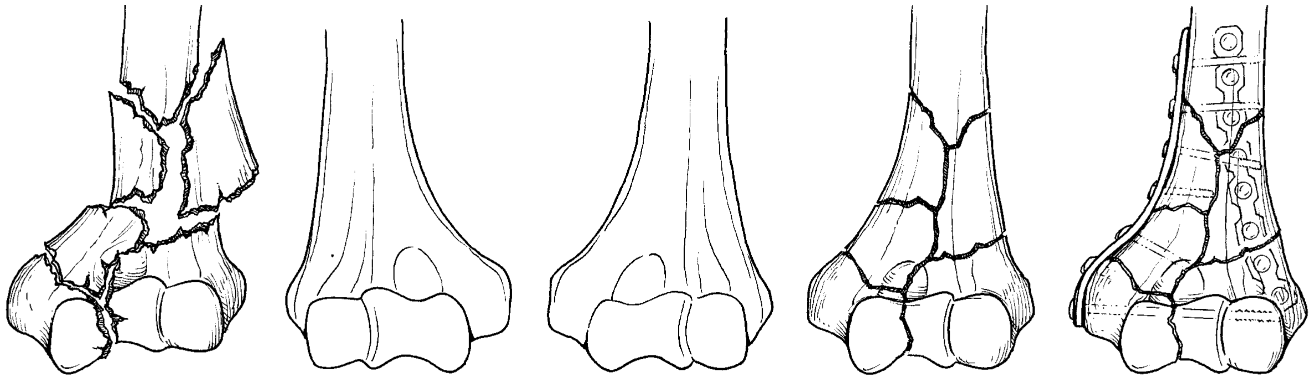


Fig. 3 Steps in preoperative planning. **A,** Drawing of fracture fragments as visualized on an anteroposterior radiograph obtained with gentle traction. **B,** Schematic representation of radiographic appearance of the normal (nonfractured) contralateral distal humerus. **C,** Schematic representation of "flipped" (turned left to right) image shown in **B**. **D,** Fracture lines (based on appearance in **A**) are drawn on image in **C** to depict the reduced fracture. **E,** Implants have been drawn in intended positions (from templates).

out, rather than attempting simultaneous planning and execution. Mistakes made on paper beforehand are obviously easier to deal with than those that occur during the course of the actual surgery.

Other Considerations

Osteosynthesis can be accomplished with the use of compression plates (preferably with the inclusion of a lag screw) via a posterior approach.[11] Ideally, the patient is in the prone position, but I have used it with reasonable facility with the patient either supine or in the lateral position. This may be necessary for the conduct of simultaneous or sequential procedures during the same anesthetic administration or when there are systemic demands on patient positioning (e.g., due to head injury).

If there is no comminution or bone loss, the placement of an interfragmentary screw will enhance the stability of the construct.[12] If there is comminution or bone loss, "biologic plating" with minimal soft-tissue stripping may be preferable.[13] (In biologic plating, the plate is used to splint the major proximal and distal fragments in their proper positions, bypassing the zone of severe injury or comminution and thereby maximally preserving soft-tissue attachments and bone-fragment vascularity in the injury zone.)

Ideally, osteosynthesis should be used in the treatment of open fractures only when the surgeon is sure that the wound is clean, free of all devitalized tissue, and amenable to closure. Attention should be directed toward minimal iatrogenic devitalization of bone. A limited-contact implant (i.e., one in which the undersurface has undulations that contact the bone surface, rather than the contact being made by the entire plate undersurface) may offer advantages with regard to preservation and eventual recovery of cortical blood supply.[14] If there is significant devitalization or contamination (Fig. 4), the surgeon may choose to delay osteosynthesis until the wound is clean and its base is viable. During this phase of staged debridement, temporary fixation

Fig. 4 **Left,** Large segment of necrotic distal humerus in a severely contaminated open fracture had to be resected. The bone had been retained after the first debridement, but when infection began to manifest itself, further debridement was necessary. **Right,** An antibiotic bead chain was later placed in the defect as a spacer. Reconstructive options were limited due to bone loss and infection, and overall functional outcome was compromised.

can be accomplished with the use of a bridging external fixator.[15]

