

# Treatment of Distal Humerus Fractures

## Léčba zlomenin distálního humeru

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### SUMMARY

The elbow is a complex joint and is vital in positioning the hand in space. We believe that open reduction internal fixation offers the best chance for return to function following intra-articular fractures of the distal humerus. We advocate the following principles for the effective treatment of these injuries: identification and protection of the ulnar nerve followed by transposition, broad exposure of the fracture utilizing an olecranon osteotomy, anatomic restoration of the articular surface with preservation of all osteochondral fragments, rigid fixation of both columns using pre-contoured plates and screws, and the institution of early range of motion post-operatively.

### INTRODUCTION

Distal humerus fractures remain a challenging injury to manage, particularly as the population ages and the prevalence of osteopenic fractures grow (9). Several variables are important in successful management of these fractures: restoration of articular congruity, secure bony fixation, achievement of bony healing, maintenance of a functional range of motion, and avoidance of complications such as heterotopic ossification and ulnar neuropathy. Our understanding of fracture morphology, operative approaches, and implant designs have substantially added to our ability to treat these fractures more effectively.

### EPIDEMIOLOGY

Distal humerus fractures make up 0.5 to 2% of all fractures, but up to 30% of fractures involving the elbow (58). In addition, the incidence of distal humerus fractures among the elderly seems to be increasing. Palvanen et al identified more than a 2-fold increase in the age-adjusted incidence of distal humerus fractures in Finnish women older than 60 between 1970 and 1995, and predicted a 3-fold increase by the year 2030 (44). This is reinforced by Court-Brown & Caesar who also identified an increasing trend in osteoporotic distal humerus fractures as people are living longer and the prevalence of osteoporosis grows (9).

In adults, most distal humerus fractures are intra-articular and involve both the medial and lateral columns (58, 22). The distribution of distal humerus fractures follows a bimodal age distribution. High-energy injuries tend to occur among younger patients, while low-energy injuries are more common in older patients.

### ANATOMY

Understanding the anatomy of the distal humerus is critical to effective treatment of distal humerus fractures. Divergent medial and lateral columns of bone support the distal humeral articular surface in an inverted-Y configuration. The medial column diverges from the central humeral axis at an angle of 45 degrees, and the lateral column at an angle of 20 degrees (22, 32).

The trochlea lies in the center and links the two columns and articulates with the olecranon. Stability of the elbow is a product of bony articulations, soft tissue tension, and the musculotendinous forces acting across it. The central sulcus of the trochlea inter-digitates with the corresponding articular ridge on the olecranon providing significant bony stability to the elbow through this highly congruent articulation. The trochlea is covered by articular cartilage over an arc of almost 300 degrees and subsequently permits a broad range of motion at the ulno-humeral joint. Compromise of the trochlea in the form of shortening, bone loss, or residual incongruity can translate into significant loss of elbow motion and stability.

The capitellum resides on the lateral column and provides 180 degrees of articulating area. In contrast to the trochlea, the posterior aspect of the lateral column is non-articular and allows for posterior placement of implants without risk of injury to cartilage or risk of impingement with flexion and extension.

The distal articular surface lies in 4 to 8 degrees of valgus and is externally rotated 3 to 4 degrees relative to the central axis of the humerus. The capitellum and trochlea are translated anteriorly relative to the humeral diaphysis, creating an angle between the central humeral axis and the distal articular segment of 30 to

40 degrees. The lateral column and epicondyle follow this anterior translation, whereas the medial column and epicondyle are in line with the humeral shaft. Compromise of these dimensions during treatment can risk loss of elbow motion.

Proximal to the articular surface are depressions in the metaphyseal level of the distal humerus, the radial and coronoid fossae, that accommodate the radial head and coronoid process, respectively. Posteriorly, the olecranon fossa accepts the olecranon process within it and must remain free of hardware during repair to allow full extension.

In addition to the stability provided by the highly congruent ulno-humeral articulation, the medial and lateral collateral ligament complexes of the elbow significantly add to elbow stability. Typically with distal humerus fractures not associated with a concomitant dislocation injury to the collateral ligament would be uncommon. But, knowledge of their anatomy must be considered during the treatment of distal humerus fractures. The medial collateral ligament has its proximal attachment along the anteroinferior aspect of the medial epicondyle and has its distal attachment along the medial aspect of the ulna immediately distal to the coronoid process (8). The lateral collateral ligament complex has its proximal attachment at a point along the lateral epicondyle that marks the axis of the ulno-humeral joint and attaches to the lateral ulna along a broad base while coalescing with fibers of the annular ligament complex (8).

