



Controversies in the Management of Intra-Articular Distal Humerus Fractures in Adults

César García-Mauriño, Pablo Vadillo-Cardona, and Alfonso Vaquero-Picado

9.1 Introduction

Distal humerus fractures in adults are challenging injuries for trauma surgeons. These fractures comprise complex regional anatomy, poor outcomes, and common complications, even when recent advances in surgical technique and implants have improved clinical outcomes [1]. These fractures have an estimated incidence of 5.7 per 100,000 persons per year in adults and represent between 0.5 and 7% of all fractures in adults and 30% of all humerus fractures [2, 3]. As in other fractures in adults, it is noted a bimodal distribution of these injuries regarding age and sex, with an early peak of incidence in young males due to high-energy trauma (traffic and sport accidents), and a late peak of incidence in elderly females as a result of low-energy trauma, such as falling from standing height [4, 5].

It is expected a raise in the incidence of these injuries as the older population increases and the motorization of the developing world continues. Working up strategies such as osteoporosis treatment and fall prevention that may reduce the incidence of these injuries should be taken into account [5].

Until the development of the AO principles of fracture management, treatment of distal humerus

fractures was predominantly nonsurgical, carrying on a high probability of functional disability. Nowadays, open reduction and internal fixation (ORIF) is the gold standard of treatment. Elderly patients, with insufficient bone stock and high degree of comminution, pose a true challenge to suitable fixation [2, 6, 7]. In spite of significant advances in the treatment of distal humerus fractures, controversy remains regarding the most adequate surgical approach, fixation method, and handling of ulnar nerve [8].

9.2 Clinical Assessment

When facing a distal humerus fracture, physical examination should always include the evaluation of ipsilateral shoulder and wrist, not to overlook associated fractures in adjacent joints, which may be present in up to 16% of patients [4, 9]. In patients sustaining high-energy trauma, associated injuries must be ruled out as well [10].

A circumferential inspection of the limb should be conducted in order to assess open fractures, which are relatively common. When open fracture occurs, they are often posterior as the injury usually results in hyperextension on an extended elbow [1, 2]. Open elbow fractures should be managed following standard open fracture protocols which include early antibiotics and tetanus prophylaxis administration, extremity stabilization and dressing, timely irrigation and

C. García-Mauriño · P. Vadillo-Cardona
A. Vaquero-Picado (✉)
Upper Limb Unit, Department of Orthopedic Surgery,
La Paz University Hospital, Madrid, Spain

debridement, and soft tissue coverage. Vascular injury should always be assessed by inspecting distal extremity color, capillary filling, and peripheral pulses. It is important to remember that due to great collateral blood supply around the elbow, it is possible to have distal pulse presence even in the setting of a brachial artery injury [1]. Sometimes, correcting the deformity by gentle traction could be needed in order to improve the vascular status on emergency setting. If it is not normalized after traction, a computed tomography (CT) angiography or surgical exploration is necessary [2]. Neurological examination must include radial, median, and ulnar nerves. Motor and sensitive status should be documented preoperatively and postoperatively. Up to 26% of incomplete ulnar neuropathy is observed in type C distal humerus fractures [4, 9].

Special attention should be paid to the development of compartment syndrome. Unrelenting pain and the inability to bear finger extension indicate the possibility of that complication. The clinical evaluation must also include data on the patient's functional status, hand dominance, comorbidities, and living situation, which may help with the therapeutic decision-making process and preoperative risk assessment [4, 10].

9.3 Anatomy and Classification

A precise knowledge of elbow anatomy is fundamental for understanding these injuries.

In the coronal plane, distal humerus has a triangular shape, which is formed by two diverging columns (the medial and lateral columns) and the articular block. Distally, the medial column consists of the medial epicondyle (origin of the flexor-pronator mass) and the most medial side of the trochlea; meanwhile, the lateral column distally comprises the capitellum and, more proximally, the lateral epicondyle (origin of the extensor muscle mass). The bone between both columns, which include the coronoid fossa and olecranon fossa, is very thin or absent. The condylar mass is in 4–8 degrees of valgus relative to the shaft [5, 6]. In the sagittal plane, the articular segment is flexed 40° relative to the longitudinal

axis of the humerus shaft, so, in the lateral side, the center of the capitellum aligns with the anterior humeral shaft line [1, 5].

There are several classification systems, but internationally the most commonly used is the Orthopedic Trauma Association (OTA/AO) classification. It distinguishes three main fracture patterns with increased complexity (A, B, and C) with further subdivision (1, 2, and 3) based on fracture pattern, location, and degree of comminution [7–9]:

- Type A fractures. Extra-articular fractures, which may involve the epicondyles (extracapsular fractures) or the metaphyseal region (intracapsular fractures).
- Type B fractures. Partial articular fractures. The fracture involves a segment of the articular mass, but the remaining is still connected to the metaphysis and diaphysis. It includes unicondylar fractures and coronal fractures of the capitellum, trochlea, or both.
- Type C fractures. Complete articular fractures. The fracture establishes a total lack of continuity between the condylar mass and the humeral shaft.