If sizable articular fragments or periarticular fragments need to be removed from the wound because of contamination or devitalization, osteosynthesis may not be possible. Other reconstructive options, such as arthroplasty, allografting, vascularized fibular fragments, and arthrodesis, may be reasonable options once the status of the wound permits. Contaminated open wounds, particularly those with associated bone loss, often involve conflicting requirements, such as the need to avoid infection, incorporate bone grafts, and maintain a reduction secure enough to permit early motion (which usually requires the placement of plates and screws). Appropriately timed staged procedures can, however, successfully effect a reasonable outcome (Fig. 5). Fortunately, most patients present with stable soft-tissue envelopes, and osteosynthesis can be carried out according to the preoperative plan on an elective basis.

Surgical Approach

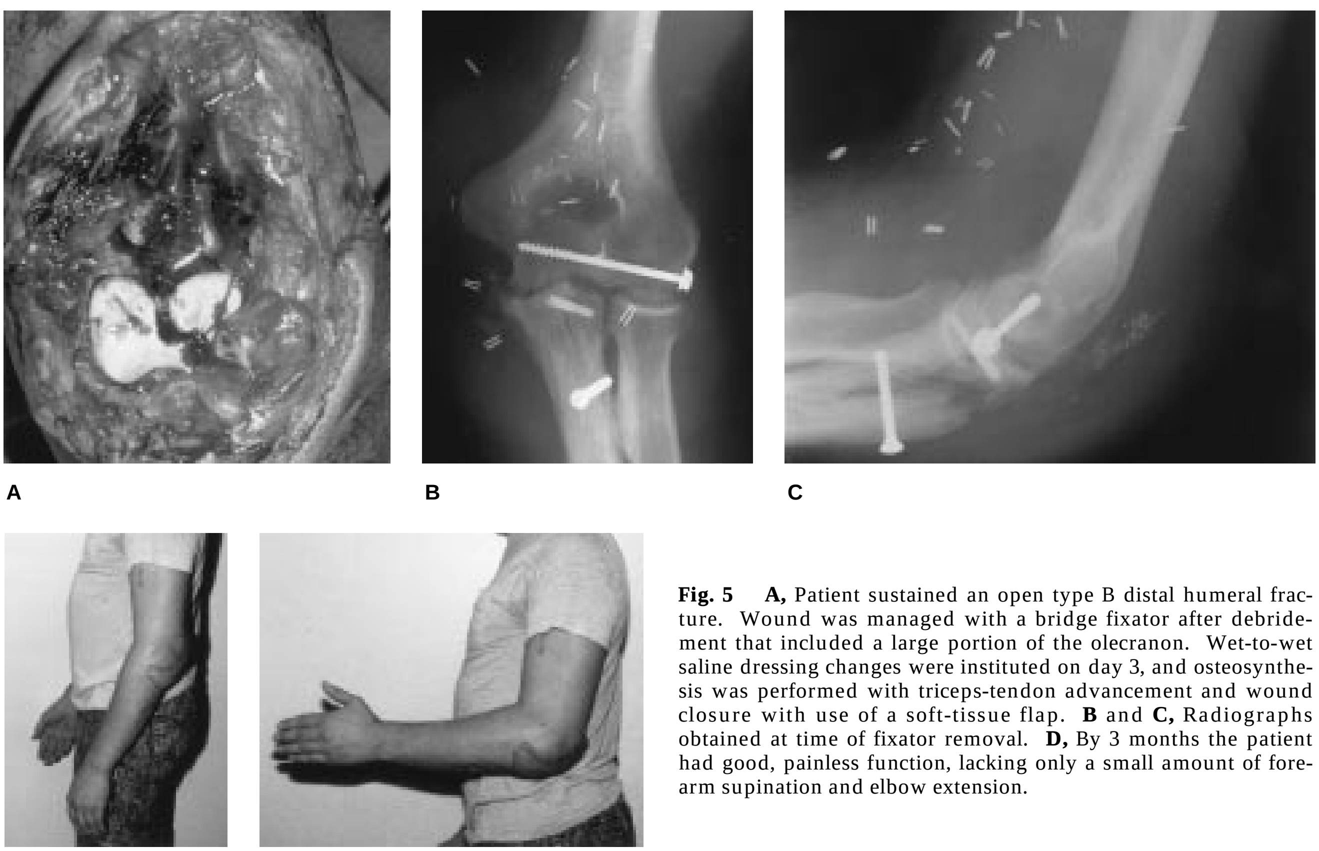
Nonarticular Fractures

Surgical exposure of the nonarticular distalmost aspect of the humerus can be accomplished by means of the Van Gorder or Campbell approach with an inverted-V turndown of the triceps tendon. This approach has been criticized, however, because it can result in some residual triceps weakness.[16]