## CLASSIFICATION

The traditional classification of distal humerus fractures has centered around the terminal ends, or the condyles, of the humerus. When discussing intra-articular fractures of the distal humerus, the term "condyle" is converted to "columns" for the sake of classification. Single column fractures in adults are uncommon and generally involve the lateral column. Both column fractures on the other hand are the most common.

Several classification systems for intra-articular both column fractures of the distal humerus have been proposed. In 1936, Reich first described "T" and "Y" intercondylar fractures (46). In 1969, Riseborough and Radin described 4 types of intercondylar "T-type" distal humerus fractures: Type 1 was a non-displaced fracture, Type 2 was displaced but without rotation of the fragments, Type 3 includes fragment rotation, and Type 4 involved severe comminution (48). Although initially relevant for its descriptive value, these classifications proved inadequate in reliably describing the fracture and directing treatment as these injuries were more frequently being treated operatively.

The Orthopaedic Trauma Association's alpha-numeric system, based on The Comprehensive Classification of Fractures of Long Bones, assigned three main types: Type A (extra-articular), Type B (partial articular), and Type C (complete articular) (38). Sub-types are given

thereafter for further fracture details. Although useful for cataloging fractures for research purposes, the OTA system's clinical application is limited and is hindered by poor inter-observer reliability beyond identification of the basic three types (57).

The classification system proposed by Jupiter and Mehne describes distal humeral fracture patterns anatomically based upon intra-operative findings yielding six categories: High or Low "T," "Y," "H," and Medial or Lateral Lambda fractures (22). Recently, isolated shearing injuries of the distal humeral articular surface have also been described (47). This spectrum of injury patterns identified through operative and radiographic findings yielded five fracture patterns: 1. the capitellum and the lateral aspect of the trochlea, 2. the lateral epicondyle, 3. the posterior aspect of the lateral epicondyle, 4. the posterior aspect of the trochlea, and 5. the medial epicondyle.

## NON-OPERATIVE TREATMENT

The indication for non-operative treatment of distal humerus fractures is limited and primarily involves patients with very low demand or in poor health. The "bag of bones" technique can be successfully employed with a brief course of immobilization followed by gradual return to supervised motion. Functional results are acceptable as long as patient expectations are tempered. The risk of fracture displacement, malunion, and non-union is high with non-operative treatment.

## OPERATIVE TREATMENT

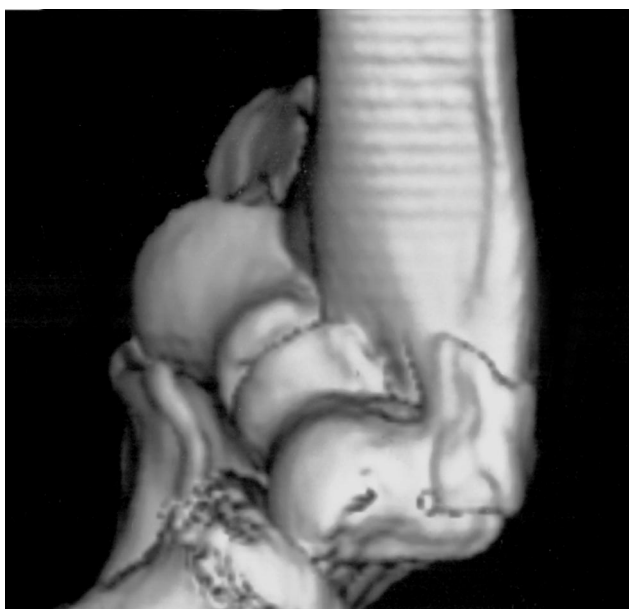
Due to the characteristic intra-articular involvement, displacement, and poor control of fracture fragments with closed treatment, we typically treat these fractures operatively. Pre-operative evaluation begins with assessment of the neurovascular status. The ulnar nerve function in particular is documented. If the injury occurred through a high-energy mechanism a full trauma evaluation is warranted and attention is given to all organ systems.

Radiographic evaluation begins with anteroposterior and lateral views. Visualization of the fracture may be improved with traction radiographs (Fig. 1). Imaging above and below the injury is directed by physical exam findings. Due to the inability of standard radiographs to adequately characterize distal humerus fracture patterns and with the increasing availability of advanced imaging modalities, we recommend routine use of computed tomography with 3-dimensional reconstructions (Fig. 2). Digital subtraction of the radius and ulna will improve characterization of the fracture pattern.

