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1 Introduction

Fractures of the distal end of the humerus account for 2–6% of all fractures and for about 30% of all elbow fractures in adults. There is a bimodal distribution with respect to age and gender with peaks of incidence in young male and in older female patients. Most fractures in elderly patients are intra-articular with bicolumnar involvement [1].

Extraarticular injuries and some simple partial articular injuries have a relatively good prognosis with effective operative treatment. Fractures with a more guarded prognosis are those that are complete articular and multifragmentary, and fractures associated with open wounds or neurovascular injury.

Stiffness, pain, and deformity are more likely with inadequate treatment or prolonged immobilization.

- The goal of operative treatment is anatomical reduction and stable fixation of the fracture so that active motion can be started within a few days of surgery.

It may be difficult to achieve stable internal fixation in patients with osteoporotic bone, and total elbow arthroplasty can be considered. However, total elbow arthroplasty, which requires strict activity limitations, will eventually fail, and may be associated with severe complications that can be difficult or impossible to treat.

- Current techniques of plate and screw fixation, especially the new LCP plates with locking head screws, allow secure reconstructions, so that the native elbow can be retained in the vast majority of patients.

2 Assessment of fractures and soft tissues

2.1 Classification

The pattern of elbow fractures can vary considerably and an understanding of the different types, leading to proper classification, is indispensable for correct decision making (Fig 6.2.3-1). Certain important groups require further comment:

| A1 | Extraarticular | Avulsion fractures of the epicondyle are usually associated with dislocation. Treatment of the dislocation takes precedence. Entrapment of bone fragments within the reduced joint, with or without nerve or soft-tissue attachments, must be avoided. The elbow must be stable after reduction. |
| B3 | Partial articular fractures have separate articular fragments, eg, capitellum or trochlea fragments | These may be multifragmentary [2] and, in the elderly, very difficult to stabilize. |
| C1 | Complete articular, articular simple and metaphyseal simple | This fracture is easy to repair, but uncommon. Hidden fracture lines should be carefully sought. |
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2.2 History/mechanism of injury

The amount of energy imparted upon the tissues is estimated by a careful history and physical exam. The strength of the patient’s bone is crucial; in the elderly a simple fall may cause complex fractures. Osteoporosis makes fixation difficult, but it is still feasible [3]. The general medical history is also vital. Good results after fixation require cooperative patients willing to practice active postoperative movements. Problems can arise in patients with severe head injuries, dementia, alcoholism, or drug addiction. Early osteosynthesis, protected by a short period of immobilization, despite some inevitable stiffness, may be preferable to failed internal fixation [4]. Heterotopic ossification may follow intracranial injury and may be more likely after delayed fixation and forced passive stretching of the elbow.

2.3 Neurovascular problems

Injury to any nerve or vessel passing the elbow may occur with distal humeral fractures, but is relatively uncommon. Among nerve injuries, neurapraxic and axonotmetic injuries (traction, contusion, or entrapment) are more common than laceration. Finger movements and sensation are tested with the arm gently supported. Severe pain and the inability to tolerate finger extension, whether active or passive, suggest the possibility of compartment syndrome (chapter 1.6).

Peripheral pulses should be palpated preoperatively, but it should be kept in mind that—due to the excellent longitudinal collateral blood supply in the elbow—it is possible to have a pulse even when the brachial artery is injured. Some trauma teams prefer to have definitive plate and screw fixation prior to vascular repair, but given the potential for prolonged and difficult surgery to repair a complex distal humerus fracture, temporary stabilization with an external fixator, or temporary shunting of the artery are also to be considered. Positioning of the patient and planning of the incisions should take into account that the brachial artery cannot be approached from posterior.

2.4 Imaging

High-quality plain x-rays (AP, lateral +/– oblique views) are needed.

- Sedation or anesthesia will permit the use of gentle traction to produce a traction x-ray. This helps to clarify the fracture pattern and to assist in preparing the definitive preoperative drawings.

Views of the uninjured side are helpful for planning. Hidden fragmentation is a hazard and is not always detected by less experienced surgeons. CT scanning with sagittal and coronal views and 3-D reconstruction (particularly with the radius and ulna subtracted from the images) provides more detailed information and is especially helpful in B3 and C3 fractures. Fixation and approach vary with the type of fracture, hence accurate classification of the fracture is essential.

