ELSEVIER
SAUNDERS

Orthop Clin N Am 39 (2008) 187–200

ORTHOPEDIC
CLINICS
OF NORTH AMERICA

Distal Humerus Fractures

J. Whitcomb Pollock, MD, FRCSC,
Kenneth J. Faber, MD, MHPE, FRCSC,
George S. Athwal, MD, FRCSC*

Hand and Upper Limb Centre, St. Joseph's Health Care, University of Western Ontario,
268 Grosvenor Street, London, Ontario N6A 4L6, Canada

The treatment of distal humerus fractures continues to present challenges despite advances in internal fixation. Successful outcomes are difficult to achieve because of the complex anatomy of the elbow, associated osteopenia, and articular and metaphyseal comminution.

In 1969, Riseborough and Radin [1] published a study comparing operative to nonoperative treatment for the management of comminuted articular fractures of the distal humerus. They concluded that surgical treatment was unpredictable and often associated with poor outcomes, which led them to recommend nonoperative treatment. Over the last 2 decades, however, enhanced operative techniques and implant designs have improved the reduction and stability of distal humerus fractures [2,3]. There is accumulating evidence that the improved stability achieved with contemporary fixation methods of Arbeitsgemeinschaft für Osteosynthesefragen (AO) type C distal humerus fractures allows early mobilization and improved outcomes [2,4–24].

This article focuses on the epidemiology, clinical evaluation, and management of AO type C bicondylar articular fractures of the distal humerus.

Epidemiology

Elbow fractures account for approximately 7% of all adult fractures; of these, approximately 30% involve the distal humerus [25,26]. Distal humerus fractures have a bimodal age distribution [27,28], with peak incidences occurring in males between the ages of 12 to 19 years and in females aged 80 years and older [28]. In young adults, the fractures generally result from high-energy injuries caused by motor vehicle collisions, falls from a height, and sports [27,28]. In contrast, greater than 60% of distal humerus fractures in the elderly occur from low-energy injuries, such as a fall from standing height [27].

Robinson and colleagues [28] reported the incidence of distal humerus fractures in adults as being 5.7 per 100,000 per year. Palvanen and colleagues [26] studied the incidence and trends of osteoporotic fractures of the distal humerus in Finnish women older than 60 years of age. They reported a twofold increase (28/100,000) in the age-adjusted incidence of distal humerus fractures from 1970 to 1995, and predicted an additional threefold increase by 2030. Considering the aging population and increasing life expectancy, and that most of these fractures require surgical treatment, the effects on health care costs and resources will be significant. Identifying and promoting strategies, such as osteoporosis treatment and fall prevention, that may reduce the incidence of these injuries should not be overlooked.

Complex metaphyseal and articular fractures are more common than simple fracture patterns. Most (96%) distal humerus fractures in adults are type C fractures, involving both columns and extending to the articular surface [29,30]. Achieving stable internal fixation of these fractures is difficult because of multiple fracture planes, metaphyseal comminution, small fragment size, and complex fragmentation of the articular surface [31].

Classification

Fractures of the distal humerus can be classified according to the Orthopaedic Trauma

* Corresponding author.
E-mail address: gathwal@uwo.ca (G.S. Athwal).

0030-5898/08/$ - see front matter
doi:10.1016/j.ocl.2007.12.002

Association/AO comprehensive classification of fractures of long bones: type A (nonarticular), type B (partial articular), and type C (complete articular) [32]. These categories are further subdivided (1–3) based on the position of the fracture line and degree of comminution. This system is widely used in the literature and helps standardize research protocols and treatment outcomes. Unfortunately, the classification system does not account for factors such as the distal fragment height or coronal fractures, both of which significantly influence the difficulty of operative management, surgical technique, and patient outcome [3,18,29].

Clinical evaluation

A complete history and physical examination should be conducted in all cases, especially because 16% of patients who have distal humerus fractures have other associated fractures [28]. A careful neurologic examination must be performed and accurately documented pre- and postoperatively. Gofton and colleagues [22] reported that 26% of patients who had type C distal humerus fractures had an associated incomplete ulnar neuropathy that occurred at the time of injury. A careful evaluation for the precipitants of the fall that resulted in the fracture should be undertaken because patients may have undiagnosed cardiac arrhythmias or cerebrovascular disease. Special attention is directed toward identifying comorbidities and reversible illness that may impact on the treatment recommendations and perioperative risk.

Standard anteroposterior and lateral radiographs of the elbow are sufficient for most distal humerus fractures. A radial head–capitellum view can help characterize coronal fractures of the capitellum and associated radial head fractures, however [33]. When faced with more complex comminuted type C distal humerus fractures, CT can provide a better understanding of the fracture pattern and assist with preoperative planning [33]. When considering arthroplasty, a CT scan can provide detailed morphology of the elbow and rule out occult fractures of the medial and lateral columns, both of which can influence the surgical procedure and implant selection [33].

Nonoperative management

Nonoperative management of distal humerus fractures in young patients is rarely recommended. Nonoperative management may be appropriate for nondisplaced fractures with sufficient inherent stability to allow early range of motion (ROM); however, in the authors' experience surgical fixation enhances stability, allows immediate motion, and obviously decreases the risk for delayed fracture displacement. Surgery may be contraindicated in patients whose medical condition places them at an unacceptable risk and in patients who have nonfunctional upper extremities because of neurologic or other impairment [25]. These patients can be treated with the ‘‘bag-of-bones’’ technique [34].

Operative management

Surgical approach

The placement of surgical skin incisions can vary; however, the posterior midline incision has various advantages. Anatomic studies have identified that there are fewer subcutaneous nerves crossing a posterior incision when compared with medial and lateral skin incisions of the same length [35]. In addition to reducing the risk for postoperative painful neuroma, a posterior incision allows unrestricted access to medial and lateral deep approaches. Finally, the same incision can be used for elbow arthroplasty if required in the future. After making the posterior skin incision, it is important to develop full-thickness fascial-cutaneous flaps to minimize the risk for ischemic flap necrosis (Fig. 1).

There is ongoing debate as to whether distal humerus fractures should be treated using an olecranon osteotomy, a triceps-sparing approach, a triceps-splitting approach, or other variations of these approaches. Although there is more to consider than visualization alone, Wilkinson and Stanley performed an anatomic study and found that the percentage of articular surface visible after triceps-splitting, triceps-sparing, and olecranon osteotomy were 35%, 46%, and 57%, respectively [36,37].

Transolecranon osteotomy

There are essential technical points that should be followed when performing an olecranon osteotomy. First, to minimize the risk for neuropathy, the ulnar nerve is identified and transposed anteriorly. The arcade of Struthers and the medial intermuscular septum are released to avoid potential sites of nerve compression following transposition. Studies have demonstrated a 0% rate of objective ulnar neuropathy with routine transposition [22,38,39], compared with 7% incidence when transposition is not performed [18].