Before proceeding to the operating room, other variables to consider include patient positioning, the surgical approach, the potential need for bone grafting, and choice of internal fixation. The patient may be positioned supine (with the arm draped across the body), prone, or lateral. We recommend lateral positioning with



*Fig. 1. Traction radiographs can improve fracture visualization and characterization.*



*Fig. 2. Computed tomography with 3-D reconstructions.*

the operative limb supported by a bolster for it allows comfortable positioning of the elbow directly in front of the surgeon, dependence of the arm that indirectly aids in reduction, easier access for the image intensifier, convenient approach to the hip if autologous bone harvesting is planned, and quicker access to the airway if necessary.

Multiple operative approaches to the distal humerus are available and are chosen based on fracture configuration. We recommend utilizing a posterior skin incision that takes advantage of the rich blood supply to the posterior elbow and diminished risk for skin necrosis

and painful post-operative neuroma formation that can occur with injury to cutaneous nerve branches (10). Full thickness flaps can be raised providing excellent exposure both medially and laterally. Prior to deep dissection the ulnar nerve must be identified and protected. We advocate routine release of the ulnar nerve beginning 8 cm proximally and extending 6 cm distal to the medial epicondyle, and include excision of the medial intermuscular septum and release of the fascia between the two heads of the flexor carpi ulnaris. At the end of the procedure, the ulnar is transposed anteriorly in a subcutaneous fashion. Thereafter, multiple approaches to the distal humerus is available.

### **Alonso-Llames Triceps-Sparing Approach**

The Alonso-Llames approach involves sub-periosteal elevation of the distal triceps off the posterior aspect of the humerus (3). This approach is applicable in treating fractures of the distal humerus by developing "windows" along the medial and lateral borders of the triceps without injuring the triceps aponeurosis and its insertion into the olecranon. This approach is limited to treating extra-articular fractures of the distal humerus that extend no more than 10 to 12 cm proximally along the humeral shaft to the level of the radial nerve.

### **Campbell Triceps-Splitting Approach**

The Campbell approach involves splitting the triceps longitudinally through the midline of the triceps aponeurosis down to bone followed by sub-periosteal elevation of the triceps medially and laterally (6). The tri-



cep's split extends distally onto the olecranon. Proximally, the radial nerve limits the extent of dissection. Closure requires meticulous repair of the medial and lateral sleeves of the triceps aponeurosis. McKee et al studied the use of the triceps-splitting approach in cases of open distal humerus fractures and noted no difference between patients treated with a triceps-splitting exposure versus olecranon osteotomy (33). In addition, regardless of approach, patients rarely regained more than 75% of flexion and extension strength compared to the unaffected side.

### Van Gordner Approach

Van Gordner provided an alternative of the triceps-splitting approach by raising a distal tongue of the triceps fascia in an inverted-V pattern before splitting the triceps longitudinally while leaving a cuff of the extensor mechanism aponeurosis intact distally to allow a secure repair of the extensor mechanism (16). The remaining triceps muscle is split longitudinally in the manner described by Campbell.

### Bryan-Morrey Approach

Bryan and Morrey described a medial approach to the elbow that involved raising the triceps and extensor mechanism as a full sub-periosteal sleeve off of the posterior humerus and proximal ulna (5). This requires meticulous technique not to violate the continuity of the extensor mechanism during dissection. Reflection of the sleeve of extensor mechanism results in exposure of the elbow joint. Closure is performed by returning the extensor mechanism to its appropriate position along the posterior elbow and repair with non-absorbable sutures and trans-osseous tunnels.

### Triceps-Reflecting Anconeus Pedicle Approach

O'Driscoll described raising the extensor mechanism by using the anconeus as a vascularized pedicle and maintaining its role as a dynamic stabilizer of the elbow joint (42). The approach begins laterally at the Kocher interval, between the extensor carpi ulnaris and the anconeus. The anconeus is raised sub-periosteally off both its ulnar and distal humeral insertion while maintaining continuity with the triceps and its pedicle proximally. The lateral collateral ligament complex is at risk with this dissection and must be protected. The anconeus-triceps flap is then completed with sub-periosteal dissection in a medial to lateral direction with elevation off of the olecranon. Subsequently, a "tongue" of soft tissue consisting of the triceps and anconeus can be detached from the ulna and retracted proximally resulting in exposure of the elbow joint. Repair requires meticulous re-approximation of the extensor mechanism with non-absorbable sutures and trans-osseous tunnels.