Up to 96% of distal humerus fractures in adults are intra-articular fractures, either affecting both columns or partial articular fractures [1, 9].

9.4 Imaging

Standard high-quality anteroposterior, lateral, and oblique radiographs should be obtained in all patients. Proximal and distal joints (ipsilateral shoulder and wrist) should be included in X-ray studies, in order to be sure concomitant fractures are not overlooked [2, 4, 6, 9, 10].

The Mckee's double arc sign can be observed in coronal fractures of the articular surface, one arc representing the capitellum and the other arc representing the lateral part of the trochlea. Characterization of intra-articular fractures of distal humerus, especially those with multiplanar fracture patterns or coronal plane injuries, can be

challenging only with plain radiographs. In these situations, performing a CT scan is of great help for assessing articular involvement, comminution, and surgical planning [11].

9.5 Treatment

In the treatment decision-making process, one must take the age of the patient, medical comorbidities, job occupation, functional status and expectations, degree of comminution, inadequate bone stock, bone quality, or underlying arthritis [2, 4, 12].

9.5.1 Nonoperative Management

Conservative management has been associated with poor functional outcomes, decreased elbow range of motion, and high rate of delayed union and nonunion [2, 6, 10].

Nowadays nonsurgical treatment is mainly reserved for non-displaced fractures and very fragile patients with ongoing medical issues which pose a high surgical risk. Other possible indications of conservative management would be patients with high-degree cognitive impairment or low-demand or nonfunctional upper extremities [2, 4, 12].

Recently, Atiken et al. reported on short- and medium-term functional outcomes in 40 elderly low-demand patients with distal humerus fractures treated conservatively (“bag of bones” strategy). Surviving patients ($n = 20$) had a mean Oxford elbow score of 30 points (7–48), and 95% of them reported a functional range of elbow flexion. The authors conclude that conservative management in a low-demand patient only gives a modest functional result but avoids the substantial surgical risks associated with primary ORIF or total elbow arthroplasty (TEA) [13].

Desloges et al. reviewed 32 low-demand, medically unwell, elderly patients with distal humerus fractures treated nonoperatively. Sixty-eight percent of patients reported good to excellent subjective outcomes, and the fracture union rate was 81% at a mean follow-up of 12 months.

They conclude that satisfactory outcomes can be achieved after nonoperative management of distal humerus fractures in selected patients [14].

Nonoperative treatment often consists of a variable period of full-arm cast immobilization (usually 3 to 6 weeks) with the elbow in 60°–90° of flexion followed by early gentle motion [2].

9.5.2 Surgical Management

In active, fit for surgery, adult patients with reconstructible fracture patterns, open reduction and internal fixation are the gold standard of treatment [1, 2, 4, 6, 8, 10, 12, 15]. The main goal is to achieve an anatomic reduction of the articular surface, a correct alignment, and metaphyseal compression in order to secure a stable fixation which allows for early motion [1, 12].

As mentioned earlier, controversy still remains regarding surgical approaches, implants, fixation method, and handling of ulnar nerve [8].

9.5.3 Surgical Approaches

Several surgical approaches have been described with differences in terms of exposure and soft tissue aggression [6]. Different variants of a posterior approach are used, existing limited comparative data. Olecranon osteotomy is reported to offer the best articular exposure, but, even when performed, up to 40% of distal humerus articular surface cannot be visualized [16]. Wilkinson et al. demonstrated an exposed articular surface of 35% for the triceps splitting approach, for the triceps reflecting approach of 46% and for the olecranon osteotomy of 57% [6].

The olecranon and triceps act as obstacles to the visualization of the articular surface, so posterior approaches can be classified in two main groups: the ones that preserve the extensor mechanism and mobilize it and the ones that disrupt it [2].

9.5.3.1 Universal Posterior Incision

A posterior midline incision is made in a straight way or curved fashion around the olecranon according to the surgeon’s preference. The mean

length of the incision is usually 4–8 cm distal and at least 10 cm proximal to the tip of the olecranon. Special attention is paid to any skin injuries present (e.g., open fractures or previous scars) that can be incorporated into the incision [2, 12, 17]. Full-thickness fasciocutaneous flaps are developed medially and laterally to prevent skin necrosis and seroma formation. It is strongly recommended to identify the ulnar nerve along the medial border of the triceps, dissecting and elevating the fascia of the triceps for better visualization. For further mobilization of the nerve, it can be freed from proximal to distal, releasing the arcade of Struthers proximally (between 2.5 and 7 cm from the medial epicondyle) and the cubital tunnel retinaculum distally, trying to preserve the motor branches to the flexor carpi ulnaris and flexor digitorum profundus muscles [8, 17, 18]. The management of the released nerve will be discussed later.

The radial nerve needs to be dissected only when the approach is extended further proximally in order to apply longer plates (fractures with diaphyseal extension). In those cases, the posterior antebrachial cutaneous branch of the radial nerve, which is often located distal and laterally, should be identified [2, 17].