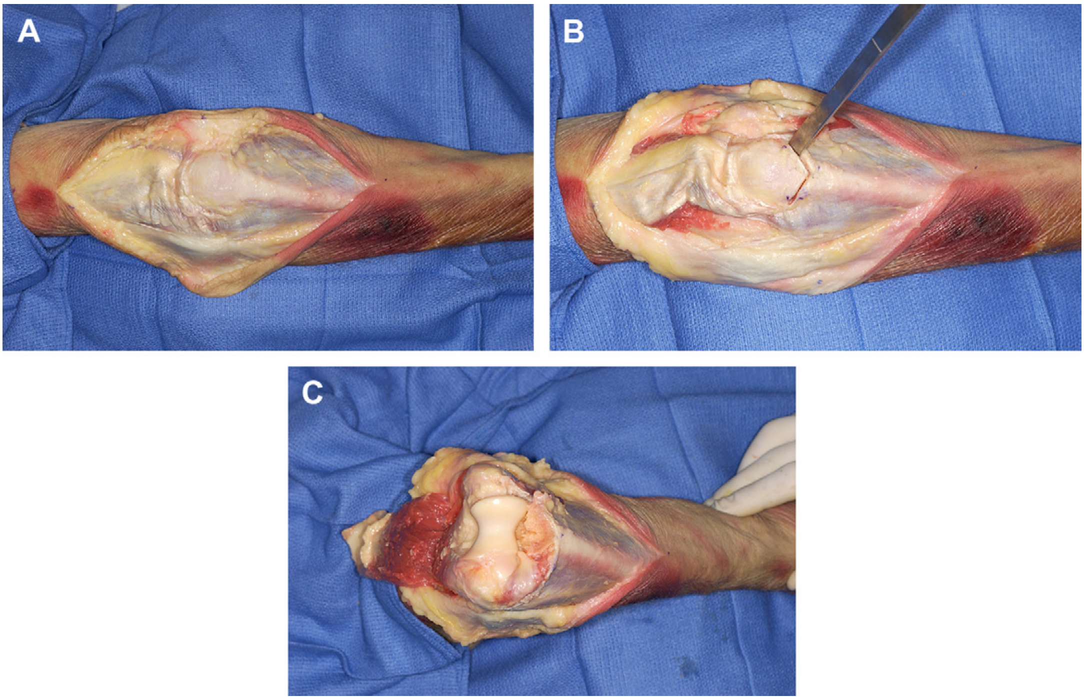

Fig. 1. An olecranon osteotomy conducted through a posterior skin incision with medial and lateral fascial-cutaneous flaps (*A*). A chevron osteotomy (*B*) allows maximal visualization of the distal humeral joint surface (*C*).

The chevron osteotomy is started by identifying the ''bare area,'' which is the nonarticular portion of the ulna between the olecranon articular facet and the coronoid articular facet. An apex distal osteotomy entering into the bare area is then marked on the subcutaneous portion of the ulna with a surgical marking pen. The osteotomy is conducted using an oscillating saw that cuts two thirds of the way through the olecranon. To prevent unpredictable osteotomy propagation, the remaining intact bone is perforated multiple times with a Kirchner wire (K-wire) in line with the osteotomy. The osteotomy is completed by using two osteotomes placed into each arm of the chevron to gently lever the olecranon fragment causing fracture of the remaining third. The fractured surface of the olecranon improves fragment interdigitation, thereby facilitating anatomic reduction during repair (see Fig. 1). A transverse olecranon osteotomy may also be conducted; however, nonunion rates have been reported to be as high as 30% [40,41].

Once the distal humerus fracture is addressed, the osteotomy can be fixed by compression plating, tension band wiring, or with an intramedullary compression screw. Our preferred method of osteotomy fixation is compression plating [42]. When using this method, the plate is applied to the olecranon with screws placed proximal and distal to the planned osteotomy site and then removed before performing the osteotomy. This ''pre-drilling'' helps achieve an anatomic reduction. Subtle dissimilarities between the contour of the plate and the patient's anatomy can cause slight malreduction of the osteotomy. To avoid this, the osteotomy is first reduced and secured in position with crossed K-wires. This additional step facilitates the application of the plate and ensures anatomic reduction.

If the osteotomy is fixed with tension band wiring, tenaculum clamps should be used to create compression across the osteotomy site [29]. Two parallel K-wires should be inserted, starting on the posterior aspect of the proximal olecranon and exiting the anterior cortex just distal to the coronoid [29]. A transverse bone tunnel is then made distally in the subcutaneous cortex of the ulna. The distance between the drill tunnel and the osteotomy should equal the distance between the osteotomy and the olecranon tip. A 22-gauge wire is then inserted in a figure-of-eight fashion through the drill holes and beneath the triceps tendon and anterior to the K-wires [29]. Finally, the medial and lateral sides of the wire are tightened simultaneously to produce equal tension on both sides [29]. Although compression plating and tension band wiring are acceptable options for fixation of olecranon osteotomies, a recent study provides support for the former. Gofton and colleagues [22] reported that none of the 14 patients treated with a contoured 3.5-mm reconstruction plate developed nonunion, hardware failure, or required hardware removal. In contrast, 2 of the 7 patients treated with tension band wiring went on to nonunion [22].

Intramedullary screw fixation is avoided in our institution. The proximal ulna has a gentle S shape, distal to the osteotomy site, which tends to dictate the position of the screw and may cause deflection of the proximal fragment resulting in malreduction at the articular surface.

An olecranon osteotomy offers the greatest exposure of the distal humerus articular surface and is our preferred approach for treating type C fractures. A recent retrospective review looked at 67 patients who had undergone a transolecranon approach for type C distal humerus fractures. Intramedullary screw and tension band fixation were used in 46 patients and plate fixation was used in 24 patients. No nonunions were reported in either group, even though more than half of the injuries were open. Removal of symptomatic osteotomy hardware was required in only 8% of the cases, regardless of the type of osteotomy fixation used [43]. Similarly, Ring and colleagues [44] achieved 98% union in 45 patients within 6 months using an olecranon osteotomy with tension band fixation. They concluded that the complication rate could be reduced with specific operative techniques, including an apex distal chevron-shaped osteotomy and bicortical K-wire fixation that exited just anterior to the coronoid. Even with meticulous technique, however, 27% of patients underwent wire removal (13% of which were symptomatic) and 2% developed a septic olecranon bursitis.

Variations of the olecranon osteotomy have been reported. Recently, Athwal and colleagues [36] described the anconeus flap transolecranon approach, which combines a proximally based anconeus flap with an apex distal chevron osteotomy of the olecranon (Fig. 2). This procedure involves incising the Kocher interval (between the extensor carpi ulnaris and anconeus muscles) and elevating the anconeus muscle in a proximal direction off the ulna. The anconeus remains attached to the proximal olecranon and triceps, which preserves its neurovascular supply. This process maintains the dynamic stabilizing effect of the anconeus muscle and also provides a vascularized bed over the osteotomy, which is hypothesized to reduce the incidence of nonunion.

Triceps sparing

The bilaterotricipital (triceps-sparing) approach was first reported by Alonso-Llames [45] in 1972. Laterally, the anconeus is elevated in conjunction with the triceps, and medially, dissection is performed along the posterior border of the intramuscular septum. Once the interval between the triceps and the intramuscular septum is developed, the triceps muscle is elevated off the posterior humerus [45,46]. Proximal extension is limited to approximately 12 cm of the diaphysis because of the radial nerve, [29] which may require identification and protection.