3 Surgical anatomy

The distal humerus forms a strong bony triangle (formed by two columns and the central trochlea). The lateral column has the capitellum on its anterior surface, but the posterior surface
is nonarticular and may be used as a site for a plate. The spool-shaped trochlea is central rather than medial and the axis of rotation lies slightly in front of the humeral shaft. The lateral column curves anteriorly with the center of rotation, but the medial column (including the medial epicondyle) are in line with the humeral shaft. Placement of a straight plate on the direct lateral surface of the humerus risks straightening of the distal humerus.

The radial head, coronoid, and olecranon fossae accommodate the corresponding processes in terminal flexion and extension. For full movement the anterior and posterior fossae must be clear of metal or scar tissue and the anterior translation of the trochlea with the shaft must be restored. The collateral ligaments are essential for stability. The medial collateral ligament originates from the undersurface of the medial epicondyle where it is vulnerable to excessive dissection (Fig 6.2.3-2).

4 Preoperative planning

Planning includes the entire surgical tactic—antibiotics, patient positioning, surgical approach, bone grafting, etc—set out step by step (Fig 6.2.3-3). If it is not possible to make an exact drawing of the planned fixation, the choice of procedure (or of surgeon) should be reviewed.

Fig 6.2.3-3a–c Planning is essential for distal humerus fractures.

a Open, complex metaphysis, simple articular fracture (13-C2).
b Preoperative plan showed extent of missing bone.
c 6 weeks after surgery. Anatomical reduction of the joint with absolute stability. Articular fracture healed. The metaphyseal bone graft is being incorporated.
4.1 Positioning and approach

Positioning is determined by the patient’s general condition, associated injuries, and fracture type. Both the lateral decubitus and the fully prone position allow excellent access to the posterior aspect of the elbow joint. In the lateral decubitus position, the arm rests on a padded bar of about 4 cm diameter allowing 120° flexion of the elbow (Fig 6.2.3-4). The patient can also remain supine, or be rolled over slightly, with the arm draped over the body. A supine position with the arm supported on a hand table is preferable for B3 fractures when an extended lateral exposure will be used. If the fracture proves more complex than anticipated, the arm can be draped over the body and an olecranon osteotomy performed. A bone graft is rarely needed, but with complex fractures it is wise to advise the patient of the possibility, and prepare a donor site.

In most cases a sterile tourniquet is placed high on the arm but should be inflated only if excessive bleeding obscures the view for surgical dissection, for example, of the ulnar nerve. It may be omitted if the humerus is short or when the fracture extends far proximally. In any event the tourniquet must be released and, if possible, removed after a maximum of 2 hours.

All aspects of the elbow can be accessed through a midline posterior skin incision raising medial and lateral flaps as needed. The advantages of a posterior skin incision include:
- avoidance of major cutaneous nerve branches;
- access to all parts of the elbow (including anterior) through a single incision;
- a relatively unnoticeable scar.

Disadvantages include a longer scar and the potential for hematoma or skin problems with the extensive skin flaps, although in practice wound and skin problems are unusual after upper extremity trauma. Some surgeons avoid an incision to the point of the olecranon, while others see no problem with a straight incision. A direct lateral incision can be used for isolated fractures involving the capitellum and trochlea.

The optimal handling of the ulnar nerve is still being debated. Many surgeons argue that complete release and subcutaneous anterior transposition of the nerve
- will leave fewer risks for potential compression from scarring, swelling, or kinking of the nerve;
- will provide additional possibilities for fixation on the medial epicondyle and increase the safety of drilling and screw application on the medial side;
- prophylactically addresses the known risk of ulnar nerve problems.

![Fig 6.2.3-4a–b](image)

**a** Positioning of the patient in lateral decubitus with the upper arm supported by a padded post.

**b** The patient lies prone with the arm on a radiolucent support, or (as illustrated) a padded post. Either gives maximum freedom to approach the elbow.
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Others would argue that

- transposing the nerve can cause a palsy that may lead to slow or incomplete recovery;
- mobilizing the nerve sufficiently to apply implants safely is adequate.