9.5.3.2 Bilaterotricipital Approach (Alonso-Llames)

Dissection is carried along the medial and lateral borders of the triceps which are elevated off the posterior periosteum of the humerus and the medial and lateral intermuscular septa. Medial and lateral windows are created, allowing the surgeon to work through either side of the muscle mass, achieving excellent visualization of the entire posterior humerus [8, 17].

This is a less aggressive approach in which the extensor mechanism is not disrupted, so there is no need to protect it postoperatively. The surgical time is shortened as well, thereby decreasing the risk of perioperative complications, and it allows for a more extensile exposure through the Kocher interval and/or an olecranon osteotomy if needed [17].

The bilaterotricipital approach is useful for supracondylar and transcondylar fractures and as

well for AO C1 and C2 intra-articular fractures; for more complex and multifragmentary articular fractures, the distal exposure is limited, and this approach would be insufficient [4, 8].

9.5.3.3 Triceps-Reflecting Approach (Bryan-Morrey)

This approach was described by Bryan and Morrey in 1982 [19]. The extensor mechanism is reflected from medial to lateral in continuity with the forearm fascia, olecranon and ulnar periosteum [8]. The ulnar collateral ligament can be released as well to gain further exposure, but it must then be reattached [17]. After fracture fixation, the triceps tendon is repaired by reattaching it to the olecranon with nonabsorbable sutures through bone tunnels [8, 20].

This surgical approach has been extensively used for elbow arthroplasty. Iselin et al. conducted a retrospective study which included 31 patients with distal humerus fractures treated with this approach and concluded that it is a valuable choice for ORIF in distal intra-articular humerus fractures since it preserves the normal joint anatomy of the olecranon, and the clinical outcomes were excellent, without any objective or subjective functional impairment related to the surgical approach [20].

9.5.3.4 Triceps-Reflecting Anconeus Pedicle Flap (TRAP)

This approach described by O'Driscoll in 2000 is a combination of modified Kocher and Bryan-Morrey approaches in which the triceps and anconeus muscles are elevated off the posterior humerus and olecranon [8, 21]; the anconeus is completely dissected from its insertion onto the proximal ulna.

Similar to Bryan-Morrey approach, it avoids the complications associated with olecranon osteotomy. Conversely, it requires familiarity with the anatomy, and the distal exposure is limited compared to the one obtained with olecranon osteotomy [21].

Traditionally, these triceps-elevating exposures have been related to weakness of extension or triceps' rupture by some authors. However, Ozer et al. have reported no significant impairment

of elbow function in 11 patients with AO type C fractures treated with a TRAP approach. Azboy et al. reviewed 40 patients with distal humerus intra-articular fractures treated with a TRAP approach as well and concluded that it is a successful approach that reduces reoperations and complications rates, with no triceps' rupture observed and only one patient with poor strength after the procedure [22].

9.5.3.5 Triceps-Splitting Approach (Campbell Approach)

The triceps' muscle mass and tendon are incised on its midline dividing the triceps in two halves which are dissected to either side. The incision carries down distally to the olecranon, leaving the anconeus laterally and the flexor carpi ulnaris medially. The radial nerve needs to be protected during proximal exposure [8, 17].

This approach can result in triceps weakness as a result of muscle and intramuscular nerve branches injury and requires a thoughtful closure of the triceps [6, 8]. Besides, it hinders the positioning of lateral plates because the lateral half of the triceps can get in the way when it comes to drilling and screw insertion [17]. It can be performed for supracondylar and transcondylar fractures, but it does not provide an adequate exposure of the distal articular surface [2].

9.5.3.6 Olecranon Osteotomy

This surgical approach offers the best articular surface visualization as mentioned before so it is widely used for intra-articular fractures of the distal humerus [2, 6, 8, 17], being especially useful in complex intra-articular fractures with severe comminution (AO type C3). Once the "bare area" of the proximal ulna is identified, approximately 3 cm distal from the tip of the olecranon, a Chevron osteotomy is performed, initially with an oscillating saw, finishing with an osteotome [6, 8, 9, 17]. This type of osteotomy is preferred by many authors, rather than a transverse one, because of its intrinsic stability. The proximal olecranon is mobilized along with the tricipital tendon proximally, and, if needed, the exposure may be extended with a bilaterotricipital approach [17]. After the procedure, the ulna is

reduced and fixed with either a lag screw, an intramedullary nail, a plate, or tension band wires, depending on the surgeon's preference [8, 17]. According to Meldrum et al., fixation with a single screw is the technique that had the least complications in their review of different types of fixation for olecranon osteotomies [12, 23].

Disadvantages of this procedure are the risk of the nonunion at the site of the osteotomy (0–9%), further need for surgery to remove symptomatic hardware (6–30%), not easy conversion to TEA, and potential risk of intra-articular adhesions [2, 21]. Furthermore, if an olecranon osteotomy is not performed, the surgeon can use the olecranon, coronoid and radial head as a three-dimensional template upon which the articular bony fragments of the distal humerus can be reassembled until final fixation is achieved.