Although this approach may not provide sufficient exposure for type C3 fractures, it does have significant advantages for types A and possibly C1 and C2 fractures [29,45,46]. For example, the olecranon is not osteotomized, thus avoiding nonunion of the osteotomy site and the need for olecranon hardware removal. Moreover, the triceps mechanism is not disrupted, which allows early and more aggressive postoperative mobilization. Another advantage of the triceps-sparing approach is that it preserves the innervation and blood supply of the anconeus muscle, which provides dynamic posterolateral stability to the elbow [46]. Finally, the triceps-sparing approach can be safely converted into a transolecranon approach if further exposure is required.

Triceps splitting

The triceps-splitting approach described by Campbell [47] involves a midline split through the triceps tendon, with preservation of the distal attachment. Access to the articular surface is challenging and may be enhanced by partial excision of the olecranon tip. The proximal extent of this approach is limited by the radial nerve as it crosses the humeral shaft. McKee and colleagues [48] compared the triceps-splitting approach to the olecranon osteotomy and reported reduced pain and better Mayo Elbow Performance and the Disabilities of the Arm, Shoulder and Hand Outcome Measure (DASH) scores with the former. In a separate study, however, McKee and colleagues [49] demonstrated a 25% loss of isometric flexion and extension strength following operative treatment of distal humerus fracture, regardless of which approach was used.

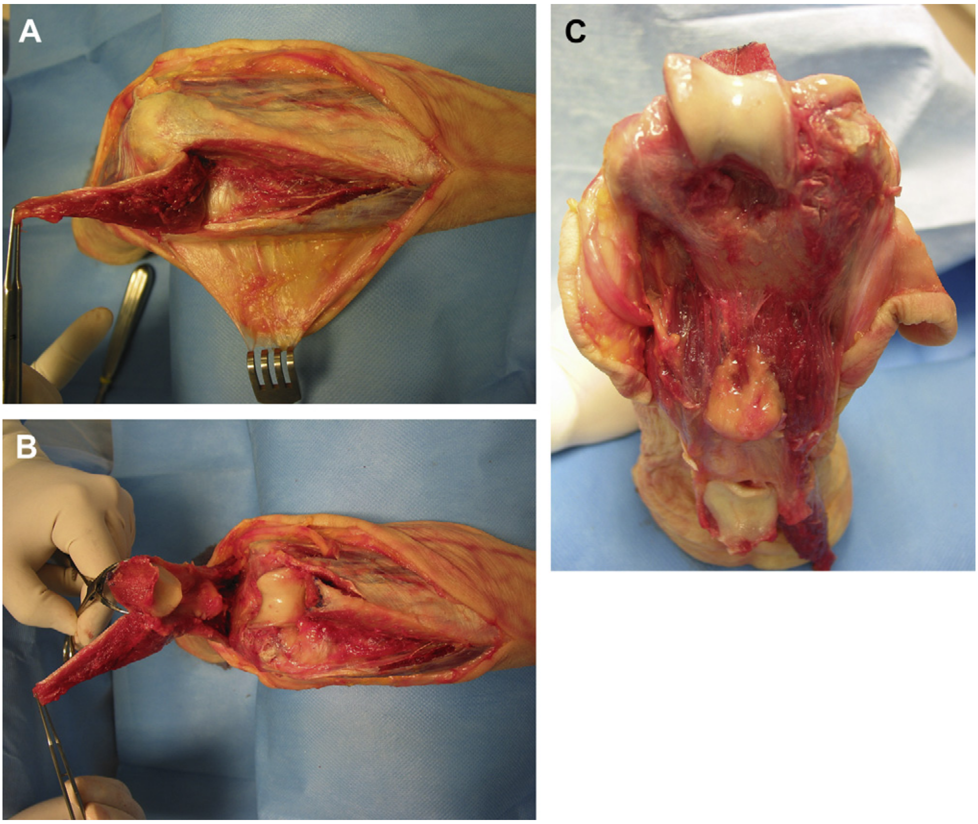

Fig. 2. The anconeus flap transolecranon approach. The anconeus muscle is raised on its proximally based neurovascular pedicle (*A*). The anconeus muscle remains attached to the olecranon fragment (*B*) as it is reflected proximally allowing visualization of the joint (*C*).

Conversely, Pajarinen and Bjorkenheim [23] showed that patients who underwent an olecranon osteotomy had increased ROM and were more likely to have a good to excellent result (67%) than those who were treated with the triceps-splitting approach (33%). Furthermore, Gofton and colleagues [22] achieved good functional outcomes and 93% patient satisfaction in a study of 23 patients who had type C distal humerus fractures who were surgically treated with a chevron olecranon osteotomy and distal humerus orthogonal plating.

Other approaches

There are several other, less commonly used, approaches to the distal humerus. The Bryan-Morrey [50] approach involves subperiosteal reflection of the triceps insertion from medial to lateral in continuity with the forearm fascia and anconeus muscle. Although the triceps tendon insertion is detached, the extensor mechanism maintains its continuity as a single sleeve through its soft tissue attachments. The Bryan-Morrey approach is appealing because it provides reasonable exposure while avoiding the complications of an olecranon osteotomy. The disadvantage of this approach is the potential for extensor mechanism weakness because of nonanatomic triceps repair or repair failure.

The triceps reflecting anconeus pedicle (TRAP) approach described by O'Driscoll involves developing a proximally based triceps-anconeus flap. The Kocher interval is used to raise the anconeus muscle and develop the lateral portion of the flap. The medial portion of the flap is created by subperiosteal dissection from the subcutaneous border of the ulna. The anconeus flap is then elevated and reflected proximally to expose the triceps insertion, which is also released. This approach provides good exposure to the posterior elbow joint while protecting the neurovascular supply to the anconeus muscle. The TRAP approach also avoids the complications of an olecranon osteotomy and allows the use of the trochlear sulcus as a template to assist with articular reduction of the distal humerus [29,51].

Ozer and colleagues [52] reported their results with the TRAP approach in 11 patients who had type C distal humerus fractures followed for more than 26 months. They obtained good to excellent functional results in 91% of patients and all fractures healed between 10 and 14 weeks. They achieved full pro-supination and a flexion/extension arc of 116 degrees (95–140) in subtypes C1 and C2 and 85 degrees in subtype C3. Flexion and extension strength (peak torque) was within 80% of the unaffected elbow. Anatomic reduction of the articular surface was achieved in all patients. Although the benefits of this approach are evident, in our opinion an olecranon osteotomy is preferred for severely comminuted type C fractures because it provides the best exposure [37].

Implant biomechanics

Controversy exists about which implant designs and plate positions provide optimal stability for distal humerus fractures. Jacobson and colleagues [53] tested five different distal humerus plating constructs in cadaveric specimens. They concluded that a medially applied pelvic reconstruction plate combined with a posterolateral (orthogonal) 3.5-mm dynamic compression plate provided the greatest sagittal plane stiffness, and equivalent frontal plane and torsion stiffness, when compared with other constructs, which included parallel and triple plating. Orthogonal plating also provided greater rigidity and fatigue resistance than a single Y plate in a cadaveric study performed by Helfet and Hotchkiss [54]. Unfortunately, this study did not include parallel plating in the comparison.