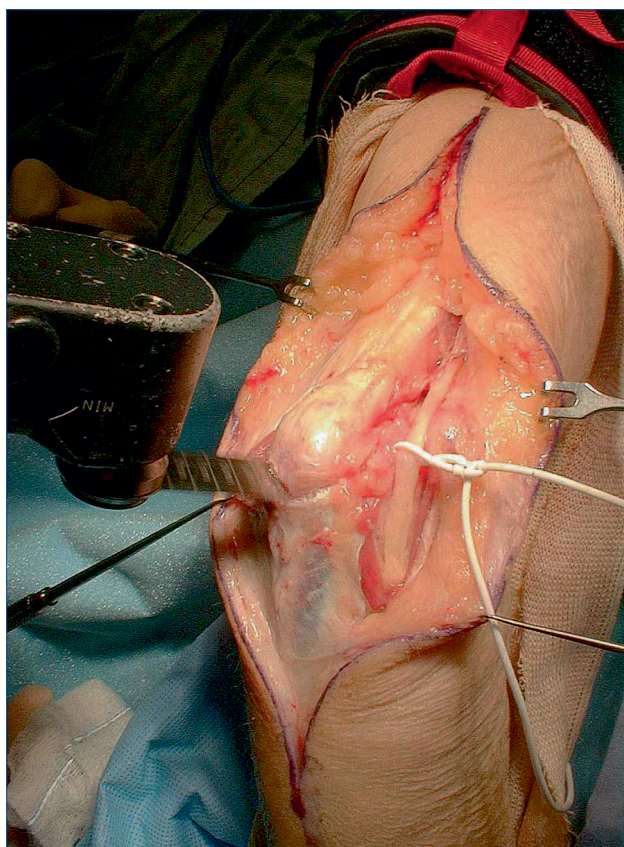


Fig. 3a. An incomplete chevron osteotomy is made with an oscillating saw and then completed with an osteotome.

### Olecranon Osteotomy

The olecranon osteotomy has been the workhorse for approaching the distal humerus and is our preferred approach. It provides the greatest exposure to the articular surface when compared to the triceps splitting and reflecting approaches, as confirmed by a cadaveric study (59). The osteotomy site can be identified in one of two ways. The first is by elevating the anconeus off of the olecranon laterally. The second is by incising the capsule medially. Either technique is effective and yielding visualization of the trochlear notch. A chevron osteotomy is made along the posterior ulna so that the osteotomy enters within the trochlear notch, an area relatively devoid of articular cartilage (Fig. 3a). The osteotomy is performed incompletely with an oscillating saw. The osteotomy is then completed by hand or an osteotome resulting in an irregular border that will allow inter-digitation of the osteotomy during repair. The olecranon is then reflected proximally along with the attached posterior elbow capsule and triceps revealing excellent exposure to the articular surface.

After reduction and fixation of the distal humerus the osteotomized fragment of olecranon is keyed back into the distal segment and temporarily stabilized with pointed bone-holding tenaculum clamps applied perpendicular to the plane of the chevron osteotomy. Two 0.045-



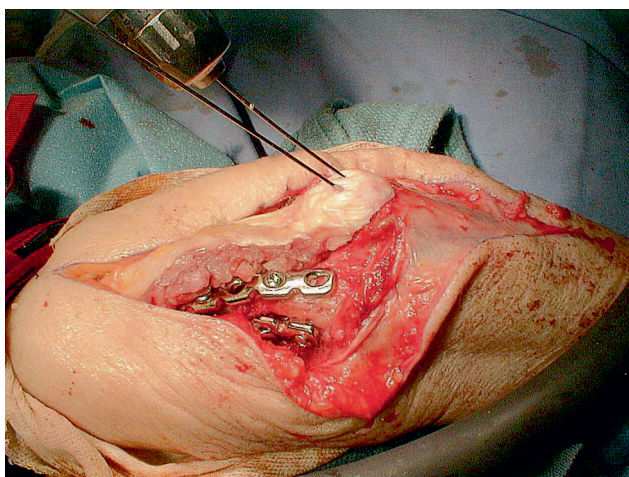


Fig. 3b. Two K-wires are drilled in parallel to reduce the osteotomy site.

inch K-wires are drilled in parallel from the posterior portion of the proximal fragment into the distal segment such that they exit the anterior cortex of the ulna just distal to the coronoid process (Fig. 3b). After drilling, the K-wires are pulled back 5 to 10mm for impaction after tensioning. The extensor carpi ulnaris and flexor carpi ulnaris are elevated off the subcutaneous border of the ulna 3 to 4 cm distal to the osteotomy site. Two 2 to 3 mm transverse holes are drilled in parallel about 1 cm apart through the distal cortex. A 22-gauge stainless steel wire is passed through each drill hole and then passed beneath the triceps insertion proximal to the previously placed k-wires in a figure-of-8 fashion. A 12 or 14-gauge angiocatheter needle can facilitate passage beneath the triceps. The wires are then tensioned by twisting medially and laterally simultaneously until all slack is removed from the wires. The twisted ends are clipped and pushed into the surrounding soft tissue. The exposed ends of the k-wires are bent 180 degrees and rotated to catch the tensioned 22-gauge wires as they are impacted deep to the triceps aponeurosis (Fig 3c). The k-wires should be sitting against the olecranon to prevent them from backing out. The osteotomy site repair is then tested by taking the elbow through a range of motion under direct visualization.