9.5.4 Implants

The main goal when treating distal humerus fractures in adults is to achieve an anatomic reconstruction of the articular surface with a rigid and stable internal fixation allowing early motion exercises, bone consolidation, and prevention of future osteoarthritis [2, 5, 8, 9]. There is unanimity in the literature on how a double plate construct is superior over single plating or screw fixation when fixing intra-articular distal humerus fractures involving both columns [24]. Many biomechanical and clinical studies highlight the advantages of double plating over other fixation methods [25–27]. Although there is general agreement on rigid fixation with dual plates as the gold-standard treatment when fixing bicolunar distal humerus fractures, the most adequate plating configuration remains controversial [2, 6, 8, 10]. The debate mostly revolves around whether the plates should be applied in a parallel fashion or orthogonal to each other [8]. In the orthogonal configuration, the two plates are applied at 90 degrees, with a medial plate on the medial column and a posterior plate on the lateral column. The parallel configuration uses a medial plate on the medial column combined with a lateral plate on the lateral column [10].

Several biomechanical studies comparing the two configurations have proven that parallel plating provides more stability than perpendicular plating [6, 9, 10]. Stoffel et al. compared the biomechanical stability of perpendicular and parallel locking plating systems for the internal fixation of 24 simulated AO Type C2 distal humerus fractures in cadaveric osteoporotic bone. They concluded that the parallel locking system showed improved stability in axial compression as well as in external rotation although both locking plate systems would allow early mobilization of the elbow [28]. Arnander et al. conducted another biomechanical study and concluded that a parallel plate configuration is significantly stronger and stiffer than a perpendicular plate configuration when subjected to sagittal bending forces [29]. Zalavras et al. compared parallel to orthogonal constructs in an intra-articular distal humerus fracture model and reported that parallel plate constructs had significantly higher stiffness than orthogonal ones during cyclic varus loading without any screw loosening compared to screw loosening in all posterior plates of orthogonal constructs. Parallel constructs had as well significantly higher ultimate load in axial/sagittal loading to failure [10, 30]. However, recent clinical studies that have compared orthogonal to parallel plating found no difference between the constructs regarding functional outcome or complication rate [6].

Shin et al. compared perpendicular to parallel plate fixation in a prospective randomized comparative study of 35 patients and found no significant differences in clinical outcomes or range of motion between treatment groups (Level II evidence) [2, 31]. Lee et al. compared orthogonal versus parallel plating in a prospective randomized trial of 67 patients (Level II evidence). They found no differences between the two groups with regard to clinical outcomes, operating time, time to union, or complication rates at a minimum follow-up time of 2 years [2, 32].

Having no differences in clinical outcomes or complication rate, it is important to apply the plates according to the fracture pattern because, if properly applied, both parallel and orthogonal positioning can provide adequate stability. Plates should be placed in the most biomechanically

adequate placement in relation to the fracture lines rather than in positions predetermined by the plate itself [33]. Parallel plating could be preferred for the fixation of fractures in the most distal end of the humerus, favored by the opportunity for additional distal screw fixation; meanwhile perpendicular plating is preferred in cases of coronal shear fractures, where anterior to posterior fixation gaining additional stability in the coronal plane is desirable [5, 8, 9].

The cornerstone to achieve stable fixation is an adequate reduction of the fracture. Without successful reconstruction of the triangular anatomy of the distal humerus and the olecranon fossa-tip relationship, solid anatomical fixation cannot be achieved [8, 33].

Different types of plates have been used for fixation of distal humerus fractures: limited contact dynamic compression plate (LC-DCP), 3.5 mm reconstruction plates, and anatomically precontoured plates. All have been proven successful to provide rigid fixation. Only one-third tubular plates are considered too weak to ensure adequate bone fixation and are no longer recommended for fixation of distal humerus fractures [8, 9, 33, 34]. Regarding the use of locking plates versus traditional compression plates, biomechanical studies have found that the use of locking screws is only superior when poor bone quality is present [35]. Otherwise, it has been shown no significant difference between both options with regard to clinical outcome, rate of nonunion, infection, and reoperation [36].

9.5.5 Fixation Methods

Once the fracture has been exposed, debris and hematoma clots are removed. We should be sure to preserve and to pay attention to the orientation of free small bony fragments which may be present and can be useful to reassemble the articular surface.

9.5.5.1 Reduction and Temporary Fixation

A traditional approach includes reducing first the articular fragments to each other with the help of

reduction forceps, manipulation, and small-diameter Kirschner wires (0.035–0.045 inches) that can be used for provisional fixation. The surgeon must foresee that these K wires won't interfere with the placement of definitive fixation plates later on. Articular fragments may be held together as well with interfragmentary lag screws, threaded K wires, or resorbable pegs, always allowing future screw insertion and plate positioning [1, 33]. Alternatively, if one column presents a relatively simple fracture pattern, the surgeon may choose to reduce and fix it first (converting an AO type C fracture into a type B fracture), reducing afterwards the articular segment to this column [1, 8]. In case of significant cartilage loss at the joint level, special care must be taken at restoring the adequate width of distal humerus, avoiding compression at this location since it would lead to articular incongruence [33].