In contrast, Schemitsch and colleagues [55] examined the construct rigidity of distal humerus fixation with plates placed in five different configurations. In the presence of a cortical gap, the greatest construct rigidity was achieved with a medial 3.5-mm reconstruction plate (Synthes, Pali, Pennsylvania) and a lateral J plate (Howmedica, Rutherford, New Jersey). They concluded that, although plating the medial and lateral column was essential, orthogonal placement was not necessary and was less rigid then parallel plating. Similarly, Self and colleagues [56] found that parallel plating had greater pre- and postcyclic loading rigidity and load to failure than orthogonal plating, although the difference did not reach statistical significance. When a parallel medial and lateral plate/bolt construct was used, however, significant increases in rigidity and load to failure were achieved. The advantages of a fixed-angle device demonstrated in this study may provide indirect support for modern locking distal humerus plates.

Although there are theoretic benefits associated with distal humerus locking plates, the scientific literature in this area remains limited. Korner and colleagues [57] reported that sagittal bending and torsional stiffness were significantly improved with the use of locking compression plates in an orthogonal configuration as compared with dorsal plating. Parallel plating was not tested in this study.

Although there is controversy regarding optimal plate positioning, the literature undeniably supports two-column plating, rigid fixation, and anatomic reconstruction of the articular surface [2,5,6,9,11,13,15,19,21,25,53–62]. If applied appropriately with suitable plates, both parallel and orthogonal positioning can provide adequate stability. Limited Contact Dynamic Compression Plate (LC-DCP), 3.5-mm pelvic reconstruction plates, and precontoured plates are sufficiently rigid to provide stable fixation. In contrast, multiple studies have found that one in three tubular plates have insufficient strength and are susceptible to breakage [2,5,8,41], and they are no longer recommended for fixation of distal humerus fractures.

Surgical techniques

To achieve absolute stability of the fracture and anatomic reduction of the elbow joint, meticulous technique and strict adherence to the principles of fracture fixation are required.

Reduction and provisional fixation of the articular surface

The first priority of open reduction and internal fixation (ORIF) is to obtain adequate exposure of the distal humerus to allow reconstruction of the articular surface. For reasons mentioned above, we recommend an olecranon osteotomy for comminuted type C fractures. If total elbow arthroplasty (TEA) is a likely possibility the bilaterotricipital, triceps-splitting, Bryan–Morrey, or TRAP approaches are preferred. The principles of internal fixation for the distal humerus have been well described by AO and more recently popularized by O'Driscoll [5]. Provisional fixation of the articular surface can be achieved by using small-diameter (0.035, 0.045) K-wires [2,11,29], which should be placed strategically to limit interference with plate application and screw insertion (Fig. 3) [2,5]. To assist with the articular reduction, a compression

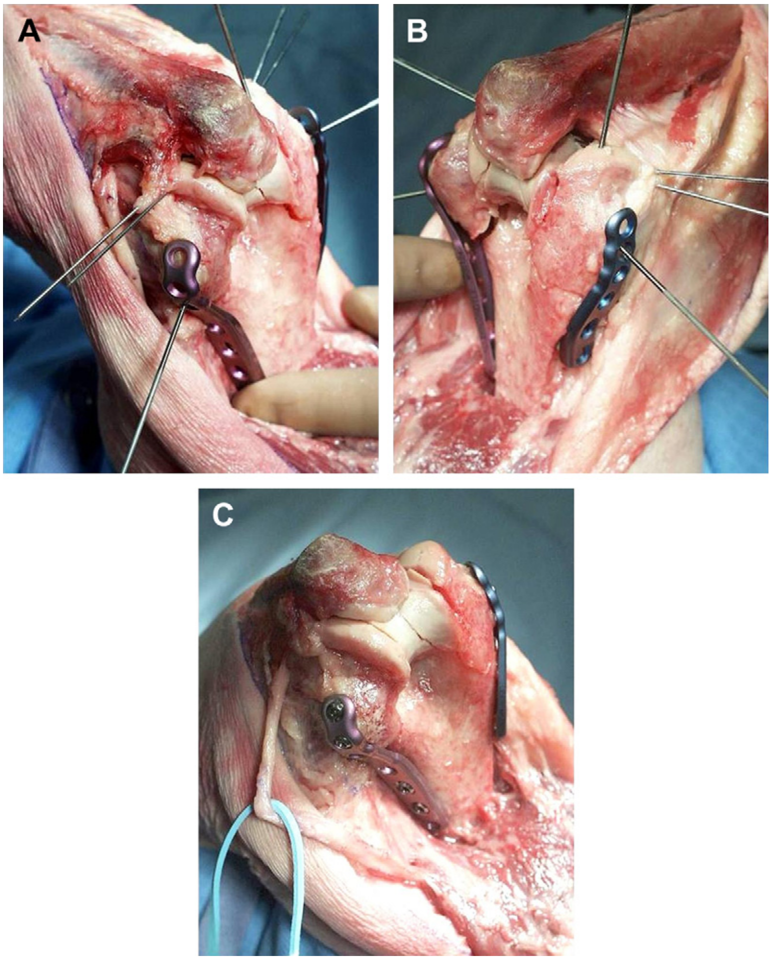

Fig. 3. Open reduction and internal fixation of a distal humerus fracture through a triceps-reflecting anconeus pedicle approach. Provisional fracture reduction and plate application are done with K-wires (*A*, *B*). Rigid internal fixation is completed with commercially available precontoured parallel plates (*C*).

screw can be inserted between two relatively large fragments in a manner that allows adequate space for later screw and plate application, which will connect the articular segment to the diaphysis.

Provisional plate application

Once the articular surface is reconstructed, the distal articular segment is reduced and stabilized with 0.065-in K-wires onto the metaphysis. Contoured 3.5-mm reconstruction plates, LC-DCPs, or precontoured distal humerus plates should be used. If the fracture extends distally, the plates should be contoured over the respective epicondyles and placed adjacent to the articular margin [2,5]. Distal plate placement may result in impingement during terminal elbow extension [29]; therefore, before definitive plate fixation the elbow should be examined to ensure an acceptable ROM with absent bony or soft tissue impingement [2,11,29]. The plates should end at different levels on the humeral shaft to minimize the stress riser effect and each plate should have at least three bicortical screws proximal to the metaphyseal comminution [2,29].

Definitive stabilization of the distal segment and articular surface

After the medial and lateral plates have been provisionally secured to the shaft, the distal articular segment is rigidly stabilized. To do so, O'Driscoll [2,5] advocates that the longest possible screws should be inserted through the plate, capture as many articular fragments as possible, and engage a fragment that is secured to the opposite column. Although this recommended technique may be ideal, it may be difficult to achieve and not always possible to perform. For example, longer screws can deflect and bend as they pass one another, causing displacement of tenuously stabilized osteochondral fragments.

K-wires that are obstructing the path of the screws should gently be withdrawn while observing the joint surface to ensure maintenance of the reduction. If small osteochondral fragments cannot be stabilized with screws, threaded K-wires can be cut at the surface and used as definitive fixation [2,11,29]. Supplementary implants may assist with stabilization of small articular fragments and should be available: mini-fragment plates, 2.7-mm reconstruction plates, headless compression screws, and bioabsorbable pins [25].