In the setting of a complex articular fracture of the distal humerus that is approached primarily from the lateral side, it has been suggested that at least a prophylactic in situ release of the ulnar nerve be considered because of frequent problems with this structure.

- It is essential that the operating room report clearly describes how the ulna nerve has been handled.

Extraarticular fractures can be repaired accurately through a triceps-splitting exposure (eg, Campbell [5, 6]), in which a midline split of the triceps brachii muscle is created and elevated away from the posterior humerus and olecranon. They may also be repaired accurately through a triceps-elevating exposure (eg, Alonso-Llamas [7]), in which the triceps brachii muscle attachment to the olecranon is not disturbed and the triceps brachii muscle is elevated away from the posterior humerus through two separate medial and lateral windows. The preferred exposure for an articular fracture is debatable. Olecranon osteotomy gives excellent, and the only extensile exposure. There may however be complications associated with the creation, fixation, and healing of the osteotomy. Alternatives include triceps-elevating exposures such as the Bryan/Morrey [8], and the triceps-reflecting anconeus pedicle (TRAP) exposure [9]. These carry the risk of triceps brachii avulsion and weakness in terminal extension, although a comparative study of olecranon osteotomy and the Campbell exposure showed comparable strength of extension [5].

Problems associated with an olecranon osteotomy can be limited by using a careful and meticulous technique for creating and repairing the osteotomy [10].

Since a transverse osteotomy is inherently unstable, a distally pointed chevron osteotomy is preferable (Video 6.2.3-1). The osteotomy is initiated with an oscillating saw and completed by fracturing the subchondral bone, levering the osteotomy open with an osteotome. Cracking the anterior cortex facilitates repositioning and increases stability of fixation due to interdigitation of the fragments (Fig 6.2.3-5; 6.2.3-6).

The olecranon osteotomy is reconstructed according to the tension band technique described in chapter 3.2.3.
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Fig 6.2.3-5a–b  Posterior approach to the elbow with olecranon osteotomy.

a The skin incision starts in the middle of the posterior aspect of the humerus curving gently on the lateral (radial) side around the olecranon to the posterior crest (1) of the ulna. An alternative is to use a straight incision. The ulnar nerve (2) must be identified and protected. The radial nerve (3) is at risk in the proximal part of the wound, but is usually not seen.

b Chevron osteotomy of the olecranon (4) allows mobilization of the triceps brachii muscle (5) either to the side or proximally. This gives excellent exposure of the distal humerus, including the trochlea (6), lateral epicondyle (7) and medial epicondyle (8).
Fig 6.2.3-6a–e  Chevron osteotomy of the olecranon: Starting with a fine oscillating bone saw (a) and finishing by breaking the last few millimeters with an osteotome (b–c). Reconstruction after surgery with two K-wires and figure-of-eight tension band wire (d–e). It is essential that the K wires are placed underneath the triceps brachii muscle.
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4.2 Reduction techniques and tools

There are two general approaches to the reduction and provisional fixation of a fracture of the distal humerus. The traditional approach is to first repair the articular fragments, securing them to one another with an interfragmentary compression screw and then attach the reassembled trochlea to the humeral shaft with plates (Video 6.2.3-2). An alternative is to provisionally fix all of the fragments back to the shaft with K-wires and then apply plates and screws. The reduction should start with the column that has the simpler fracture pattern. This technique is considered a better alternative for \( \lambda \)-shaped fractures in which one of the columns is fractured very high and the other low [11]. The larger fragment is secured to the shaft and then the small fragments are reassembled one by one.

Reduction can be assisted by the positioning of the arm, direct manipulation, and the use of reduction forceps. Smooth K-wires used for provisional fixation are placed carefully so that they will not interfere with implant application. Very small articular and metaphyseal fragments that contribute to the shape of the joint may be secured with small threaded K-wires or resorbable pins placed through the subchondral bone of adjacent fragments.