Once the articular surface has been rebuilt, it has to be reduced and fix to the humerus shaft at the metaphyseal level using provisional 0.065 K wires. As mentioned before, limited contact dynamic compression plate (LC-DCP), 3.5 mm reconstruction plates, or anatomically precontoured plates can be used for definitive fixation after an optimal reduction is achieved. The plates are applied to both columns and should have different lengths in order to reduce the stress riser effect and risk of peri-implant fracture [6, 8, 9].

The literature supports that each plate should have at least three screws proximal to the metaphyseal fracture line. A biomechanical study published by Zarifian et al. reported that the optimal configuration should include four screws in the distal segments of both plates, three screws in the medial plate proximal segment, and five screws in the lateral plate proximal segment, so the construct resists all bending, axial, and torsional forces [37].

A plate applied directly over the lateral column should be precontoured at its distal end, so it matches the anatomical tilt of the capitellum; the medial column does not angle forward distally, but, in low fractures, the medial plate should wrap around the medial epicondyle to maximize screw insertion in the articular fragments [1, 33].

9.5.5.2 Definitive Fixation

Once the plates have been placed in the desired position, the articular segment must be firmly secured. O'Driscoll enunciated eight technical principles that should guide the fixation of distal humerus fractures [34]:

1. Every screw in the distal fragments should pass through a plate.
2. 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.

Additional implants should be available if definitive fixation of small articular fragments is needed: mini-fragment plates, 2.7-mm reconstruction plates, headless compression screws, and bioabsorbable pins [9].

Next, proximal fixation and supracondylar compression should be achieved, aided by reduction clamps and the dynamic compression holes in the plates. If there is extensive metaphyseal comminution and significant bone loss, shortening of the humerus is tolerable up to 2–3 cm [2, 33]; in some cases, bone grafting and bridge plating may be necessary. Autologous bone from the iliac crest, demineralized bone matrix allograft, and structural cadaveric allograft are some of the options available.

Prior to closure, elbow range of motion and stability should be assessed, checking there is no bony or soft tissue impingement. Under fluoroscopic examination, adequate fracture reduction and plates and screws position should be verified, ensuring that no screws penetrate the joint [1, 9] (Figs. 9.1 and 9.2).