Metaphyseal compression and definitive proximal fixation

Once the articular segment is anatomically reduced and rigidly fixed to the medial and lateral plates, metaphyseal comminution and proximal fixation is addressed [2]. When metaphyseal bone loss is present, the humerus may be shortened. Alternatively, bridge plating and autogenous bone grafting can be performed [29].

If fracture stability is insufficient to allow immediate mobilization, then triple plating could be considered, as has been recommended by Gofton and colleagues [22] and Jupiter and Mehne [30]. Triple plating can also assist with fixation of coronal plane fracture fragments (Figs. 4 and 5).

Before closure, the elbow should be examined to ensure acceptable ROM and adequate osseous and ligamentous stability that will permit immediate postoperative mobilization. Fluoroscopic examination is necessary to confirm fracture reduction and stability and to verify satisfactory hardware position [25].

Postoperative management

Numerous studies emphasize the importance of achieving sufficient fracture stability to allow early mobilization, which is essential for good outcomes [12,20,41,63,64]. Active assisted ROM should commence immediately [2,3,5,11,12,19,22,23,25,29]. There are situations in which the desired stability is not achievable and a short period of immobilization may be required [22,29]; however, immobilization exceeding 3 weeks has been associated with poor outcomes [12,15,16,20,21,23,41,63,64]. Papaioannou and colleagues [16] reported on 75 patients who had type C intra-articular fractures of the distal humerus. Seventy-eight percent of patients experienced good to excellent results when stable osteosynthesis was achieved using AO fixation principles and early mobilization. In cases with less stable fixation requiring prolonged mobilization, however, the rate of good to excellent results dropped to 38%. Similarly, Pajarinen and colleagues [23] found 100% good to excellent results in patients who had early (<3 weeks) active mobilization, as compared with only 33% in patients who were immobilized longer than 3 weeks.

Total elbow arthroplasty

TEA for treatment of comminuted distal humerus fractures is a viable option for elderly low-demand patients [65]. The studies comparing TEA to ORIF for the primary treatment of distal humerus fractures are retrospective and have relatively short-term follow-up. The disadvantages of TEA are the imposed activity restrictions and the potential for serious complications, such as infection, periprosthetic fractures, and aseptic loosening. Many of these complications can occur long after joint replacement and are not well described in the current literature because of the absence of long-term outcome studies.

Kamineni and Morrey [66] conducted a retrospective review of 49 patients (mean follow-up 7 years) who had distal humerus fractures treated acutely with TEA. The average age of the patients was 67 years. At final follow-up, 35 patients reported no pain and 8 patients had mild pain. The average Mayo Elbow Performance score was 93 points, with a mean flexion-extension arc of 24 to 131 degrees. Fourteen patients (29%) had a single complication and five revision arthroplasties were required. The reasons for revision included: septic loosening (1), repeat falls resulting in periprosthetic fractures (3), and aseptic loosening at 9 years (1). The importance of this study is that it illustrates the risk for late complications, including the high incidence of repeated falls in this older, lower-demand patient population.

Frankle and colleagues [67] retrospectively reviewed 24 patients older than 65 years who underwent TEA or ORIF for type C2 or C3 distal humerus fractures. At a mean follow-up of 57 months, the ORIF group had 4 excellent, 4 good, 1 fair, and 3 poor outcomes. In comparison, the TEA group had 1 good and 11 excellent outcomes [67]. Although the outcomes certainly

Fig. 4. Open reduction and internal fixation of a comminuted distal humerus fracture (*A*, *B*) done by way of an anconeus flap transolecranon approach. Commercially available precontoured medial and lateral plates are applied in association with an accessory posterior plate required because of the excessive articular comminution (*C*, *D*). An Acutrak (Acumed, Hillsboro, Oregon) headless compression screw was used to provisionally fixate articular segments and the olecranon osteotomy was fixated with a precontoured 3.5-mm plate.

favor the TEA group, the results should be interpreted with caution because 8 of the 12 patients treated with TEA had pre-existing rheumatoid arthritis (RA) and consequently had lower functional demands. Furthermore, 25% of patients in the ORIF group experienced fixation failure [67], which is higher than that reported in other similar studies [22,49,52]. Although the study size was small and the follow-up short term (2 years), the authors support the use of TEA in elderly patients who have distal humerus fractures, particularly in the setting of osteoporosis and RA.

Garcia and colleagues [68] provided additional support for TEA in a study that examined 19 patients who did not have RA who underwent TEA for acute distal humerus fractures. At a mean follow-up of 3 years, 68% of patients were pain-free, 94% were satisfied with their

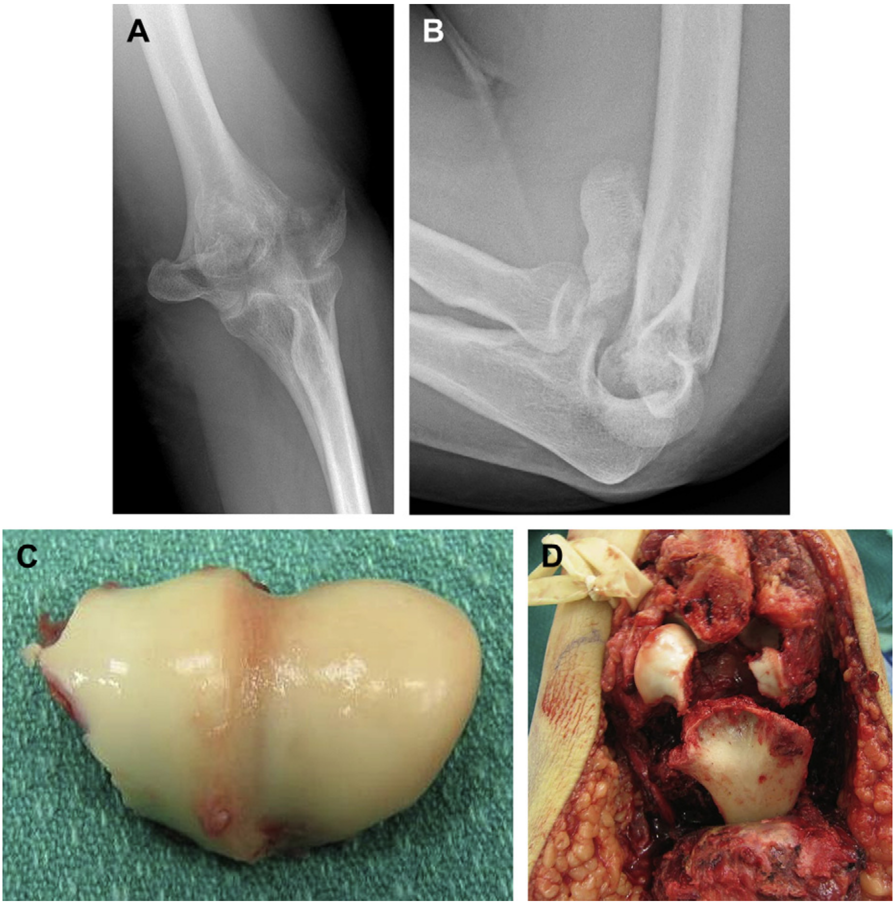

Fig. 5. A 46-year-old female who had a type C3 distal humerus fracture (*A*, *B*, *C*). An olecranon osteotomy was used to achieve adequate exposure (*D*). Triple plating and an Acutrak screw (Acumed) were used to achieve stable internal fixation (*E*, *F*, *G*). This patient developed necrosis of the medial fascial-cutaneous flap, which was treated with a radial forearm rotational flap (*H*, *I*, *J*, *K*).

outcome, no implants loosened, the mean extension/flexion arc was 24 to 125 degrees, and the mean Mayo Elbow Performance score was 93. Again, despite the short-term follow-up, the outcomes of TEA are encouraging.

