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Decision Making in Complex Fractures of the Distal Humerus: Current Concepts and Potential Pitfalls

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Abstract: Complex fractures of the distal humerus present challenging reconstructive dilemmas. Open reduction with rigid internal fixation is the treatment of choice for the majority of these fractures. Restoration of the articular surface is difficult and mandates a thorough understanding of the detailed topographic anatomy of the distal humerus. Plating the articular segments to the two supporting columns is necessary to achieve rigid fixation. Two plates oriented at right angles to each other offer the most stable biomechanical construct. Recent reports of primary total elbow arthroplasty for complex distal humerus fractures in the elderly demonstrate an effective alternative to rigid internal fixation in selected patients. Complications after treatment of these fractures are numerous. Loss of motion occurs frequently and necessitates close monitoring of active and passive motion in the postoperative period. Stretching, brace therapy, and occasionally contracture release are modalities used to regain motion. Non-union, malunion, ulnar neuropathy, and heterotopic ossification often necessitate further surgical intervention.

Introduction

Fractures of the distal humerus present a difficult clinical challenge. The elbow is one of the most constrained joints in the body and any alteration in the architecture of the joint has the potential to limit motion and compromise function. The goal when managing fractures of the distal humerus is to restore pain-free function. The complex articular anatomy of the distal humerus and limited bone stock for internal fixation present continuous challenges to even the most experienced surgeon.

Anatomy

The most difficult aspect of reconstruction of fractures of the distal humerus is the restoration of normal anatomic relationships. The distal humerus is comprised of a medial and lateral column that flare outward in the coronal plane and terminate at the transversely oriented articular segment of the trochlea (Figure 1). The capitellum is the anterior articular extension of the lateral column. The medial column deviates at approximately twice the angle of the lateral column, and thus maintains a more distinct bony prominence. The triangle bounded by the medial column, lateral column, and articular surface defines the olecranon fossa posteriorly and the coronoid and radial fossa anteriorly. When placing screws in these areas, an appreciation for these features can help prevent inadvertent joint penetration.

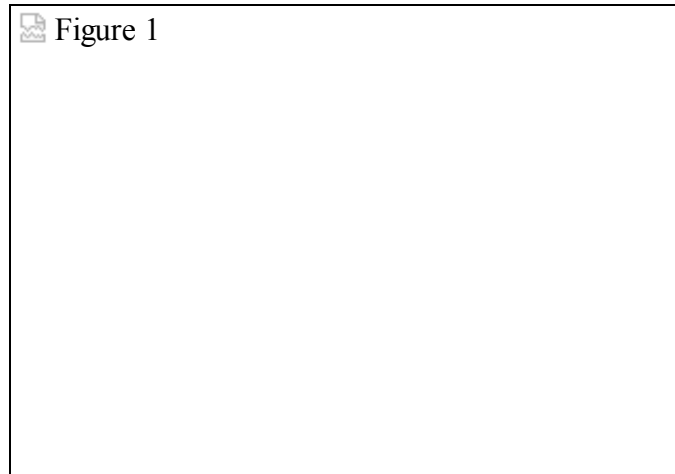


Fig. 1. Architecture of the distal humerus. The trochlea resembles a central spool-shaped structure bounded by the medial and lateral columns. (Reprinted with permission from: Mehne DK and Jupiter JB: Fractures of the distal humerus. In: BD Browner, JB Jupiter, AM Levine, et al. (eds.). *Skeletal Trauma. Fractures, Dislocations, Ligamentous Injuries*. Philadelphia, WB Saunders, p. 1146, 1992.)

To reconstruct the articular surface, the surgeon must first appreciate the topographical anatomy of the distal humerus. The trochlea is a spool-shaped structure with prominent medial and lateral ridges that bound a central trochlear sulcus. It is important to note that in the sagittal plane, the diameter of the trochlea at the central sulcus is only one half the diameter of the leading edge of either the medial or lateral trochlear ridge. The axis of rotation of the elbow is internally rotated 3 to 8 degrees from the transepicondylar axis and in slight valgus with respect to the long axis of the humeral shaft. This creates a valgus carrying angle of the elbow in extension.