My preference has been to use a nonarticular, obliquely directed olecranon osteotomy and to reflect the triceps with its insertion (Fig. 6). An alternative is the Bryan approach,[16] which calls for an axially directed skin incision on the medial aspect of the olecranon, identification and protection of the ulnar nerve, and detachment (from medial to lateral) of the triceps-tendon insertion in continuity with the proximal ulnar periosteum, which exposes the posterior aspect of the distal humerus.

Intra-articular Fractures

Surgical exposure of the distal humeral articular surface can be



A B C D E

Fig. 5 **A,** Patient sustained an open type B distal humeral fracture. Wound was managed with a bridge fixator after debridement that included a large portion of the olecranon. Wet-to-wet saline dressing changes were instituted on day 3, and osteosynthesis was performed with triceps-tendon advancement and wound closure with use of a soft-tissue flap. **B** and **C,** Radiographs obtained at time of fixator removal. **D,** By 3 months the patient had good, painless function, lacking only a small amount of forearm supination and elbow extension.

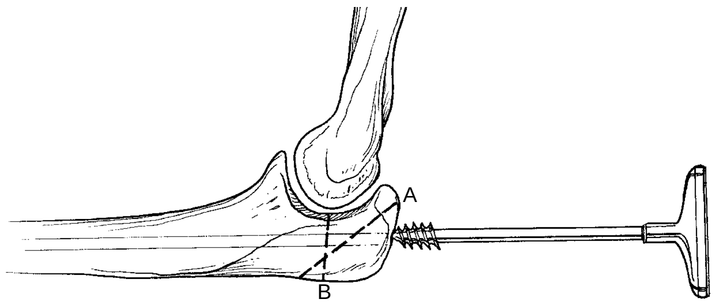


Fig. 6 Exposure of the nonarticular distalmost aspect of the humerus. A 3.2-mm pilot hole is made in the ulna, and a 6.5-mm tap is used at the cortex of the proximal ulna to cut a thread for a 6.5-mm cancellous screw. Line A represents the bone cut for a nonarticular osteotomy; line B, bone cut for a transarticular osteotomy.

accomplished by continuing the Bryan exposure around the lateral margin of the olecranon, releasing the anconeus origin as well as the lateral capsular attachment and the annular ligament. This exposure results in a near-complete denuding of the soft-tissue attachments of the olecranon but entails only a minimal likelihood of osteonecrosis (there were no instances in more than 50 cases reported by Morrey et al[17]). I have had limited experience with this approach.

The posterior approach that I have used most frequently for intra-articular fractures involves an olecranon osteotomy. This approach was originally advocated by Cassebaum[18] as a way of enhancing joint-surface visualization. The chevron modification of this osteotomy makes residual rotational offset less likely when the osteotomy is repaired at the close of the procedure (Fig. 7). The skin incision is axially directed on the posterior aspect of the arm, with distal extension over the lateral aspect of the olecranon. The incision is taken through the fascia, and the radial and ulnar nerves are identified, isolated (usually with a vessel loop), and protected.

A 3.2-mm drill is used to make a pilot hole for seating a 6.5-mm cancellous lag screw for fixation of an olecranon osteotomy (Fig. 6). The hole is tapped until good torsional resistance is encountered, at which point the depth of insertion of the tap is measured to guide later selection of screw length (L. E. Dahners, MD, personal communication, July 1995). The lateral and medial aspects of the waist of the olecranon are defined down to the margin of the articular surface. A Freer elevator is used to protect the articular cartilage surface while making a chevron-shaped osteotomy with a thin oscillating saw. The osteotomy is completed with a thin, sharp, fine-tipped osteotome (the apex of the chevron cut points distally).