## INTERNAL FIXATION

The goal of operative treatment is to restore elbow function by obtaining anatomic and stable reduction of the articular surface. Central to this goal is rigid fixation of the anatomic surface so that early motion may be instituted. Partial articular fractures with large fragments can be fixed directly using the lag technique to the intact medial or lateral column. Complete articular fractures are managed by converting them to a partial injury by quickly restoring one column. Thereafter, remaining fragments are fixed to the stabilized column. Alternatively or in conjunction with this method of fixation, 1 or 2 screws can be directed along the axis of

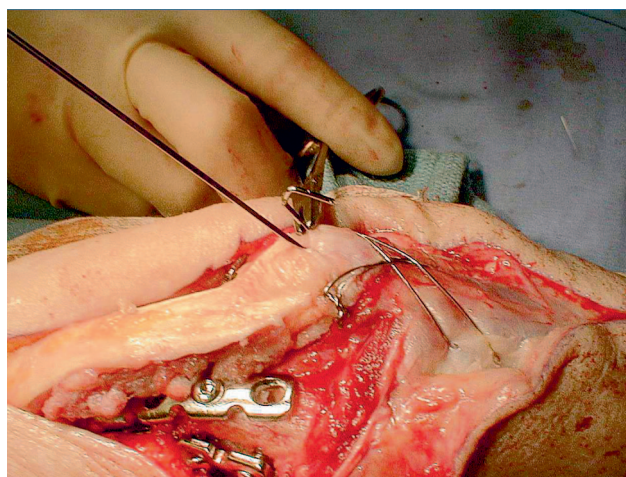


Fig. 3c. Two transverse drill holes are placed distal to the osteotomy site along the dorsal ulnar cortex to allow passage of stainless steel wire. The two holes should be approximately 1 cm apart.

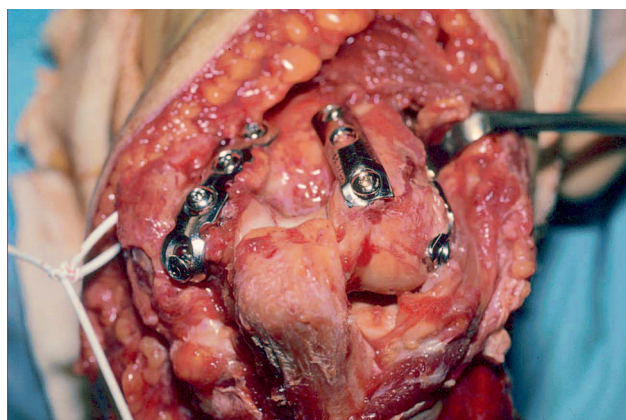


Fig. 4. Traditionally, one plate is applied medially and the second posterolaterally to provide orthogonal plating. In addition, a plate can be applied posteriorly along the lateral column to provide additional fixation.

elbow rotation through the trochlea and capitellum. Whenever possible, these screws should be passed through contoured plates to provide additional stability. Inter-fragmentary compression should be used with caution in the presence of articular comminution where the articular surface may be inadvertently shortened or deformed resulting in restriction of ulno-humeral motion. In addition, osteochondral fragments should be retained whenever possible and secured with buried implants; such as countersunk mini-fragment screws, headless variable-pitch screws, or small threaded K-wires.