Preoperative Considerations

Classification

Various classification systems have been proposed to express the differences in distal humerus fracture patterns. Because of the complex anatomy of the distal humerus, a useful classification that describes all fracture patterns and assists in treatment is difficult to devise.

The Riseborough and Radin classification [26] is probably the simplest. Unfortunately, its simplicity limits its usefulness. Intercondylar fracture patterns without comminution are grouped into one of three categories depending on the degree of articular displacement and rotation. All comminuted fractures are grouped together without distinction (Figure 2).

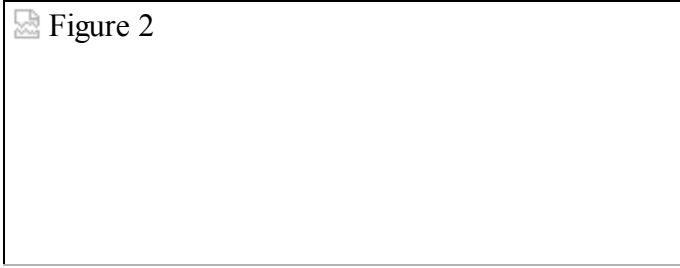
 Figure 2

Fig. 2. The Riseborough and Radin classification of fractures of the distal humerus. Type I: non-displaced. Type II: displacement without rotation. Type III: Displaced with rotation. Type IV: Type III with intercondylar comminution. (Reprinted with permission from: DeLee JC, Green DP, Wilkins KE. Fractures and dislocations about the elbow. In: Rockwood, CA, Green, DP (eds.). *Fractures in Adults*. Philadelphia, JB Lippincott, p. 576, 1984.)

The classification proposed by Mehne and Matta [15] involves six categories (Figure 3). With this system, the fracture pattern is classified according to the orientation of the fracture line and its distance from the articular surface. This assists in formulating a more detailed operative plan before surgery. However, this classification fails to characterize many of the complex fractures of the distal humerus.