Once the remaining capsular attachments at the margin of the proximal olecranon have been cut, the tip of the olecranon and the attached triceps-tendon insertion are retracted proximally, lifting the triceps off the posterior aspect of the humerus and thereby affording a clear view of the fracture, including its articular portion. The ulnar and radial nerves are protected and simultaneously further isolated and delineated as necessary.

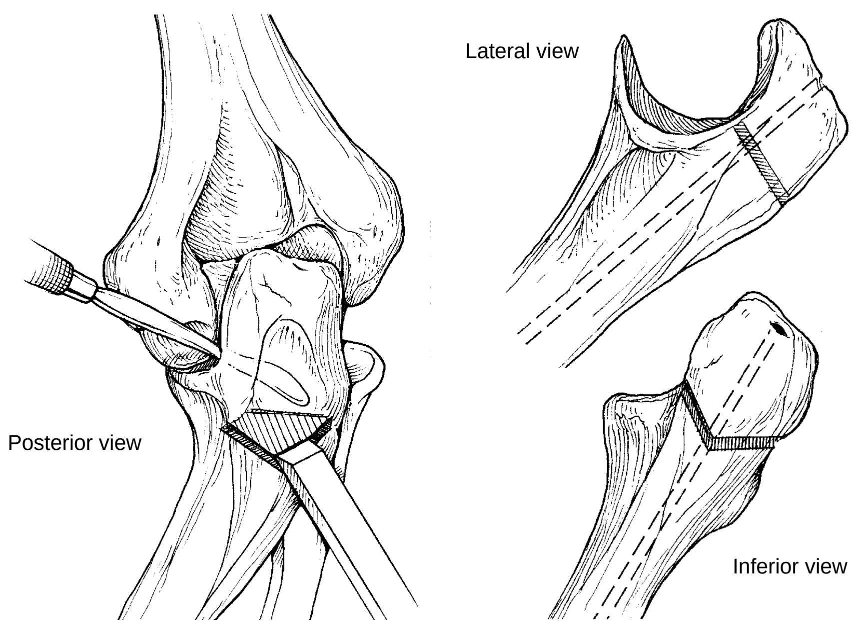


Fig. 7 Posterior approach for an intra-articular fracture. A Freer elevator is used in the ulnotrochlear joint space to protect cartilage. An oscillating saw with a thin blade is used to fashion the chevron osteotomy. Osteotomy is completed with a sharp, fine-pointed osteotome so that there is minimal loss of articular cartilage and subchondral bone. (If the oscillating saw were used for the entire cut, the loss would be the thickness of the saw blade.) The chevron osteotomy is fashioned so that the point is distal (if made proximally, there would be a greater likelihood of splitting the proximal olecranon with compression).