Screw fixation alone is seldom adequate to provide the type of rigid fixation needed to permit early motion. Plate fixation of the distal humerus has traditionally involved two orthogonal plates, as described by the AO-ASIF group (37). One plate is placed along the posterolateral aspect of the distal humerus along the lateral column and capitellum. The second plate is placed medially and is contoured around the medial

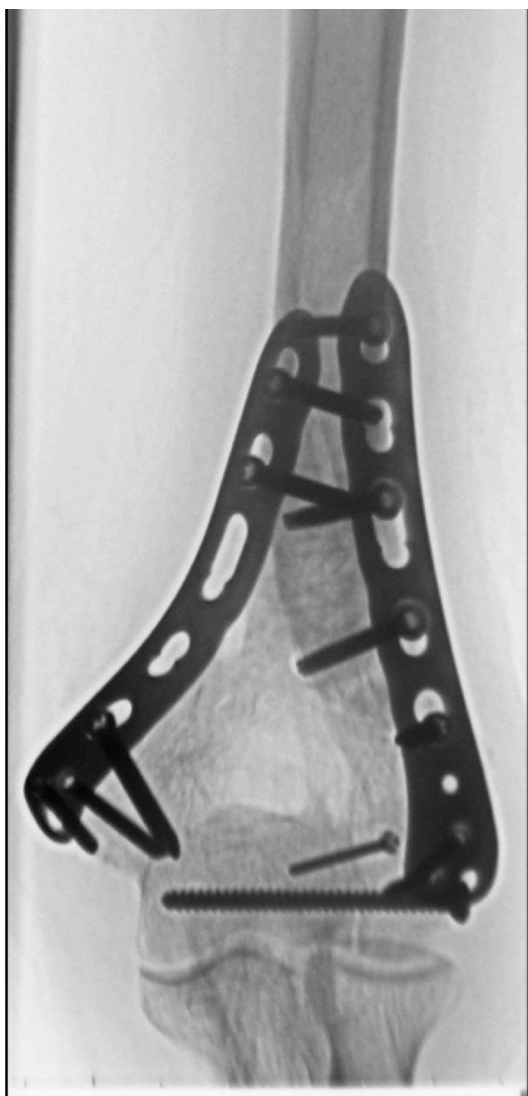
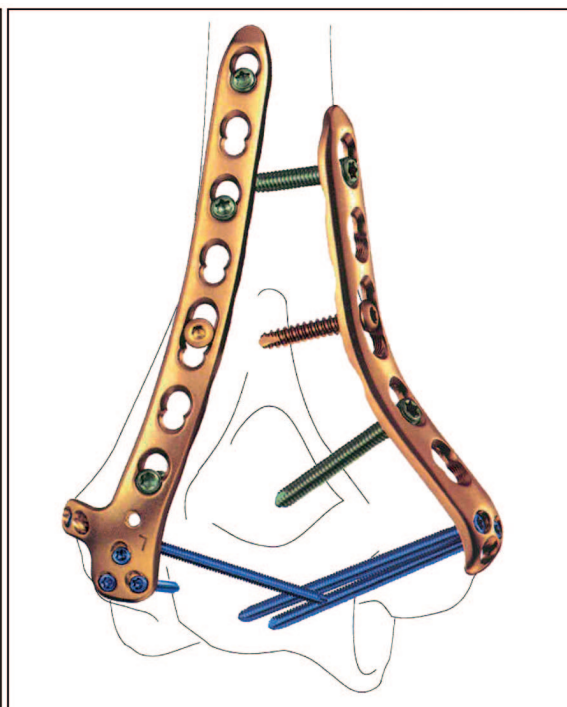
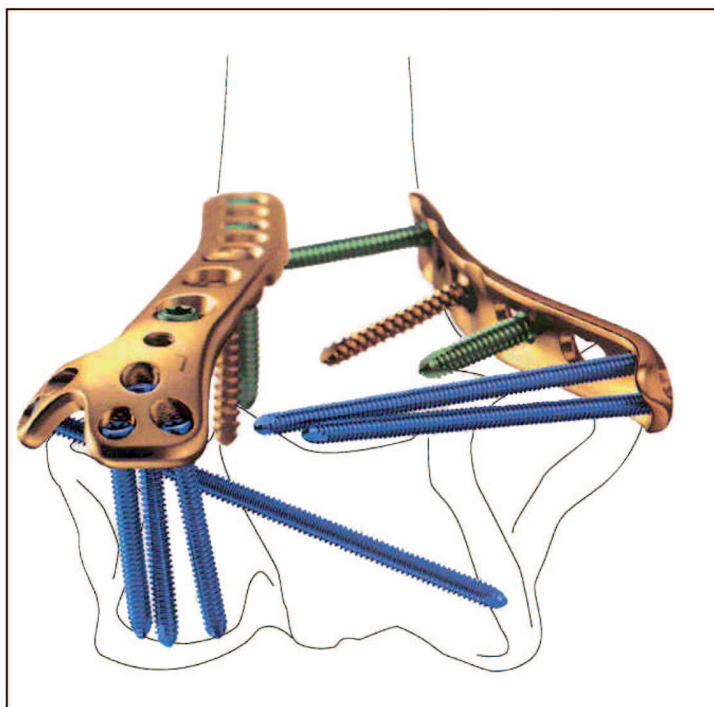


Fig. 5a & 5b. Locked plating can provide greater biomechanical stability.



column. In cases with significant comminution or osteoporosis a third plate can be applied posteriorly along the lateral column for additional fixation (21), (Fig. 4).