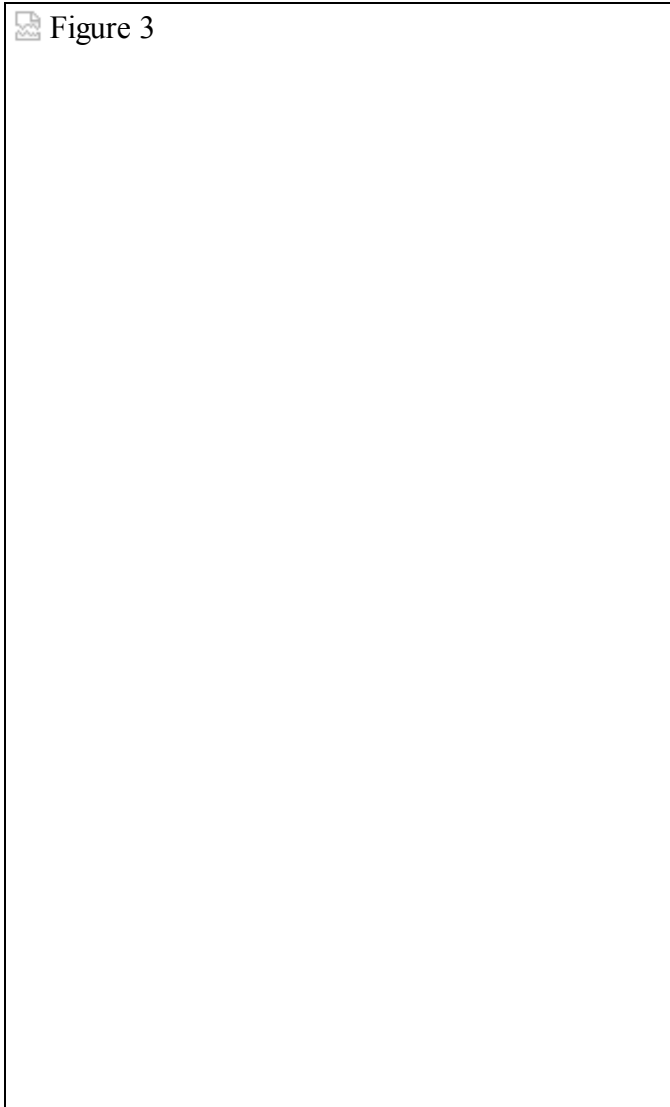


Fig. 3. Classification system of Mehne and Matta. (Reprinted with permission from: Jupiter JB. Internal fixation for fracture about the elbow. *Op Tech Orthop* 4:34, 1994.)

The AO/ASIF classification [24] provides the greatest amount of information for determining severity of injury. Fracture patterns are grouped into three categories---A, B, and C. Type A are extraarticular fractures. Type B are partial articular fractures. Type C are completely articular fractures. Each type has three groups, and each group has three associated subdivisions. A working knowledge of the nine main categories is usually sufficient to describe fracture patterns adequately and conceptualize a general treatment plan. The complete classification system is cumbersome, which limits its utility in pre-operative planning.

Open Reduction Internal Fixation

General considerations

Open reduction and internal fixation of complex distal humeral fractures has been shown to produce favorable results in the majority of patients [4,12,13,16,25,28,31]. With appropriate post-operative

rehabilitation, good to excellent results can be expected in up to 75% of patients. The pre-requisites for a satisfactory outcome include restoration of the structural integrity of the distal humerus, achieving rigid stabilization of the fracture, and beginning an early range of motion program. Failure to achieve any of these pre-requisites will compromise elbow function.

Operative approach

The choice of operative approach depends on the degree of articular involvement and physician experience. For complex fractures of the distal humerus the most versatile approach is a posterior approach [23] with an olecranon osteotomy. A modification of the chevron osteotomy originally described by Albee [2] provides rotational stability and an area for keying in the two fragments at the time of closure. The osteotomy is performed with a thin oscillating saw at the bare area in the base of the greater sigmoid notch. The osteotomy is completed with a thin osteotome.

Early identification and control of the ulnar nerve is mandatory to prevent inadvertent injury. Dissection along the medial and lateral intramuscular septum allows the olecranon to be reflected proximally. Formal ulnar nerve transposition is not mandatory but is preferred if internal fixation along the medial column extends to the cubital tunnel.

The Bryan-Morrey triceps reflecting approach [3] has been advocated by some for management of these fractures. It provides excellent visualization of the medial and lateral column, ulnar nerve, and posterior aspect of the trochlear articular surface. The anterior articular segments are not well visualized and limit the application of this approach in distal humerus fractures that have articular involvement in the coronal plane. The surgeon with limited experience with these fractures should use the posterior approach with olecranon osteotomy because it provides the most complete visualization of the articular surface.

Surgical technique

The goals of fixation of distal humerus fractures are to re-establish the articular surface and to fix the articular segment to the medial and lateral columns. Typically, the articular surface is reconstructed and then fixed to the medial and lateral column. Occasionally, the medial or lateral column is reconstructed first and the articular surface is then reconstructed around this intact column. This approach is particularly helpful when one column remains intact and there is significant articular comminution.


Restoration of the articular surface can be extremely challenging. An understanding of the topography of the articular surfaces of the distal humerus is mandatory. Reduction and provisional fixation of the articular fragments with Kirshner wires allows the proper placement of the medial and lateral column plates without interference from the articular fixation.