Osteosynthesis

Nonarticular Fractures

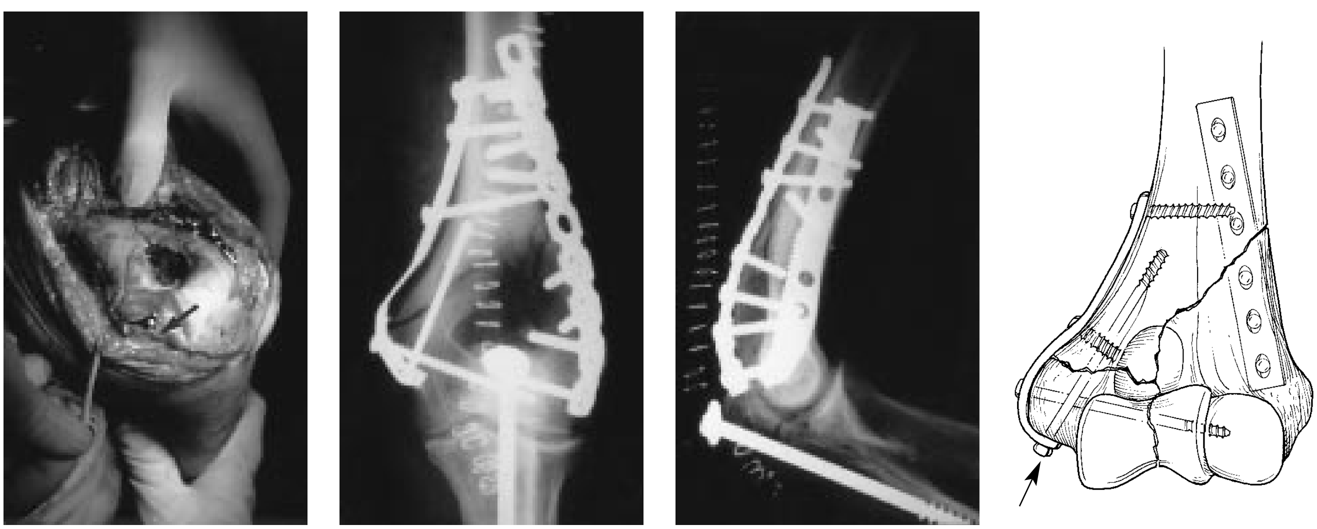
Fixation of nonarticular type A fractures is dictated by the fracture pattern. As mentioned previously, when two plates are used (one on each of the distal humeral columns), their orientation should be at 90 degrees to each other in cross section. The use of lag-screw fixation when the fracture pattern permits is advisable, but due to the thinness of the bone at the olecranon fossa, this is sometimes not feasible (e.g., if the screw protrudes into the olecranon or the coronoid fossa, the olecranon or coronoid will impinge on it and block elbow motion). With low medial-column fractures, the plate (e.g., the flattened end of a one-third tubular plate) may be contoured around the medial epicondyle so as to permit the placement of an interfragmentary lag screw that addresses the medial-column fracture line (Fig. 8). If the fixation device impinges on the cubital tunnel in this fashion, it is necessary to do an ulnar-nerve transposition to keep the nerve from being irritated or compressed.

Intra-articular Fractures

The intra-articular components are usually addressed first. Reduction is accomplished under direct vision and can be provisionally held with one or more Kirschner wires. Definitive fixation is achieved with use of a lag screw, placed either independently or through a hole in a contoured plate, depending on the fracture pattern. A cannulated screw can be used to advantage when low medial- or lateral-column fractures prompt lag-screw placement through the end hole of a contoured plate.

The guide pin is then placed, and a hole is drilled at the end of the aluminum template. The template is pressed against the bone surface with the guide wire through the drilled hole. The template is then used to guide the contouring of the plate. (Ideally, many of these details germane to fixation will have been anticipated in the preoperative plan.) The use of soft-tissue protection sleeves and/or an oscillating drill attachment will help ensure avoidance of injury to the neurovascular structures during the course of the procedure. Provisionally fixed low articular fractures may need to be reduced to the shaft fragments and held temporarily, depending on whether the preoperative plan calls for screws to be situated at the end of the plate in the articular fragment.

For most T- or Y-variety type C fractures, one plate is situated medially along the medial column. A second plate is situated on the posterior aspect of the lateral column; this plate can extend as far distally as the posterior aspect of the capitellum. The intra-articular fracture line is compressed with either a separate lag screw or a lag screw from an end hole in one of the plates. When there is a segmental articular fragment (Fig. 9), the



A B C D

Fig. 8 **A,** Pathologic type A fracture with a low medial-column component. A flattened one-third tubular plate contoured to go around the medial epicondyle was used for fixation. Instrumentation imposed on the cubital tunnel (arrow) and necessitated transposition of the ulnar nerve. Anteroposterior **(B)** and lateral **(C)** radiographs depict arrangement of the plates at right angles to each other. **D,** Lag-screw fixation through a medial-column plate (arrow) often encroaches on the cubital tunnel and necessitates an ulnar-nerve transposition.