Locking compression plates offer improved stability in areas where screw purchase may be tenuous. Locked plates have been shown to provide a marked increase in resistance to bending, torsion, and axial compression loading among distal humerus fractures as compared to standard fixation with traditional non-locking plates, (24), (Fig. 5a, b).

O'Driscoll recently defined principles of fixation of distal humerus fractures using parallel locking pre-contoured plates and defined two goals that should be met: First, fixation within the distal fragment must be maximized, and second, all fixation in distal fragments should contribute to stability between the distal fragments and the shaft (40). In addition, he defined eight technical objectives by which these principles are met:

1. Every screw in the distal fragments should pass through a plate.
2. Every screw should engage a fragment on the opposite side that is also fixed to a plate.
3. As many screws as possible should be placed in the distal fragments.
4. Each screw should be as long as possible.
5. Each screw should engage as many articular fragments as possible.
6. The screws in the distal fragments should lock together by interdigitation, creating a fixed-angle structure.
7. Plates should be applied such that compression is achieved at the supracondylar level for both columns.
8. The plates must be strong enough and stiff enough to resist breaking or bending before union occurs at the supracondylar level.

These principles can be achieved using parallel plates. Linking the plates together through the bone with screws, thereby creating the architectural equivalent of an arch, offers the greatest biomechanical stability for comminuted distal humeral fractures (51). The arch is formed by inter-digitation of locking screws passing through the distal fragments from both plates in the sagittal plane.

In cases involving significant metaphyseal comminution, two treatment options exist. The first is to resect the comminution and shorten the distal humerus to achieve contact, compression, and union (41). The second option is to bridge the comminution with longer plates. The rich blood supply around the humerus facilitates healing when stable fixation is achieved proximally and distally to the comminution. The addition of bone graft can also augment healing.

### Outcomes with Internal Fixation

Using different instruments for measuring outcome, authors have reported good or excellent results in the literature with open reduction internal fixation of intra-articular distal humerus fractures (2, 4, 13, 18-19, 22,

25-26, 28, 33, 43, 50-53, 56). Good or excellent results typically represent stable, painless elbow, with a functional range of motion.

Sanchez-Sotelo et al recently evaluated their results using locking parallel plating technique in thirty-four consecutive patients (50). There were no hardware failures or loss of reduction. All but one healed primarily. The average arc of ulno-humeral motion was 99 degrees. They achieved good and excellent results in 27 cases, fair for 2, and poor for 3. There was one deep infection and five cases that needed additional surgery for stiffness.

### Post-Operative Management

The central goal of post-operative rehabilitation is early range of motion. In the immediate post-operative state the arm should be splinted and elevated to minimize swelling. The elbow may be splinted in either extension or flexed to 90 degrees. Starting on the first post-operative day the splint is removed and gravity-assisted range of motion exercises are begun. Extension is achieved by allowing gravity to extend the elbow while the patient stands. Flexion is achieved by having the patient lie supine and holding the arm vertical. The contralateral arm is used to control the rate and degree of motion. Motion against resistance is not begun until radiographic evidence of healing, typically after 6 to 8 weeks. The presence of an olecranon osteotomy is not a contraindication to early motion. In cases with tenuous fixation, range of motion exercises can be delayed for 2 weeks. Delaying beyond 3 weeks significantly increases the risk for developing post-traumatic elbow stiffness.

### TOTAL ELBOW ARTHROPLASTY

In cases with extensive articular comminution in osteoporotic bone or with fractures in joints with pre-existing arthritic changes, internal fixation may not be the best treatment choice. In these circumstances, total elbow arthroplasty using semi-constrained prosthesis have been promising (7, 11, 12, 14, 23, 27, 35, 39, 45). The advantage of elbow arthroplasty is immediate stability and motion and no fracture related issues such as malunion, nonunion, and osteonecrosis. Figgie et al initially presented the use of elbow arthroplasty in cases with distal humerus fracture nonunions (11). Morrey et al later successfully applied elbow arthroplasty to elbows with post-traumatic arthritis as well as rheumatoid arthritis (7, 35).