In 2003, Obremskey and colleagues [65] published a review of the existing literature and concluded that there was insufficient evidence available comparing TEA to ORIF for distal humerus fractures to guide clinical decision making. All studies reviewed at that time had a follow-up of less than 4 years, were retrospective, and had heterogenous patient groups. The functional outcome scores following ORIF were less predictable than those obtained with TEA, 80% compared with 90%, respectively. When fracture union was achieved, however, the success rates were similar, which is consistent with other studies [16,19,65]. This finding may suggest that the success rate of ORIF may be improved with the advent of new fracture-specific implants (precontoured plates and locking compression plates) and enhanced operative techniques designed to maximize stability and promote union. To illustrate, in 2005, Huang and colleagues [6] achieved 100% good to excellent functional results in 19 patients older than 65 years (mean age 72 years), with ORIF of comminuted articular distal humerus fractures.

In summary, TEA should be considered in patients older than 65 years of age who have severely comminuted fractures with poor bone quality. Although more standardized studies with longer follow-up are required, the results of TEA for primary treatment of distal humerus fracture

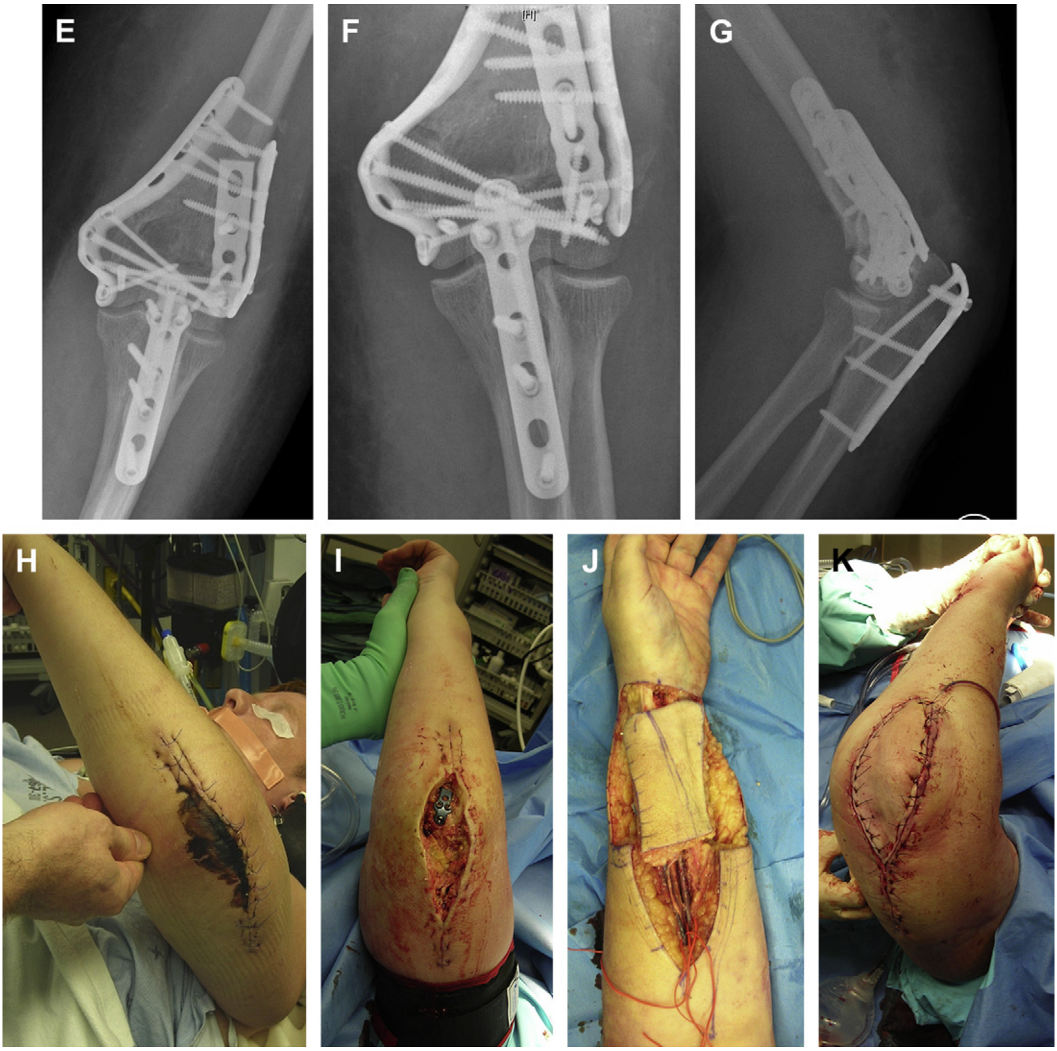

Fig. 5 (*continued*)

are encouraging, particularly in patients who have severe osteoporosis or RA [69]. If rigid fracture stability and early motion can be achieved, however, ORIF should be attempted, because stable fixation can result in equal success without imposing the significant activity restrictions and the possible long-term sequelae of TEA.

Outcomes/complications

Functional outcome

Gofton and colleagues [22] reported on 23 patients who had type C distal humerus fractures who were surgically treated with an olecranon osteotomy and orthogonal plating. Even though these patients were treated by subspecialized elbow surgeons, the complication rate was 48%. Complications included heterotropic ossification (17%), olecranon nonunion (9%), and infection (9%). Failure of fixation did not occur in any of the patients. At a mean 45 months of follow-up, patients demonstrated on average a reduced flexion/extension arc (122 degrees), full pro-supination, 17% loss of flexion torque, 22% loss of extension torque, and approximately 20% loss of pro-supination strength. Patients had minimal functional loss, low pain scores, and 93% were satisfied with their outcome. The flexion and extension peak torque losses observed in this study were consistent with other studies [22,49,52].

Aslam and Willett [70] also reported on the functional outcome of 26 patients (all older than 60 years of age) who had AO type C fractures treated with orthogonal plating. Good to excellent results were achieved in 70% of patients who had a mean flexion/extension arc of 112 degrees. Grip strength was 82% compared with the uninjured side. Hardware removal was required in 15% of the cases and the overall complication rate was 35%, which is consistent with other studies [48,66]. Eighty-five percent of patients were satisfied with their final outcome and 75% of patients returned to their preinjury level of occupation and activity [70].