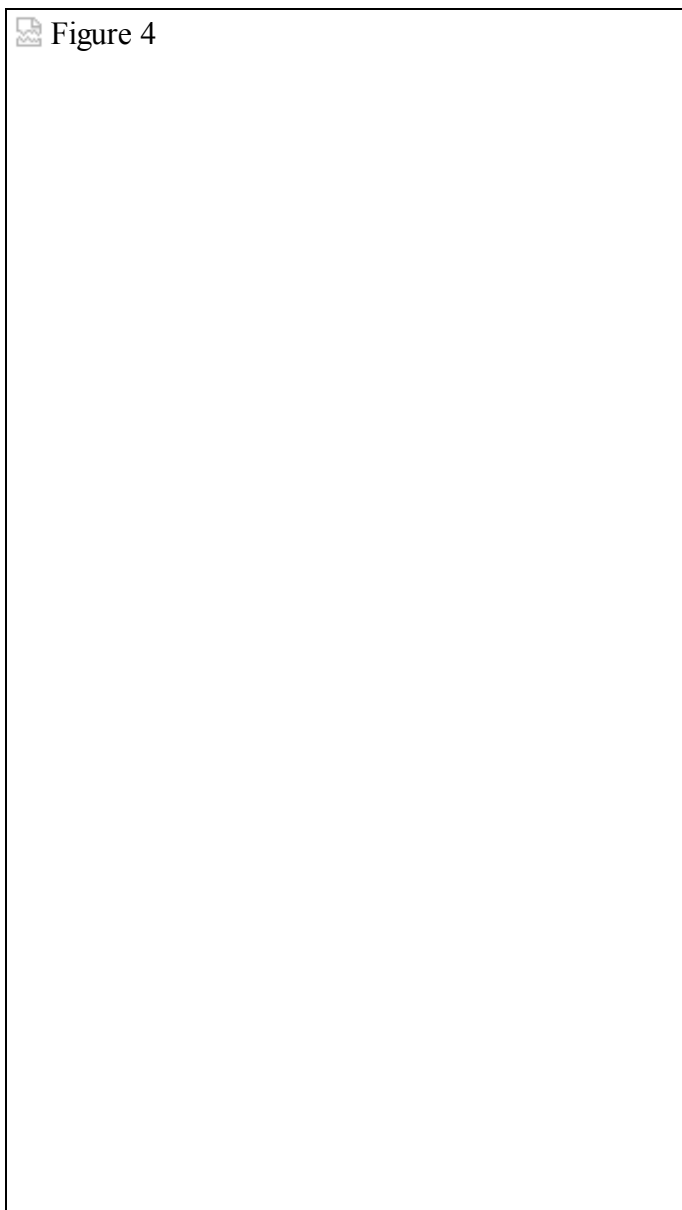
Definitive fracture fixation usually begins with inter-fragmentary screw fixation of the sagittal plane fracture across the trochlea. A 3.5-mm bi-cortical screw is preferable, but a 4.0-mm cancellous screw is acceptable. If articular comminution is present in the sagittal plane care must be taken not to overcompress the fracture fragments. The proximal fragment of the ulna can be used as a template for articular width. With significant comminution, iliac crest bone graft is used to re-establish articular width. If bone graft cannot be used in the acute setting (e.g., open fractures), then intercondylar gaps can be left and grafted at a later date.


Coronal plane fractures complicate these difficult fractures. Herbert screws or ASIF screws placed with a countersink are adequate for fixation of large fragments. Smaller osteochondral fragments can be fixed with small threaded Kirschner wires cut flush and burred beneath the articular surface. Impaction or loss of the subchondral cancellous bone requires bone grafting to support these articular fragments.

Fixation of the articular segment to the medial and lateral column is best achieved with medial and lateral plate fixation. Biomechanical studies using a supracondylar fracture model have shown that the