Frankle et al compared internal fixation versus total elbow arthroplasty in women over 65 years of age that incurred an intra-articular distal humerus fracture that warranted surgical intervention in 24 patients (7). After two years of follow-up and using the Mayo Elbow Performance Score they achieved 4 excellent, 4 good, 1 fair, and 3 poor (requiring conversion to a total elbow arthroplasty) in the internal fixation group. In the arthroplasty group there were 11 excellent and 1 good. Alt-

though long-term data is not yet available, total elbow arthroplasty proves to be a viable option for treatment of difficult distal humerus fractures in the older population.

Disadvantages of total elbow arthroplasty include permanent functional and weight-bearing restrictions on the patient, risk for serious complications such as infection, and the potential for prosthesis failure and the need for revision. Therefore, we limit the use of total elbow arthroplasty to infirm and low-demand older patients.

## COMPLICATIONS

Complications are common in the management of distal humerus fractures and include elbow stiffness, heterotopic ossification, nonunions, neuropathies, and infections. Post-traumatic elbow stiffness can arise from both intrinsic and extrinsic sources. Intrinsic causes of stiffness include joint adhesions, synovitis, articular incongruity, and intra-articular loose bodies. Extrinsic causes include capsular contractures and heterotopic ossification. Loss of some motion is expected after distal humerus fractures, particularly terminal extension. Loss of flexion is less tolerated than loss of extension. Although functional range of motion has been defined as 30 to 130 degrees of flexion, even small decreases in motion can cause functional impairment depending upon the patient's needs (36).

Post-traumatic elbow stiffness is best managed by avoidance and diligent post-operative rehabilitation. During the early post-operative period motion should be instituted and edema minimized. Also, splinting in full extension will tension the anterior capsule, compress posterior structures, and relax the ulnar nerve. Lack of progression in motion over the first 3 post-operative months warrants more aggressive modalities including serial casting and static progressive splinting. If non-operative methods fail to restore motion, patients can be considered for surgical release. Both open and arthroscopic techniques have proven successful in restoring motion (15, 20, 29, 55).

Heterotopic ossification is common after distal humerus fractures. Susceptible patients include those with brain or spinal cord injury, severe trauma or open injuries, and a history of prior heterotopic ossification. Such patients should receive prophylaxis against heterotopic ossification. Up to 3% of patients with local injury to the elbow develop heterotopic ossification but in most cases do not cause functional impairment (49). Traditionally, the teaching has been to wait until complete radiographic maturation of the heterotopic bone, typically 12 to 18 months, before attempting excision. However, the recurrence rate after early excision, such as 3 to 6 months post-operatively, combined with external beam radiation has been shown to be no higher than that for delayed excision and as such is becoming the favored approach (30). Early excision also provides the advan-

tage of minimizing capsular and ligamentous contracture, muscular atrophy, and articular degeneration from restricted motion (30, 54).

Nonunion occurs in 2 to 10% of distal humerus fractures treated with open reduction internal fixation (17). Risk factors include comminution, bone loss, and inadequate fixation. Treatment options include revision open reduction internal fixation with bone graft or total elbow arthroplasty in older low-demand patients with poor bone stock (1, 17, 34). Helfet et al reported their series of 52 patients with delayed union or nonunion of the distal humerus that were treated with revision open reduction internal fixation (17). They achieved a 98% union rate after re-operation (with autogenous bone graft used in 88% of cases).

Neuropathy, particularly of the ulnar nerve, may occur from the initial injury, iatrogenically during surgery, or secondarily from post-operative scarring. Release and subcutaneous transposition of the ulnar nerve at the time of surgery reduces the risk of future neuropathy. Despite adequate release and transposition, irritation and transient sensory changes have occurred in up to 50% of patients in some series (13, 17, 18, 26, 28, 39). McKee et al found that neurolysis and transposition resulted in significant symptomatic relief and functional improvement for patients with post-operative ulnar neuropathy (31). However, improvement in motor strength is often incomplete and may take several years.

## ZÁVĚR

Loket je složitý kloub mající velký význam pro polohování ruky v prostoru. Podle našeho názoru nabízí vnitřní fixace pomocí otevřené repozice nejlepší šanci na obnovu funkce po intraartikulární zlomenině distálního humeru. Pro účinnou léčbu těchto poranění zastáváme tyto zásady: identifikace a ochrana ulnárního nervu s následnou transpozicí, dostatečný přístup s případnou osteotomií olekanu, anatomická rekonstrukce kloubní plochy se zachováním všech osteochondrálních fragmentů, stabilní osteosyntéza obou pilířů s využitím tvarovaných dlah a časná pooperační rehabilitace.

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