4.3 Choice of implant

Depending on the type and site of the fracture there is a selection of implants that can be used:

- **A1 fracture**: Fixation is rarely needed in A1 fractures, as the principal injury is a dislocation. For larger fragments, 3.5 or 4.0 mm screws are more reliable than K-wires. Cannulated screws may facilitate the procedure.

- **B fracture**: For isolated partial fractures of the lateral or medial column a single plate, or screws alone, may be used. Articular avulsion fractures of the capitellum and anterior trochlea are secured with implants such as headless screws, screws with countersunk heads, small threaded K-wires, or resorbable pins.

- **A2, A3, and C fracture**: Both-column or complete articular fractures are stabilized with two plates. Reconstruction plates 3.5 are easier to contour, but limited contact dynamic compression plates (LC-DCP) are stronger. The rather weak one-third tubular plates should only be used as a buttress on the ulnar column, but always in combination with a second, stronger plate. Parallel plate placement (one direct medial and one direct lateral plate) is an option with several advantages, particularly for very low fractures or fractures with extensive articular fragmentation. Orthogonal plate placement is usually cited as the strongest form of fixation [12, 13], but there is biomechanical evidence that rather supports parallel plating [14].

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**Video**

Video 6.2.3-2  As a first step the articular block is reconstructed and temporarily held with a pointed reduction forceps or K-Wires, followed by cannulated lag screws.
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- Precontoured plates have been developed by several manufacturers and some of the newer designs incorporate locking head screws (LHS) providing angular stability. These plates, such as the LCP (chapter 3.3.4) may be useful in patients with very low columnar fractures, substantial metaphyseal comminution or poor bone quality (Video 6.2.3-3) [15].

- Total elbow arthroplasty is only appropriate in patients with very limited functional demands or preexisting elbow arthritis [16].

The early results of total elbow arthroplasty are seductively good: It is a very straightforward procedure to perform, rapid functional restoration is the rule, and on average the range of motion is better than that obtained with internal fixation [17].

The enthusiasm for total elbow arthroplasty is however tempered by
  - strict life-long activity restrictions (5 kg lifting limit);
  - inevitable failure of the prosthesis;
  - potential devastating complications, such as deep infection or end-stage osteolysis (severe bone loss after multiple revisions), for which there is currently no good treatment option.

The decision to perform total elbow arthroplasty is usually made preoperatively, based more upon the patient characteristics than the fracture characteristics (Fig 6.2.3-7). However, if the surgeon is planning to attempt internal fixation and use total elbow arthroplasty as a bail out, an olecranon osteotomy should not be used to expose the fracture. When the decision

Video 6.2.3-3  ORIF with the new precontoured LCP distal humerus.

Fig 6.2.3-7a–b
a  A 55-year-old female with a fracture of the distal humerus and rheumatoid arthritis. The fracture enters the articular surface. Severe osteoporosis and severe preexisting arthritic changes.
b  Function was restored with a linked total elbow prosthesis.
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is made to proceed with total elbow arthroplasty, excision of the fragments provides ample working space and the insertion of the triceps brachii muscle on the olecranon can be left intact (basically an Allonso-Llamas exposure).

Surgical treatment—tricks and hints

Because adult elbows are notorious for becoming stiff after injury, the goal of operative treatment is a fixation that is stable enough to allow immediate active exercises and functional use of the limb for light tasks.

These fractures therefore require internal fixation with absolute stability. “Minimalistic” procedures such as screws alone will not allow early movement and will usually fail. Children are more tolerant of joint immobilization and, for them, minimal fixation is usually adequate.