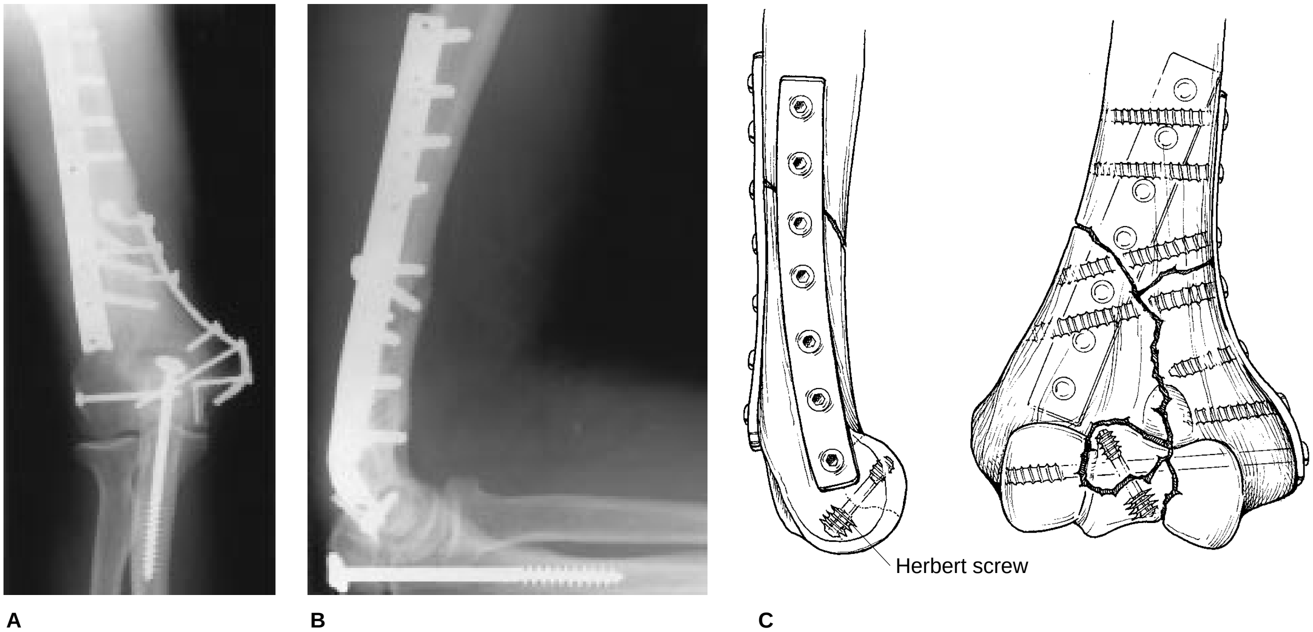


Fig. 9 Anteroposterior **(A)** and lateral **(B)** views of a type C fracture with shaft extension. Segmental intra-articular fragment was fixed with a bipolar threaded screw (Herbert type). Ulnar-nerve transposition was necessitated by the imposition of the distal aspect of the medial plate. **C,** Position of the interfragmentary lag screw and the bipolar threaded screw must be planned so that interference is avoided. The olecranon osteotomy in this case was not a chevron cut. Although union occurred without further intervention, it was delayed.

reduced fragment can sometimes be advantageously secured with a differential-pitch bipolar threaded screw (e.g., a Herbert screw) or an interfragmentary screw with the head situated (by countersinking) just below the articular surface level. Care must be taken to avoid interfering with the position of the main interfragmentary lag screw. Screw cannulation and sighting down the guide pin with a C-arm fluoroscope to verify proper positioning may be advantageous.

Bone Grafting

The need for bone grafting should be anticipated and included as a detail in the preoperative plan.

Delayed Union

Autogenous cancellous bone grafting is sometimes advisable when the diaphyseal portion of the fracture is comminuted or when delayed union or nonunion of this portion of the fracture necessitates bone graft placement and/or reosteosynthesis (Fig. 10).

Bone Loss

Appropriately shaped and sized corticocancellous autografts or allografts (supplemented with autogenous cancellous autograft) can be used to repair bone-loss defects when the wound is clean and free of infection risk. This is usually ill advised in the acute setting, however, because of the risk of infection. Antibiotic beads used as a spacer may be helpful in this setting.

Intra-articular Comminution

When intra-articular comminution precludes anatomic reduction and fixation of major medial and lateral joint fragments, the comminuted zone may be grafted with cancellous bone. A positioning (noncompression) screw is seated with threads engaging the major articular fragments so as to maintain their relative position[12] (Fig. 11). In my experience, the need for this strategy arises very infrequently.

Repair of Osteotomy and Closure

If an osteotomy has been utilized, repair is performed with a 6.5-mm-diameter cancellous screw over a washer. The appropriate length of the screw is predetermined by advancing the tap until torsional resistance is felt and then measuring the length of the inserted tap. A figure-of-eight wire loop can be used to supplement the fixation.[19] Care should be taken to seat the hardware with minimal prominence, lest it bother the patient when active motion is resumed.