greatest rigidity is provided by two plates oriented at 90° to one another [11,27]. In the majority of intercondylar distal humerus fractures where the fractures exit the supracondylar columns above the olecranon fossa, one plate along the medial column and a second plate along the posterior aspect of the lateral column provides sufficient fixation. In certain low distal humerus fractures, the fracture line exits the columns at the level of the epicondyles. In this situation plate placement is dictated by the available bone stock in the distal fragment and 90°--90° plate orientation is frequently difficult to achieve. Several options exist for these challenging fractures. A medial 3.5-mm reconstruction plate can be contoured to cradle the medial epicondyle (Figure 4). A second option for the medial column is to contour the plate around the medial column to the medial wall of the trochlea (Figure 5). This plate has a tendency to be prominent in thin patients and occasionally causes problems. Lateral plate fixation takes advantage of the absence of articular cartilage on the posterior aspect of the lateral column. A 3.5-mm reconstruction plate brought to the articular margin provides some bone for distal fixation. However, the presence of the articular surface of the capitellum anteriorly limits posterior to anterior screw placement to cancellous screw type. An alternative for lateral fixation is the anatomically contoured DuPont lateral condyle plate (Howmedica Rutherford, New Jersey). This plate extends to the lateral articular margin of the distal humerus along the lateral column and allows screw fixation from lateral to medial across the distal humerus. The brachioradialis and common extensor mass must be released, but are repaired to the triceps fascia at the conclusion of the case.

 Figure 4



 Figure 5

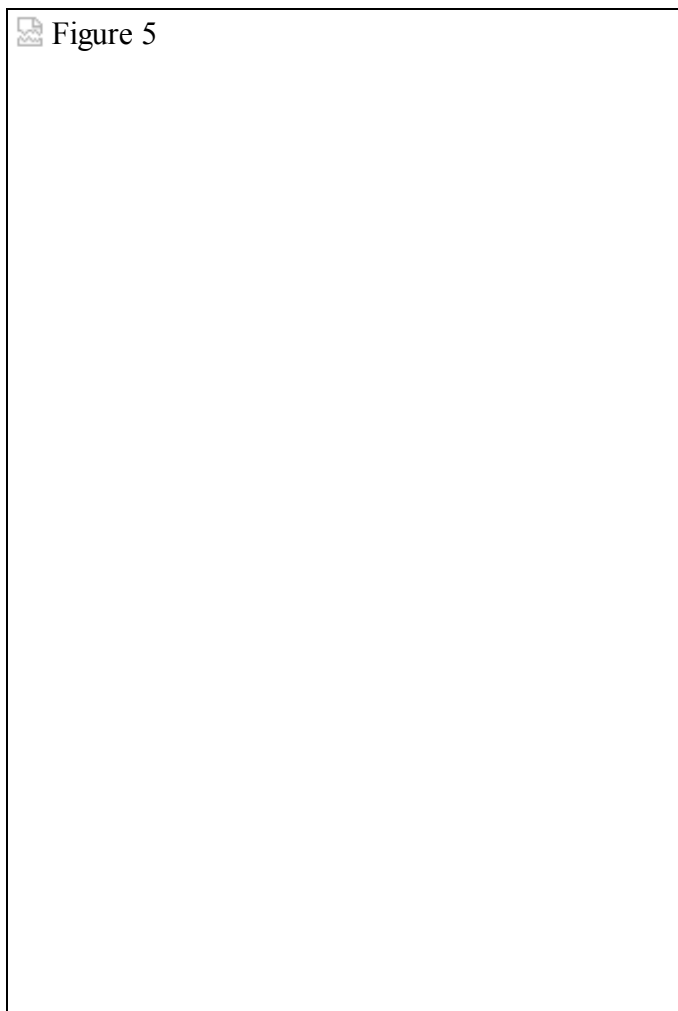


Fig. 4. Lateral radiograph demonstrating the use of a 3.5-mm reconstruction plate to stabilize the medial column. Note that the reconstruction plate was contoured to cradle the medial epicondyle allowing long column screws to be placed.

Fig. 5. Repair of a distal humeral non-union. A 3.5-mm reconstruction plate was contoured along the medial column against the medial wall of the trochlea. Long column screws secure fixation to the cortical bone of the opposite column.