For optimal fixation, a well drawn plan should be followed throughout the operation. The aim, when feasible, is to place two, or preferably three, screws above and below the fracture in each plate. The olecranon fossa must be free of metallic implants. When possible, plates at right angles to each other create a girder-like structure, which strengthens the fixation (Fig 6.2.3-8). The posterolateral plate, which will function as a tension band during elbow flexion, is applied provisionally first. It is contoured according to the shape of the bone to restore the anterior tilt of the capitellum. It may reach down to the joint surface. Initial fixation around the triangle of the distal humerus should be provisional only. A slight malrotation of the trochlea fragments frequently prevents completion of the final corner of the triangle, requiring the initial fixation to be adjusted. Once the medial side plate is in place, the lateral plate can be definitively fixed. A long cortex screw, lagged to allow compression, passes transversely through the medial plate. However, if this screw is lagged in the presence of central comminution or a gap, it may result in narrowing of the trochlea and articular incongruity. Precise plate positioning is critical for optimal fixation. Each screw should have as long a trajectory through the bone as possible. Each screw should fix as many articular fragments as possible. Fragments should not be thrown away as even the smallest may give a clue to correct reassembly. Small fragments may safely be left in place if the remainder of the fixation is stable. Small intermediate articular fragments are fixed with additional countersunk 1.5 or 2.0 mm screws, headless screws, or small threaded K-wires. Bone grafts for articular defects are rarely needed.

A plate placed directly on the lateral column must be contoured to angle forward at the distal limit of the plate. A straight plate will angle off the bone posteriorly at its proximal limit. Attempts to make this plate stay directly on the lateral column proximally will risk losing the normal anterior translation of the distal humerus.

The medial column is straight. For low fractures it is useful to contour the medial plate around the medial epicondyle in order to increase the number of screws in the distal fragments.

When LCPs are used for intraarticular fractures, the articular bone block is restored first using conventional screws. K-wires are used for temporary fixation of the restored joint block to the proximal fragment. LCPs are contoured near-anatomically to the underlying cortex. Since prominent implants interfere with the soft tissues, conventional screws can be used initially to approximate the plate to the bone. They can be exchanged for locking head screws at the end of the procedure. A potential disadvantage of the LCPs is that the orientation of the screws is defined by the implant, though the new anatomically pre-shaped LCPs distal humerus (LCP-DHP) tend to reduce this problem (Fig 6.2-9b).
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Fig 6.2.3-8a–e Steps in reconstructing a multifragmentary distal humerus fracture.

- **a** Inside-out technique for the K-wire (1.6 mm) to reconstruct the trochlea and capitellum.
- **b–c** After reduction of three articular fragments, the K-wire is drilled in the reverse direction. It may be used as a guide for a 3.5 mm cannulated screw, or a screw may be placed parallel to it (c).
- **d** Once the articular components are firmly fixed as one block, the latter is joined to the humeral shaft using temporary K-wires.
- **e** To join the articular block to the humerus a precisely contoured LC-DCP 3.5 is placed first on the posterolateral side. It may curve around the capitellum which has no cartilage posteriorly. On the medial side the plate is placed on the crest of the bone (at right angles to the lateral plate), which increases stability. A reconstruction plate 3.5 is easier to contour, particularly if the plate needs to extend distally to the medial epicondyle. In humeri with decreased bone quality and in fractures with metaphyseal comminution, LCPs in a 90° configuration are preferred, since they provide higher biomechanical stability. Care must be taken to avoid joint penetration with the angular-stable screws.
The new precontoured locking plates for the distal humerus have the advantage of better adaptation to the anatomical characteristics of the distal humerus and safer locking head screw orientation (Fig 6.2.3-9).

If anterior articular fragments (capitellum and trochlea) do not seem to fit properly, there is probably some impaction of the lateral column that must be addressed. Realignment of the impacted lateral column or posterior trochlea will usually allow accurate application of the anterior fracture fragments. The lateral column should then be fixed with a plate.

The vast majority of open fractures can be treated with immediate internal fixation after debridement and irrigation of the wound. Small puncture wounds are left to heal. For large wounds, delayed primary closure at 48 hours is safer.

The reconstructed elbow is put through a full range of motion, including pronation and supination. Careful palpation is required to exclude impinging screws or wires and to detect any movement between the fragments. The ulnar nerve can be replaced in its original bed or transposed anteriorly into the subcutaneous tissues. Its position should be recorded in case additional surgery is necessary.

Fig 6.2.3-9a–b
a Complex distal humerus fracture (13-C3) with a very low lateral column fragment.

b X-ray 6 weeks after fixation with two anatomically preshaped LCPs distal humerus, allowing multiple locking head screw fixation of the capitellum.
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6 Postoperative treatment

Some surgeons prefer to splint the elbow in extension overnight due to the relative difficulty of regaining extension.