Nonunion

The average time to union of distal humerus fractures has been reported to be 14.6 weeks [6]. Nonunion of distal humerus fractures treated with ORIF has been reported to be between 2% and 10% [71]. In the Helfet and colleagues [71] series of 33 distal humerus nonunions, 75% were the result of failed internal fixation. A 98% union rate was obtained following revision ORIF. A total of 29% of patients needed additional surgery after the revision procedure and complications included two superficial infections, two deep infections, and five cases of ulnar neuropathy. Based on this study, the authors concluded that successful treatment of distal humeral nonunions requires aggressive contracture release, stable fixation, and autogenous bone graft [18,71].

Heterotropic ossification

The reported incidence of heterotropic ossification (HO) after surgical treatment of distal humerus fractures varies from 0% [6,38] to 49% [15]. In most patients, HO does not cause functional deficits [10,13,22] and resection is not always necessary [8]. Some studies have found that a delay in treatment of greater than 48 hours increases the rate of HO from 0% to 33% [41,72]. Similarly, Kundel and colleagues [15] reported an increased rate of HO from 29% to 80% when surgical treatment was delayed by more than 24 hours, which was also associated with significantly worse ROM and function. The routine use of indomethacin for HO prophylaxis remains controversial.

Summary

Intra-articular fractures of the distal humerus are among the most challenging fractures to manage. Nonoperative treatment, although appropriate for some patients, often leads to loss of motion and unsatisfactory functional outcomes. Over the last 2 decades, enhanced operative techniques and implant designs have improved the reduction and stability of distal humerus fractures leading to better outcomes. Careful preoperative planning, adequate exposure, and stable fixation facilitating early mobilization are essential to achieve successful outcomes with internal fixation.

References

[1] Riseborough EJ, Radin EL. Intercondylar T fractures of the humerus in the adult. A comparison of operative and non-operative treatment in twenty-nine cases. J Bone Joint Surg Am 1969;51:130–41.
[2] O'Driscoll SW. Supracondylar fractures of the elbow: open reduction, internal fixation [review]. Hand Clin 2004;20:465–74.
[3] Ring D, Jupiter JB. Complex fractures of the distal humerus and their complications [review]. J Shoulder Elbow Surg 1999;8:85–97.
[4] Korner J, Lill H, Muller LP, et al. Distal humerus fractures in elderly patients: results after open reduction and internal fixation. Osteoporos Int 2005;16(Suppl 2):S73–9.
[5] O'Driscoll SW. Optimizing stability in distal humeral fracture fixation. J Shoulder Elbow Surg 2005;14:186S–194S.
[6] Huang TL, Chiu FY, Chuang TY, et al. The results of open reduction and internal fixation in elderly patients with severe fractures of the distal humerus: a critical analysis of the results. J Trauma 2005;58:62–9.
[7] Allende CA, Allende BT, Allende BL, et al. Intercondylar distal humerus fractures—surgical treatment and results. Chir Main 2004;23:85–95.
[8] Tyllianakis M, Panagopoulos A, Papadopoulos AX, et al. Functional evaluation of comminuted intra-articular fractures of the distal humerus (AO type C). Long term results in twenty-six patients. Acta Orthop Belg 2004;70:123–30.
[9] Soon JL, Chan BK, Low CO. Surgical fixation of intra-articular fractures of the distal humerus in adults [see comment] [erratum appears in Injury. 2004 Sep;35(9):954]. Injury 2004;35:44–54.
[10] Gupta R, Khanchandani P. Intercondylar fractures of the distal humerus in adults: a critical analysis of 55 cases. Injury 2002;33:511–5.
[11] O'Driscoll SW, Sanchez-Sotelo J, Torchia ME. Management of the smashed distal humerus [review]. Orthop Clin North Am 2002;33:19–33.
[12] Ring D, Jupiter JB. Fractures of the distal humerus [review]. Orthop Clin North Am 2000;31:103–13.

[13] Kinik H, Atalar H, Mergen E. Management of distal humerus fractures in adults. Arch Orthop Trauma Surg 1999;119:467–9.
[14] Gupta R. Intercondylar fractures of the distal humerus in adults. Injury 1996;27:569–72.
[15] Kundel K, Braun W, Wieberneit J, et al. Intraarticular distal humerus fractures. Factors affecting functional outcome. Clin Orthop Relat Res 1996;332:200–8.
[16] Papaioannou N, Babis GC, Kalavritinos J, et al. Operative treatment of type C intra-articular fractures of the distal humerus: the role of stability achieved at surgery on final outcome. Injury 1995; 26:169–73.
[17] McKee MD, Jupiter JB. A contemporary approach to the management of complex fractures of the distal humerus and their sequelae [review]. Hand Clin 1994;10:479–94.
[18] Helfet DL, Schmeling GJ. Bicondylar intraarticular fractures of the distal humerus in adults [review]. Clin Orthop Relat Res 1993;292:26–36.
[19] Sanders RA, Raney EM, Pipkin S. Operative treatment of bicondylar intraarticular fractures of the distal humerus. Orthopedics 1992;15:159–63.
[20] Gabel GT, Hanson G, Bennett JB, et al. Intraarticular fractures of the distal humerus in the adult. Clin Orthop Relat Res 1987;216:99–108.
[21] Horne G. Supracondylar fractures of the humerus in adults. J Trauma 1980;20:71–4.
[22] Gofton WT, Macdermid JC, Patterson SD, et al. Functional outcome of AO type C distal humeral fractures. J Hand Surg [Am] 2003;28:294–308.
[23] Pajarinen J, Bjorkenheim JM. Operative treatment of type C intercondylar fractures of the distal humerus: results after a mean follow-up of 2 years in a series of 18 patients. J Shoulder Elbow Surg 2002;11:48–52.
[24] Ruedi T, Buckley R, Moran C. AO principles of fracture managment. 2nd expanded edition. New York: Thieme Medical Publishing; 2007.
[25] Anglen J. Distal humerus fractures [review]. J Am Acad Orthop Surg 2005;13:291–7.
[26] Palvanen M, Kannus P, Niemi S, et al. Secular trends in the osteoporotic fractures of the distal humerus in elderly women. Eur J Epidemiol 1998; 14:159–64.
[27] Palvanen M, Kannus P, Parkkari J, et al. The injury mechanisms of osteoporotic upper extremity fractures among older adults: a controlled study of 287 consecutive patients and their 108 controls. Osteoporos Int 2000;11:822–31.
[28] Robinson CM, Hill RM, Jacobs N, et al. Adult distal humeral metaphyseal fractures: epidemiology and results of treatment [see comment]. J Orthop Trauma 2003;17:38–47.
[29] McCarty LP, Ring D, Jupiter JB. Management of distal humerus fractures [review]. Am J Orthop 2005;34:430–8.
[30] Jupiter JB, Mehne DK. Fractures of the distal humerus [review]. Orthopedics 1992;15:825–33.
[31] Ring D, Jupiter JB. Elbow and forearm: adult trauma. In: Vaccaro A, editor. Orthopaedic knowledge update 8. Rosemont (IL): AAOS; 2005. p. 307–15.
[32] Muller M, Nazanan S, Koch P, et al. Fracture and dislocation compendium. Orthopaedic trauma association committee for coding and classification. J Orthop Trauma 2001;10(Suppl 1):311–24.
[33] Lowden C, Garvin G, King GJ. Imaging of the elbow following trauma [review]. Hand Clin 2004; 20:353–61.
[34] Eastwood W. The T-shaped fracture of the lower end of the humerus. J Bone Joint Surg Am 1937; 19:364–9.
[35] Dowdy PA, Bain GI, King GJ, et al. The midline posterior elbow incision. An anatomical appraisal. J Bone Joint Surg Br 1995;77:696–9.
[36] Athwal GS, Rispoli DM, Steinmann SP. The anconeus flap transolecranon approach to the distal humerus. J Orthop Trauma 2006;20:282–5.
[37] Wilkinson JM, Stanley D. Posterior surgical approaches to the elbow: a comparative anatomic study [see comment]. J Shoulder Elbow Surg 2001; 10:380–2.
[38] Eralp L, Kocaoglu M, Sar C, et al. Surgical treatment of distal intraarticular humeral fractures in adults. Int Orthop 2001;25:46–50.
[39] Wang KC, Shih HN, Hsu KY, et al. Intercondylar fractures of the distal humerus: routine anterior subcutaneous transposition of the ulnar nerve in a posterior operative approach. J Trauma 1994;36:770–3.
[40] Gainor BJ, Moussa F, Schott T. Healing rate of transverse osteotomies of the olecranon used in reconstruction of distal humerus fractures. J South Orthop Assoc 1995;4:263–8.
[41] Holdsworth BJ, Mossad MM. Fractures of the adult distal humerus. Elbow function after internal fixation. J Bone Joint Surg Br 1990;72:362–5.
[42] Hewins EA, Gofton WT, Dubberly J, et al. Plate fixation of olecranon osteotomies. J Orthop Trauma 2007;21:58–62.
[43] Coles CP, Barei DP, Nork SE, et al. The olecranon osteotomy: a six-year experience in the treatment of intraarticular fractures of the distal humerus. J Orthop Trauma 2006;20:164–71.
[44] Ring D, Gulotta L, Chin K, et al. Olecranon osteotomy for exposure of fractures and nonunions of the distal humerus. J Orthop Trauma 2004;18:446–9.
[45] Alonso-Llames M. Bilaterotricipital approach to the elbow. Its application in the osteosynthesis of supracondylar fractures of the humerus in children. Acta Orthop Scand 1972;43:479–90.
[46] Schildhauer TA, Nork SE, Mills WJ, et al. Extensor mechanism-sparing paratricipital posterior approach to the distal humerus. J Orthop Trauma 2003;17: 374–8.
[47] Campbell WC. Incision for exposure of the elbow joint. Am J Surg 1932;15:65–7.
[48] McKee MD, Kim J, Kebaish K, et al. Functional outcome after open supracondylar fractures of the