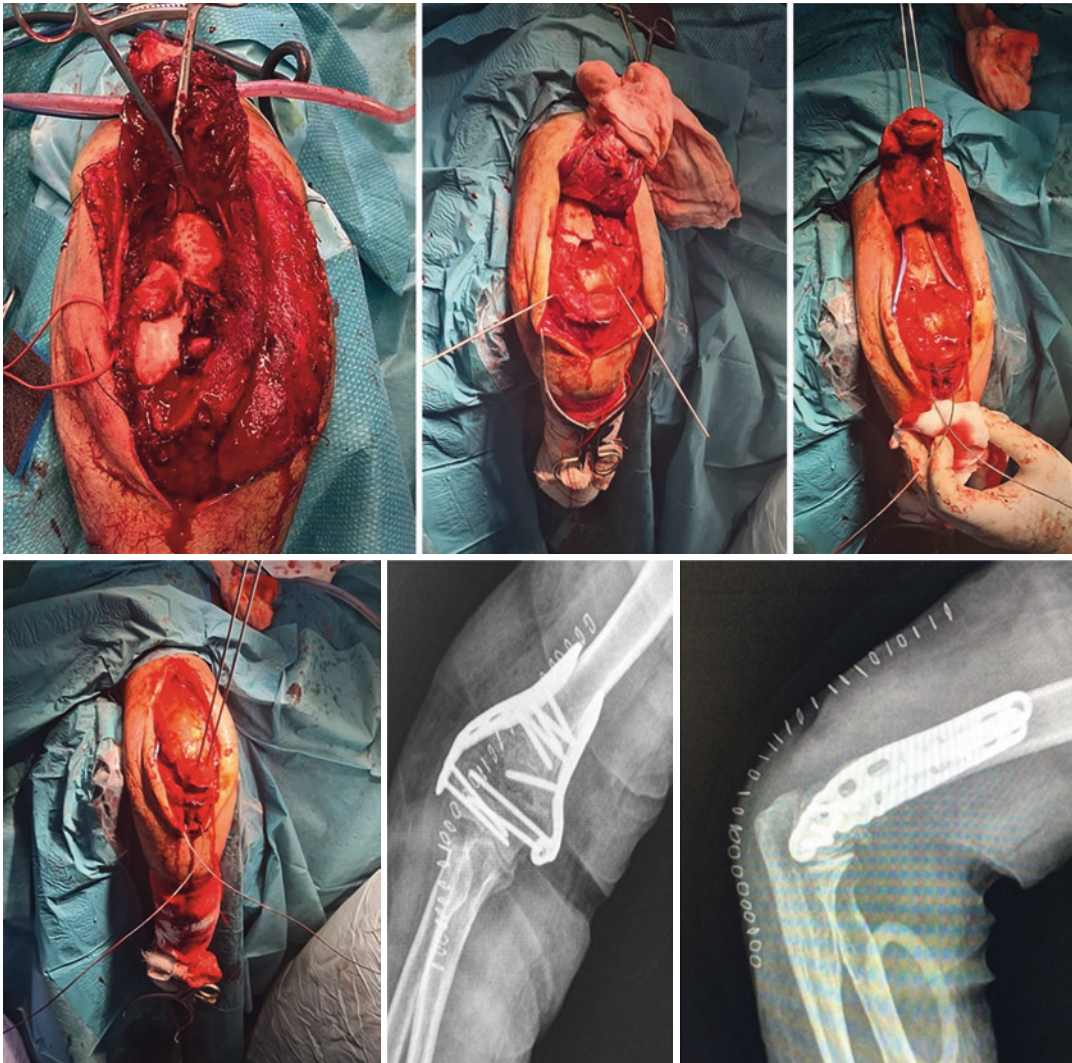


Fig. 9.1 Comminuted type C supracondylar fracture. From left to right, from up to down: Olecranon osteotomy provides extensile exposure to distal humerus, including part of the articular surface; provisional fixation with K-wires is helpful; fixation is best achieved by a combina-

tion of isolated lag screws and parallel anatomic precontoured 3.5 mm plates; olecranon osteotomy is closed with a cerclage; anteroposterior postoperative radiograph; lateral postoperative radiograph

9.5.6 Management of Ulnar Nerve

The operation protocol should clearly detail how the ulnar nerve was handled during surgery [1]. Although it is acknowledged that the ulnar nerve must be identified and protected during the procedure, controversy still remains regarding the best management of the nerve after the distal

humerus fracture has been fixed. The options include returning the ulnar nerve to its initial location or to transpose it anteriorly [2, 6].

A 2018 meta-analysis by Shearin et al. included five retrospective studies, totaling 366 distal humerus fracture cases that underwent ORIF and either the ulnar nerve underwent in situ management or anterior transposition.