Screw placement is dictated in many instances by the position of medial and lateral plates. Screw placement in the distal fragment generally presents the greatest challenge because of the articular geometry and the lack of distal humeral bone stock. Long 3.5-mm cortical pelvic screws placed up the column are particularly useful (Figure 5). These screws are passed proximally to gain purchase in the firm cortical bone of the opposite column. Alternatively, smaller screws can be placed in the bone around the olecranon fossa that provides excellent purchase as well. Care must be taken not to place a screw in the olecranon fossa, as this will limit extension.

Comminution of the medial or lateral columns requires careful consideration. Overcompression of the columns produces angular deformity and reduces the size of the olecranon fossa causing a loss of extension. Iliac crest bone graft should be used to re-establish column length when necessary.

The elbow is taken through a range of motion to assess the stability of the fixation construct. Inadequate fixation should be revised or supplemented to provide stable fixation. An option when dual plating is insufficient is to place three plates: one along the lateral column, one along the posterior aspect of the lateral column, and one around the medial epicondyle. The olecranon osteotomy is reduced and fixed with a tension band technique.

Aftercare

Active motion is initiated on the first or second post-operative day. The patient is instructed on active and passive-assisted exercise for flexion, extension, pronation, and supination. Motion is monitored carefully in the postoperative period. If the patient is unable to perform the prescribed exercises a splint program to regain motion is initiated once fracture union is evident radiographically. Supervised physical therapy is not particularly helpful in regaining motion in patients who fail to progress with a home stretching program. Aggressive physical therapy can inflame the elbow and perpetuate the stiffness cycle.

Primary Total Elbow Arthroplasty (TEA)

The value of primary joint replacement in the treatment of hip fractures in the elderly is well recognized. It would seem reasonable to assume the benefits of joint replacement after hip fracture could apply to fractures of the distal humerus. The success of total elbow arthroplasty (TEA) in patients with rheumatoid arthritis has resulted in the expansion of the indications for its use. A recent clinical study reported the use of primary TEA in elderly patients with comminuted fractures of the distal humerus in a group of carefully selected patients. Pre-existing rheumatoid involvement of the elbow influenced the decision to proceed with TEA in many patients. All patients had a satisfactory result at 3.3-year follow-up without any complications [5].

The surgical technique for TEA for acute fractures uses a triceps-sparing approach. The medial and lateral aspect of the triceps is identified and the ulnar nerve is controlled. The flexor-pronator muscle mass and the medial collateral ligament are released from the distal humeral fracture fragments. Similarly, the common extensor muscle mass and lateral collateral ligament are released from the lateral aspect of the distal humeral fracture fragment. The forearm is displaced medially and the humerus is delivered laterally to the margin of the triceps. The intramedullary canal of the humerus is prepared for implant insertion. Forearm supination delivers the ulna for preparation and implantation of the ulnar component. After implant insertion, the components are articulated and the flexor-pronator and common extensor muscle masses are sutured to the triceps fascia. The ulnar nerve is transposed subcutaneously.

Selection of an appropriate implant is critical to the success of this surgery. Linked, semi-constrained implants are required for the management of these fractures (Figure 6). Unlinked, resurfacing implants rely on intact bone stock and ligaments for implant stability and have no place in this application.