humerus. The effect of the surgical approach. J Bone Joint Surg Br 2000;82:646–51.
[49] McKee MD, Wilson TL, Winston L, et al. Functional outcome following surgical treatment of intra-articular distal humeral fractures through a posterior approach. J Bone Joint Surg Am 2000; 82:1701–7.
[50] Bryan RS, Morrey BF. Extensive posterior exposure of the elbow. A triceps-sparing approach. Clin Orthop Relat Res 1982;166:188–92.
[51] O'Driscoll SW. The triceps-reflecting anconeus pedicle (TRAP) approach for distal humeral fractures and nonunions. Orthop Clin North Am 2000; 31:91–101.
[52] Ozer H, Solak S, Turanli S, et al. Intercondylar fractures of the distal humerus treated with the triceps-reflecting anconeus pedicle approach. Arch Orthop Trauma Surg 2005;125:469–74.
[53] Jacobson SR, Glisson RR, Urbaniak JR. Comparison of distal humerus fracture fixation: a biomechanical study. J South Orthop Assoc 1997;6:241–9.
[54] Helfet DL, Hotchkiss RN. Internal fixation of the distal humerus: a biomechanical comparison of methods. J Orthop Trauma 1990;4:260–4.
[55] Schemitsch EH, Tencer AF, Henley MB. Biomechanical evaluation of methods of internal fixation of the distal humerus. J Orthop Trauma 1994;8: 468–75.
[56] Self J, Viegas SF, Buford WL Jr, et al. A comparison of double-plate fixation methods for complex distal humerus fractures. J Shoulder Elbow Surg 1995;4: 10–6.
[57] Korner J, Diederichs G, Arzdorf M, et al. A biomechanical evaluation of methods of distal humerus fracture fixation using locking compression plates versus conventional reconstruction plates. J Orthop Trauma 2004;18:286–93.
[58] Ali A, Douglas H, Stanley D. Revision surgery for nonunion after early failure of fixation of fractures of the distal humerus. J Bone Joint Surg Br 2005; 87:1107–10.
[59] Huang TL, Chiu FY, Chuang TY, et al. Surgical treatment of acute displaced fractures of adult distal humerus with reconstruction plate [review]. Injury 2004;35:1143–8.
[60] Korner J, Lill H, Muller LP, et al. The LCP-concept in the operative treatment of distal humerus fractures—biological, biomechanical and surgical aspects [review]. Injury 2003;34(Suppl 2):B20–30.
[61] Yang KH, Park HW, Park SJ, et al. Lateral J-plate fixation in comminuted intercondylar fracture of the humerus. Arch Orthop Trauma Surg 2003;123: 234–8.
[62] Sodergard J, Sandelin J, Bostman O. Mechanical failures of internal fixation in T and Y fractures of the distal humerus. J Trauma 1992;33:687–90.
[63] Letsch R, Schmit-Neuerburg KP, Sturmer KM, et al. Intraarticular fractures of the distal humerus. Surgical treatment and results. Clin Orthop Relat Res 1989;241:238–44.
[64] Henley MB, Bone LB, Parker B. Operative management of intra-articular fractures of the distal humerus. J Orthop Trauma 1987;1:24–35.
[65] Obremskey WT, Bhandari M, Dirschl DR, et al. Internal fixation versus arthroplasty of comminuted fractures of the distal humerus [review]. J Orthop Trauma 2003;17:463–5.
[66] Kamineni S, Morrey BF. Distal humeral fractures treated with noncustom total elbow replacement. J Bone Joint Surg Am 2004;86:940–7.
[67] Frankle MA, Herscovici D Jr, DiPasquale TG, et al. A comparison of open reduction and internal fixation and primary total elbow arthroplasty in the treatment of intraarticular distal humerus fractures in women older than age 65. J Orthop Trauma 2003;17:473–80.
[68] Garcia JA, Mykula R, Stanley D. Complex fractures of the distal humerus in the elderly. The role of total elbow replacement as primary treatment. J Bone Joint Surg Br 2002;84:812–6.
[69] Armstrong AD, Yamaguchi K. Total elbow arthroplasty and distal humerus elbow fractures [review]. Hand Clin 2004;20:475–83.
[70] Aslam N, Willett K. Functional outcome following internal fixation of intraarticular fractures of the distal humerus (AO type C). Acta Orthop Belg 2004;70:118–22.
[71] Helfet DL, Kloen P, Anand N, et al. Open reduction and internal fixation of delayed unions and nonunions of fractures of the distal part of the humerus. J Bone Joint Surg Am 2003;85:33–40.
[72] Ilahi OA, Strausser DW, Gabel GT. Post-traumatic heterotopic ossification about the elbow. Orthopedics 1998;21:265–8.