- Regardless of the position of splinting, it is preferable to initiate active-assisted elbow exercises and light functional use of the limb immediately after surgery.

When the fixation obtained is somewhat tenuous—as a result of either the complexity of the fracture, poor bone quality or both—it may be preferable to immobilize and protect the elbow for about 4 weeks and deal with developing stiffness rather than to lose the fixation and have to salvage with a total elbow arthroplasty.

- Active-assisted exercises are recommended, while passive manipulation should be avoided.

Resistive exercises are not initiated until fracture union is clearly advancing, usually for a minimum of 6 weeks after surgery. Dynamic or static progressive elbow splints can be useful for helping to regain elbow motion.

7 Pitfalls and complications

7.1 Stiffness

Stiffness may be related to
- extraarticular deformity (e.g., loss of the normal anterior translation of the distal humerus);
- intraarticular deformity (e.g., articular incongruities or arthrosis);
- ulnar neuropathy;
- heterotopic ossification;
- prominent implants;
- capsular contracture (this is the most common cause);
- delayed surgery, which may be responsible for heterotopic ossification and capsular contracture.

Prophylaxis against heterotopic ossification is not routinely used because it can also affect fracture healing. Release of capsular contracture [18], heterotopic bone [19], and ulnar nerve compression [20] have become more predictable over the last few decades, and substantial function is often achieved when secondary surgery for stiffness is undertaken.

7.2 Nonunion

Nonunion usually occurs at the supracondylar level. Risk factors include:
- inadequate fixation (wires, screws only, or inadequate plates);
- excessive use of the limb in the early postoperative period;
- metaphyseal comminution;
- bone loss.
Surgical management consisting of elbow arthrolysis, ulnar nerve neurolysis, stable internal fixation, and autogenous cancellous bone grafting leads to healing and adequate function in most patients [21].

### 7.3 Infection

Infection is relatively rare despite the thin soft-tissue cover, which is often punctured in the initial trauma. Deep infection is treated with serial debridement and organism-specific intravenous antibiotics. The implants can be left in place, provided they are not loose, although later implant removal (after fracture healing) may be necessary to completely eradicate the infection.

### 7.4 Ulnar neurapraxia

Tingling in the ulnar nerve distribution is common but rarely persists.

- **Traction on the retracted ulna nerve must be avoided during the operation.**

A more severe palsy with weakness may be quite prolonged and sometimes permanent. Occasional late ulnar palsy may need decompression, hence the need to record the exact position of the nerve relative to the metalwork.

### 7.5 Exposure related complications

Nonunion of the olecranon osteotomy can be salvaged by repeating internal fixation and bone grafting. Migration and prominence of the wires used for fixation can be limited by careful technique [10].

Triceps-elevating exposures are occasionally complicated by triceps brachii avulsion. In contrast to olecranon nonunion, this is a very difficult problem to address.

### 8 Results

Before stable fixation techniques were developed, a strong body of opinion was opposed to operative intervention. The “bag of bones” technique of fostering early movement and ignoring the fracture results in an average range of motion of about 90°. It was believed that recovery to anything resembling normality was impossible and any discernable movement was hailed as a good result.

Comparisons between operative series are hampered by use of differing criteria for good, fair, etc. Most series using criteria found that 75–80% of patients achieved at least a good rating (Fig 6.2.3-10) [22, 23]. Fractures of the distal humerus are very
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**Fig 6.2.3-10a–e**

a  13-C1 fracture of the distal humerus in a 34-year-old male.

b–c  Postoperative view with orthogonal reconstruction plate 3.5 fixation.

d–e  2-year follow-up with excellent functional result.
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difficult to manage and no one claims less than about 15% of poor results.

- Limited open reduction or poor internal fixation technique, inevitably requiring immobilization, combine the disadvantages of both closed and open treatments.

9 Conclusion

Recognition of the injury pattern and all injury components, open anatomical reconstruction and rigid internal fixation followed by early active exercises offer the best functional results after fracture of the distal humerus. With sound technique and compliant patients, satisfactory results can be achieved in about 80% of the cases.

10 Bibliography

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11 Acknowledgment

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