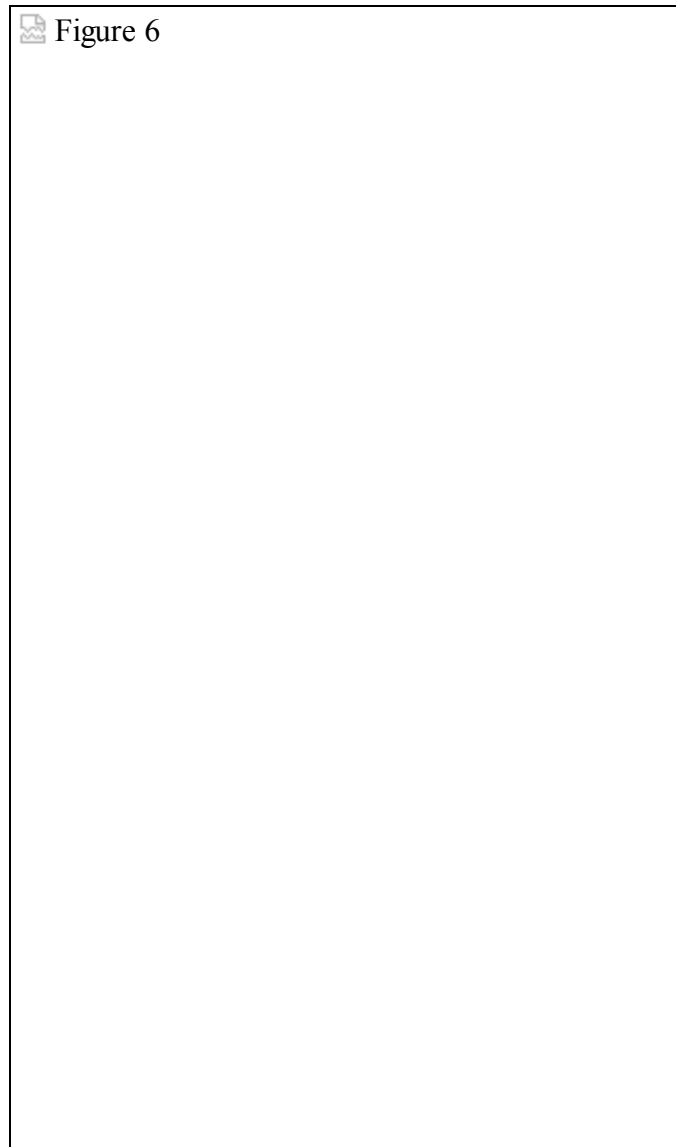


Fig. 6. Photograph of a linked, semi-constrained implant (Coonrad-Morrey Prosthesis; Zimmer, Warsaw, IN) used for total elbow arthroplasty.

Salvage Procedures

The success of open reduction and internal fixation and more recently TEA in the treatments of complex distal humerus fractures has eliminated the need for many salvage procedures. In some instances, however, other alternatives must be considered. Grossly contaminated open fractures (Gustilo Grade III) are best managed with external fixation and local wound care. Although possible to convert to internal fixation at a later date, external fixation can be used for definitive fixation. Other techniques include casting, bag of bones, and olecranon pin traction. All of these techniques can result in significant morbidity and usually provide less than optimal results [14].

Complications

Loss of motion

Stiffness is a common complication of fractures of the distal humerus and is most often caused by inadequate post-operative rehabilitation. The functional arc of elbow motion required for the majority of daily activities is from 30 to 130 degrees of flexion and 50 degrees each of pronation and supination [22]. It is preferable to avoid contractures rather than treat them once they are established. Contractures can be treated with a splint program for up to 1 year after injury but the majority of meaningful gains in motion occur in the first 6 months. Several factors combine to cause loss of motion after fracture. First, the initial trauma to the soft tissues from the injury combined with the surgical insult results in aggressive scarring of the periarticular soft tissues. Second, extension of the fracture to the joint surface results in intra-articular scarring that can compromise motion. Third, post-operative pain limits the ability to participate in a stretching program and reinforces the stiffness cycle. To prevent stiffness, all patients are taught range of motion exercises in the immediate post-operative period beginning with active assisted exercises and then progressing to passive exercises for flexion-extension and forearm rotation.

Established contractures are classified as intrinsic and extrinsic [7,21]. Extrinsic contractures involve contracture of the peri-articular soft tissues or heterotopic bone formation in the soft tissues about the elbow. The articular surface is generally well preserved. Intrinsic contractures result from intra-articular adhesions or incongruity of the articular surface and are typically accompanied by an element of extrinsic contracture.

If range of motion is limited after several weeks, brace therapy is initiated. Available methods to regain motion through a splint program include dynamic and static splints. Dynamic splints use the concept of tissue creep by applying a continuous force to contracted tissue. These splints require extended wear and can be very uncomfortable and painful to the patient. Static splints use the principle of stress relaxation to achieve their desired results. The elbow is placed in flexion or extension in a position of slight tissue tension and held in this position for an extended period. Over time the contracted tissue accommodates this elongated position.