A B

Fig. 10 **A,** Type C distal humeral fracture in a 20-year-old man. Osteosynthesis was complicated by nonunion and fatigue of the plates, which were placed in almost the same cross-sectional plane. The patient underwent reosteosynthesis with placement of a contoured 3.5-mm plate medially on the medial column and a reconstruction plate posteriorly on the lateral column. A cancellous bone graft was placed at the site of nonunion. **B,** Three months later, the patient had good elbow function, lacking only 15 degrees of full extension, and a healed fracture.

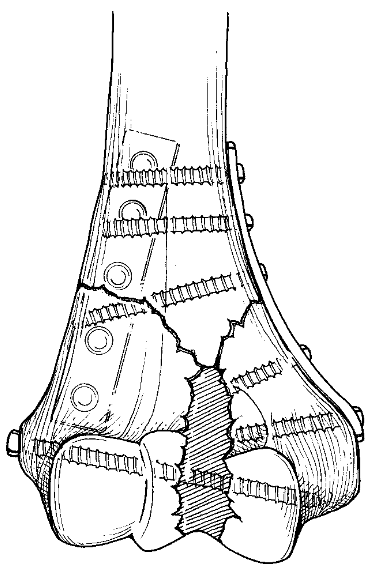


Fig. 11 A fully threaded positioning screw can be used when there is intra-articular comminution that is not amenable to fixation with a bipolar threaded screw.

Aftercare and Rehabilitation

Postoperatively, gentle passive or active assisted (with the patient's good arm) motion should be started early. Initially, this can take the form of a gentle jog of elbow flexion and extension from 90 degrees while the arm is supported in a sling. Excursion and transition are gradually increased until active motion commensurate with patient comfort is possible. Motion against resistance is prohibited until fracture healing has occurred, usually at 8 to 12 weeks.

When the stability of fracture fixation is in question (e.g., potential "debricolage" due to poor technique or poor bone quality), the use of a hinged functional brace (brace hinge colinear with elbow hinge) is advisable.

Complications

Complications that occur with some frequency include elbow stiffness, usually manifested as a lack of terminal extension; hardware prominence, sometimes manifested as pain with placement of the elbow on a hard surface; and olecranon bursitis (usually related to hardware prominence). Other complications, fortunately occurring far less frequently, are delayed union and nonunion (for both the fracture and the olecranon osteotomy) and heterotopic bone formation with significant elbow motion restriction. Patients with burns or head / spinal cord injuries are predisposed to heterotopic bone formation.

Summary

Distal humeral fractures, particularly those that involve the articular surface, are best managed by restoring the osseous anatomy and accomplishing fixation or stabilization sufficient to permit early restoration of painless elbow motion. This is best accomplished by carefully constructing and following a preoperative plan formulated from anteroposterior and lateral radiographs of the injured side (preferably taken with traction) as well as the noninjured side.

The chevron modification of the olecranon osteotomy provides for a more stable repair and affords excellent visualization of the articular surface. The ulnar nerve is identified, isolated, and protected at the cubital tunnel and for several centimeters proximal to it. The radial nerve is identified, isolated, and protected more proximally, particularly in fractures with shaft extension.

The careful reassembly of the articular surface is critical to a successful end result. When there are two primary articular fragments, an interfragmentary lag screw (independent or, in low column fractures, through a lower plate hole) provides good stability. When there are segmental fragments, an interfragmentary bipolar threaded (Herbert type) screw or a countersunk screw may be useful. Once the articular segments have been addressed, the medial and lateral humeral columns can be reduced and fixed. Contoured plates oriented at right angles to each other provide the best construct. Transposition of the ulnar nerve is done when there is encroachment on the cubital tunnel by the hardware. Repair of the olecranon osteotomy can be accomplished with a 6.5-mm lag screw, provided the threads gain a good purchase in the ulna. Supplementation of this fixation with a tensioned figure-of-eight wire loop is an option.

After osteosynthesis, early functional joint motion should be encouraged. Resistance and loading should be avoided, however, until the bone has healed (usually by 10 to 12 weeks).

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