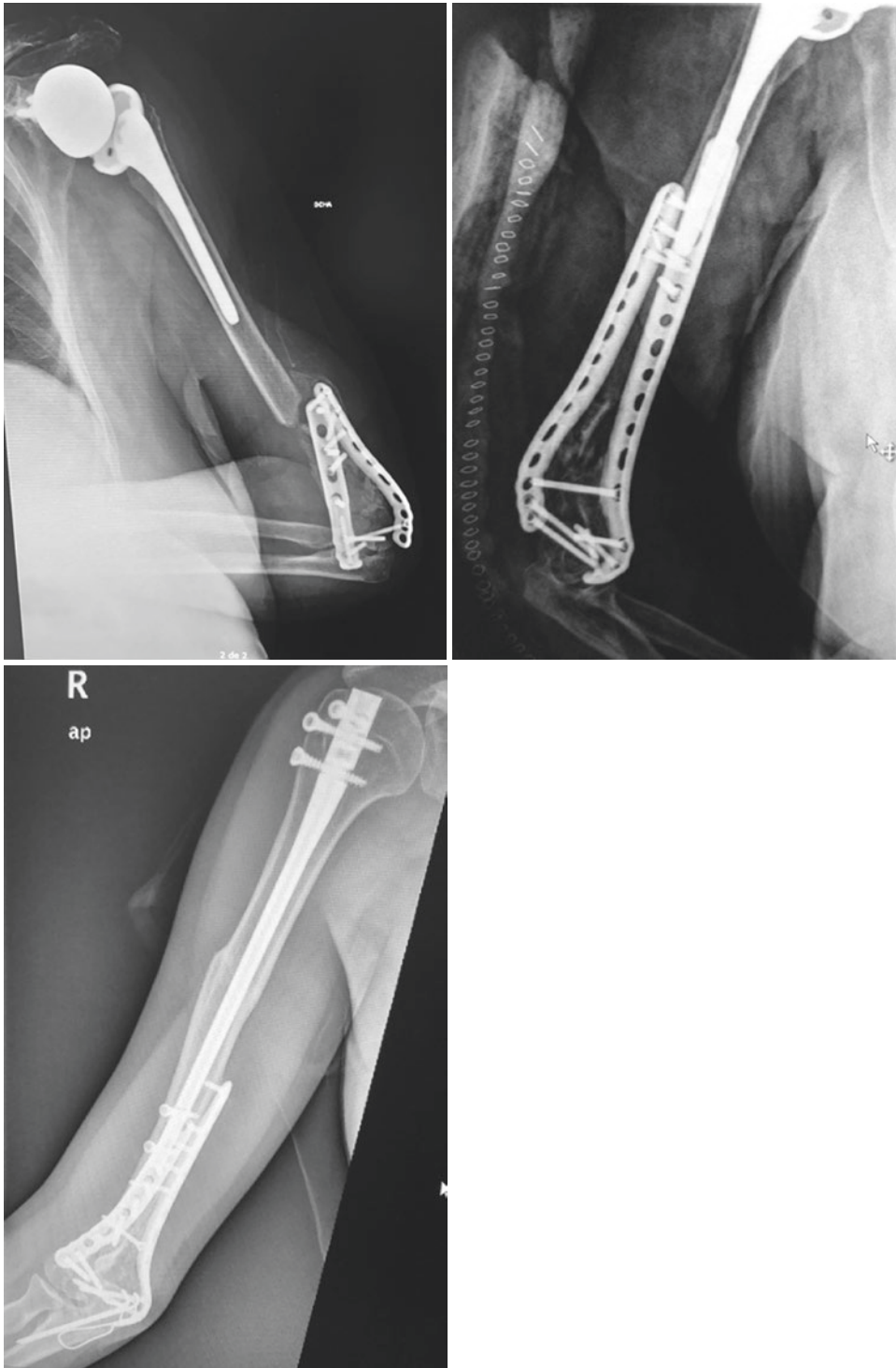


Fig. 9.2 In supracondylar fractures of the humerus, one plate should be larger than the other to avoid a stress riser point. It is especially important in case of previous implants such as shoulder prosthesis (top left), plates (top

right), or nails (bottom left). Overlap in the proximal implant is also recommended to facilitate fracture consolidation

They observed that postoperative ulnar neuropathy was increased in patients who had transposition versus in situ management and concluded that transposition does not have a protective effect against the development of late ulnar neuropathy after distal humerus fracture repair surgery [38].

Either way, at the end of the procedure, ulnar nerve stability and relationship to the implants through complete elbow range of motion should be tested.

9.6 Postoperative Management

As mentioned before, early mobilization of the elbow after surgery is pursued in order to obtain the best outcomes [1, 2, 4–6, 9, 10, 14, 33, 39]; however, if the quality of the fixation is not optimal (i.e., due to fracture complexity or poor bone quality), it is advisable to immobilize and protect the elbow for 3–4 weeks to ensure the fracture consolidates in an adequate position. Although immobilization for more than 3 weeks has been associated with poorer outcomes, most patients will not develop significant stiffness, and if they do it is simpler to deal with stiffness rather than a loss of fixation [1, 9].

A posterior splint in neutral position can be applied for 24–48 h to protect the soft tissues; after it has been removed, active exercises of ipsilateral shoulder and wrist and active assisted exercises of the elbow are initiated. Light functional use of the extremity for daily live activities such as eating or personal hygiene is encouraged, not being allowed lifting weights over 1 kg. If an olecranon osteotomy has been performed, extension against gravity or resistance is banned for 6 weeks [33]. Exercises against resistance are initiated at approximately 6 weeks. Three months after surgery, full strengthening exercises are allowed, and, at 6 months postoperatively, patients can return to a preinjury activity level. Improvement can be achieved over the first year after surgery [1, 9, 12].

9.7 Complications of Surgical Management

9.7.1 Stiffness

Some degree of reduced elbow motion is often observed after ORIF in distal humerus fractures, particularly regarding extension. For some authors, this would be the most common complication. However, many studies in the literature report achieving a functional range of motion [2, 33].

9.7.2 Nonunion

Distal humerus fractures are estimated to attain union in an average time of 14.6 weeks. With current surgical techniques and fixation principles, exceptional union rates are reported, varying between 90% and 98% [9, 33]. Nonunion typically occurs in the metaphyseal region and, when present, in a 75% of the patients is thought to be caused by inadequate initial fracture fixation. Other factors that contribute to nonunion are infection, nutritional and smoking status, and underlying endocrine conditions [2, 6].

Management of nonunion includes contraction release, revision of the fixation, and bone grafting.

9.7.3 Heterotopic Ossification

The incidence of heterotopic ossification (HO) described in the literature is highly variable, with rates ranging from 0% to 50% according to different series [6, 9]. However, it is often not associated with functional problems. Some risk factors for heterotopic ossification have been described: head injury, multiples surgeries, delayed surgical treatment, bone grafting, high-energy injuries, or open fractures [2, 33].

Naut et al. reported a heterotopic ossification rate of 8.6% [40]. Recently, Foruria et al. reported

in their retrospective study a symptomatic HO rate of 41%. HO was associated with significant loss of extension and overall decreased flexion–extension arc of less than 100° [41].

To date, there is no quality data regarding HO prophylaxis in the management of distal humerus fractures treated surgically. Radiation therapy and indomethacin treatment have been suggested. Shin et al. reported a 3% rate of symptomatic HO and a nonunion rate of 6% after radiation therapy and 2 weeks of indomethacin [31]. Similarly, Liu et al. reported a 3% rate of symptomatic HO as well and a nonunion rate of 3% after 6 weeks of celecoxib [42].