Established contractures not responsive to splint therapy require surgical management if functional motion is to be achieved. Purely extrinsic contractures respond well to anterior and posterior capsular release, whereas intrinsic contractures require soft tissue release combined with joint interposition if more than 50% of the articular surface is destroyed.

Distraction arthroplasty used alone or in combination with fascial interposition can improve motion for patients with post-traumatic stiffness. The distraction device is a hinged external fixator that allows motion while maintaining distance between the articular surfaces. Although technically more demanding, this technique may provide improved motion compared with fascial interposition alone [21].

Non-union

Non-union is most commonly the result of inadequate fixation. The symptoms, age, and functional status of the patient determine the appropriate management for non-union of the distal humerus. Non-union of the distal humerus is frequently complicated by intra-articular adhesions. In fact elbow motion frequently occurs through the non-union with no motion through the elbow joint. The non-union may be stable or unstable, in which case a flail extremity can result.

In young patients with high functional demands, takedown of the non-union, autogenous bone grafting, anterior and posterior capsular releases, and ulnar nerve transposition have produced excellent results. Union rates of approximately 90% have been achieved after revision internal fixation and bone grafting [1,18,19].

Patients unlikely to benefit from revision open reduction internal fixation are those with marked

osteopenia, intraarticular scar, and limited bone stock. This situation occurs predominantly in elderly patients. Total elbow arthroplasty provides an excellent alternative with predictably good results in carefully selected patients [8].

Malunion

Two basic types of malunion occur after complex distal humerus fractures: intra-articular and extra-articular. Intra-articular malunion causes loss of motion, pain, and early arthritis. Extra-articular malunion causes loss of motion and deformity such as cubitus valgus and cubitus varus. Severe cubitus valgus can cause tardy ulnar nerve palsy [6]. If symptomatic, malunions are best treated by osteotomy to realign the extremity and revision open reduction and internal fixation with bone grafting as necessary [18].

Heterotopic ossification

Heterotopic ossification can cause functional impairment near the elbow. In the absence of injury to the central nervous system (CNS) the incidence of heterotopic bone about the elbow after closed elbow injuries is only 3% [29]. The incidence increases to approximately 5% in patients with injury to the CNS without any elbow injury. Interestingly, the incidence increases to 89% in those with injury to both the elbow and the CNS [10]. In patients without CNS injuries, ectopic bone can be excised when heterotopic bone appears mature on plain radiographs alone. Bone scan and alkaline phosphatase remain elevated for a prolonged period and are not good markers for the maturity of heterotopic bone. Early excision (within 3--8 months post-injury) followed by radiation therapy has been shown to provide good results without recurrence [17]. In either case, excision should be performed before ectopic bone causes prolonged functional impairment (e.g., prolonged stiffness). In patients with CNS injuries, excision should be performed when the patient maximizes cognitive rehabilitation and spasticity has been minimized [9,20].

Other complications

Post-traumatic arthritis is a concerning and often unavoidable consequence of complex fractures of the distal humerus. Damage to cartilage, small amounts of displacement, and bone loss likely predispose the elbow to arthritis. Ulnar neuropathy can also occur. Transposition of the ulnar nerve at the time of surgery has been shown to reduce the likelihood of subsequent ulnar nerve palsy [30].

Summary

Complex distal humerus fractures are among the most difficult fractures to treat. A thorough understanding of the anatomic features of this area is essential to management. Open reduction internal fixation with inter-fragmentary screws and double plating techniques is the preferred method of treatment. As both technique and implant design improves, the role of primary TEA in the treatment of these fractures expands. Non-operative treatment has limited application and should be reserved for extraordinary circumstances. Complications of distal humerus fractures are common. Careful attention to the post-operative management of these patients is essential to achieve the best possible outcomes. Loss of motion, non-union, malunion, heterotopic ossification are complications that have well-defined treatment options.

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