9.7.4 Ulnar Neuropathy

Ulnar neuritis can be present in up to 19% of patients. Management of this complication includes neurolysis or anterior transposition [2].

9.7.5 Other Complications [33]

- Fixation failure
- Hardware pain or prominence
- Superficial or deep infection
- Radial nerve palsy
- Malunion
- Posttraumatic osteoarthritis and avascular necrosis

9.8 Outcomes

Despite the controversies and complications previously discussed, when anatomic reduction of the articular surface, rigid bicolumnar internal fixation, and early motion are achieved, satisfactory outcomes can be expected [10]. Overall outcomes of ORIF in intra-articular fractures of distal humerus are satisfactory or better in 71–86% of patients. Overall arc of motion of approximately 100° can be expected, and patients should also expect approximately 75% return of strength in the distal humerus fractured arm versus their uninjured arm [33].

Doomberg et al. reported on 30 patients that were evaluated at an average of 19 years after open reduction and internal fixation of a fracture of the distal humerus, to assess the range of elbow motion and the functional outcome. The average final flexion arc was 106°, and the average pronation-supination arc was 165° [43]. The average American Shoulder and Elbow Surgeons (ASES) score was 96 points, with an average satisfaction score of 8.8 points on a 0 to 10-point visual analog scale. The authors concluded that the long-term results of open reduction and internal fixation of intra-articular fractures of the distal humerus are similar to those reported in the short term, suggesting that the results are durable.

9.9 Elbow Arthroplasty

Indications for prosthetic replacement after a distal humerus fracture include unreconstructible fractures, with high degree comminution and/or the presence of poor bone quality in low-demand elderly patients. Also, it can be beneficial in patients with preexisting inflammatory arthropathy. In this context, total elbow arthroplasty (TEA) is a recognized alternative treatment [2, 10, 12]. Contraindications include ipsilateral hand neurological impairment, noncompliant patient, acute open fracture, or active infection [12].

McKee et al. conducted a prospective randomized controlled trial to compare functional outcomes, complications, and reoperation rates in elderly patients with displaced intra-articular distal humeral fractures treated with open reduction and internal fixation or primary semiconstrained total elbow arthroplasty. Forty-two patients over 65 years were included and randomized. The Mayo Elbow Performance Score (MEPS) and Disabilities of the Arm, Shoulder, and Hand (DASH) score were determined at 6 weeks, 3 months, 6 months, 12 months, and 2 years. They reported that TEA resulted in more predictable and improved 2-year functional outcomes compared with ORIF and that TEA may result in decreased reoperation rates. The authors concluded that TEA is a preferred alternative over

ORIF in elderly patients with complex distal humeral fractures that are not amenable to achieve a stable fixation [44].

A systematic review and meta-analysis was performed by Githens et al. in order to compare outcomes and complication rates in elderly patients with intra-articular distal humerus fractures, being treated with either total elbow arthroplasty or open reduction and internal fixation with locking plates. They selected 27 studies including 563 patients with an average follow-up of 3.8 years. They concluded that TEA and ORIF for the treatment of geriatric distal humerus fractures provided similar functional outcome scores and range of motion, without significant complication rates [45].

Nonetheless, total elbow arthroplasty has its own limitations and complications. Patients should be warned about the postoperative restriction of lifting no more than 2–5 kg and no repetitive lifting more than 0.5–1 kg. Complications include prosthetic loosening, periprosthetic fracture, mechanical failure, and deep wound infection. Consequently, although TEA may provide similar outcomes when compared with ORIF in appropriately selected patients, it can cause terrible complications, and appropriate patients must be carefully selected [2, 4, 10].

9.10 Conclusions

Despite the controversies and complications previously discussed, when anatomic reduction of the articular surface, rigid bicolumnar internal fixation, and early motion are achieved, satisfactory outcomes can be expected. Overall outcomes of ORIF in intra-articular fractures of distal humerus are satisfactory or better in 71% to 86% of patients. Overall arc of motion of approximately 100° can be expected, and patients should also expect approximately 75% return of strength in the distal humerus fractured arm versus their uninjured arm.

Indications for prosthetic replacement after a distal humerus fracture include unreconstructible fractures, with high degree comminution and/or the presence of poor bone quality in low-demand

elderly patients. Also, it can be beneficial in patients with preexisting inflammatory arthropathy. In this context, TEA is a recognized alternative treatment. Contraindications include ipsilateral hand neurological impairment, non-compliant patient, acute open fracture, or active infection.

TEA and ORIF, for the treatment of geriatric distal humerus fractures, provide similar functional outcome scores and range of motion, without significant complication rates. Nonetheless, total elbow arthroplasty has its own limitations and complications. Patients should be warned about the postoperative restriction of lifting no more than 2–5 kg and no repetitive lifting more than 0.5–1 kg. Complications include prosthetic loosening, periprosthetic fracture, mechanical failure, and deep wound infection. Consequently, although TEA may provide similar outcomes when compared with ORIF in appropriately selected patients, it can cause terrible complications, and appropriate patients must be carefully selected.

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