2 Open Reduction and Internal Fixation (ORIF) for Distal Humerus Fractures

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2.1 Background and Key Principles

Successful open reduction internal fixation of distal humerus fractures requires careful preoperative planning and principle based fixation. Distal humerus fractures account for 30% of elbow fractures. The complex anatomy of the distal humerus and the demand for early mobilization presents unique technical challenges when considering fixation. The goal of distal humerus reconstruction is to provide a construct rigid enough to allow for early motion, while also restoring the articular surface and anatomic geometry. In order to achieve these goals, fixation of each distal fragment must contribute to maximizing stability between the distal fragment and the humeral shaft. Eight technical objectives were initially described in order to guide fixation such that every fixation effort maximizes stability [1]:

1. All screws used in fixation should pass through a plate.
2. Each screw should engage fragments that are also part of a plated construct.
3. Fixation should include as many screws as possible.
4. All screws should be the maximum length possible.
5. Every screw should engage as many articular fragments as possible.
6. The distal most screws should interdigitate, locking together.
7. Supracondylar compression should be applied via plating in both columns.
8. Plates themselves must be applied in a rigid enough construct for union, specifically at the supracondylar level, which is at highest risk for nonunion.

2.2 Indications

The indications for ORIF of distal humerus fractures includes most displaced distal humerus fractures. We group them into extra-articular fractures (transcondylar fractures, supracondylar fractures, and epicondyle fractures) and intraarticular fractures (intercondylar fractures and purely articular fractures [coronal shear]).

2.3 Contraindications

Nonsurgical management can be considered for nondisplaced fractures and for infirm patients, but remains rare. Total elbow arthroplasty is considered for elderly patients with commi-

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nuted fractures. TEA is also preferable in patients with inflammatory arthritis such as rheumatoid arthritis [2].

2.4 Special Considerations

Preoperative imaging is critical for surgical planning, and should include plain films (anterior–posterior (AP) and lateral) and computed tomography (CT) with three-dimensional reconstruction (Fig. 2.1). These reconstructions allow for detailed evaluation of the articular fragments for pre-operative planning. The ideal position for CT is with the patient's arm over their head for maximum radiographic clarity. A careful preoperative neurologic and vascular exam is also key, as many patients will have nerve mediated symptoms, most commonly involving the ulnar nerve.

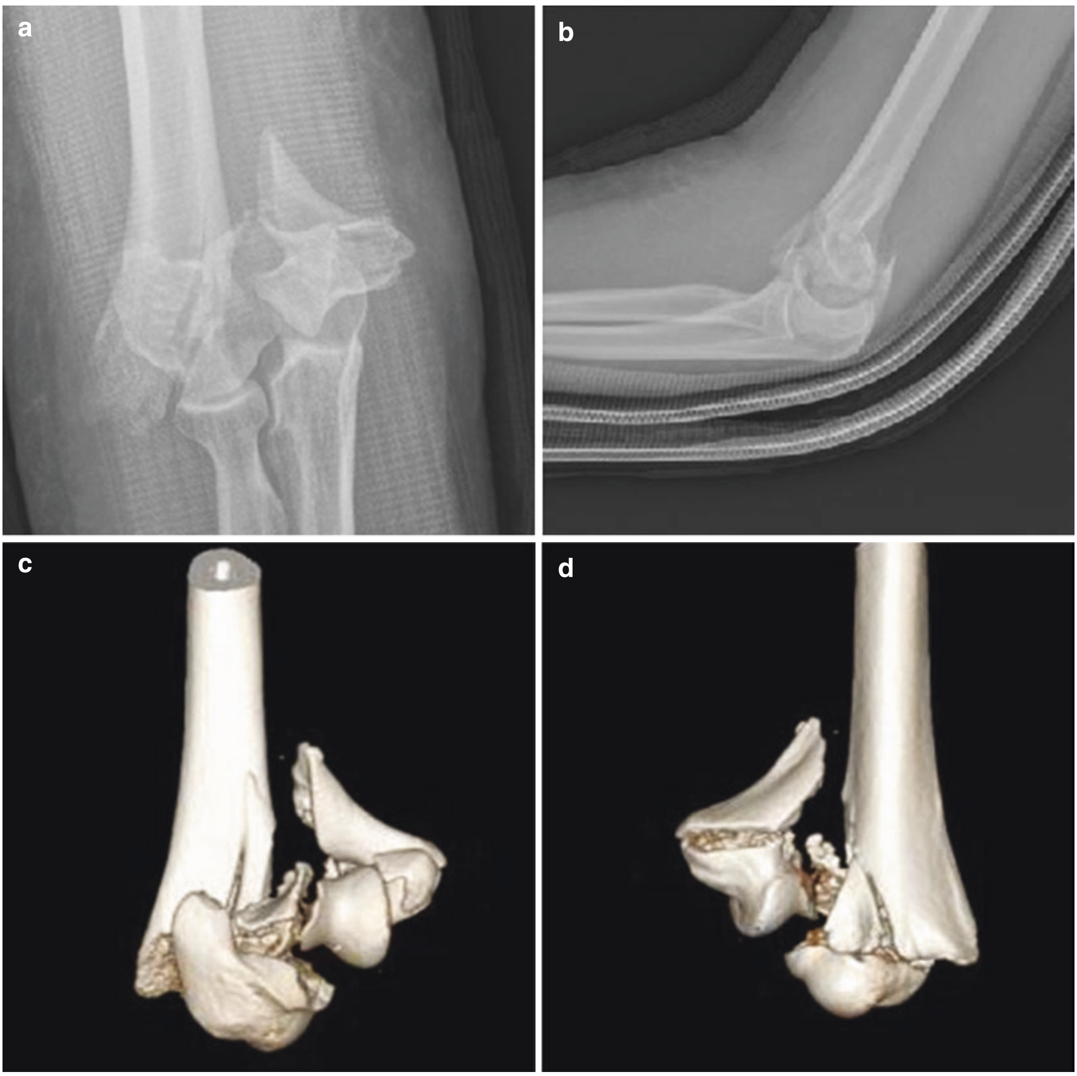

Fig. 2.1 (**a**) Anterior–posterior (AP) and (**b**) lateral plain films of a bicolumnar distal humerus fracture with intraarticular involvement. (**c**) Anterior view computed tomography (CT) three-dimensional reconstruction of the same fracture, demonstrating articular comminution and columnar displacement. (**d**) Posterior CT reconstruction of the same fracture

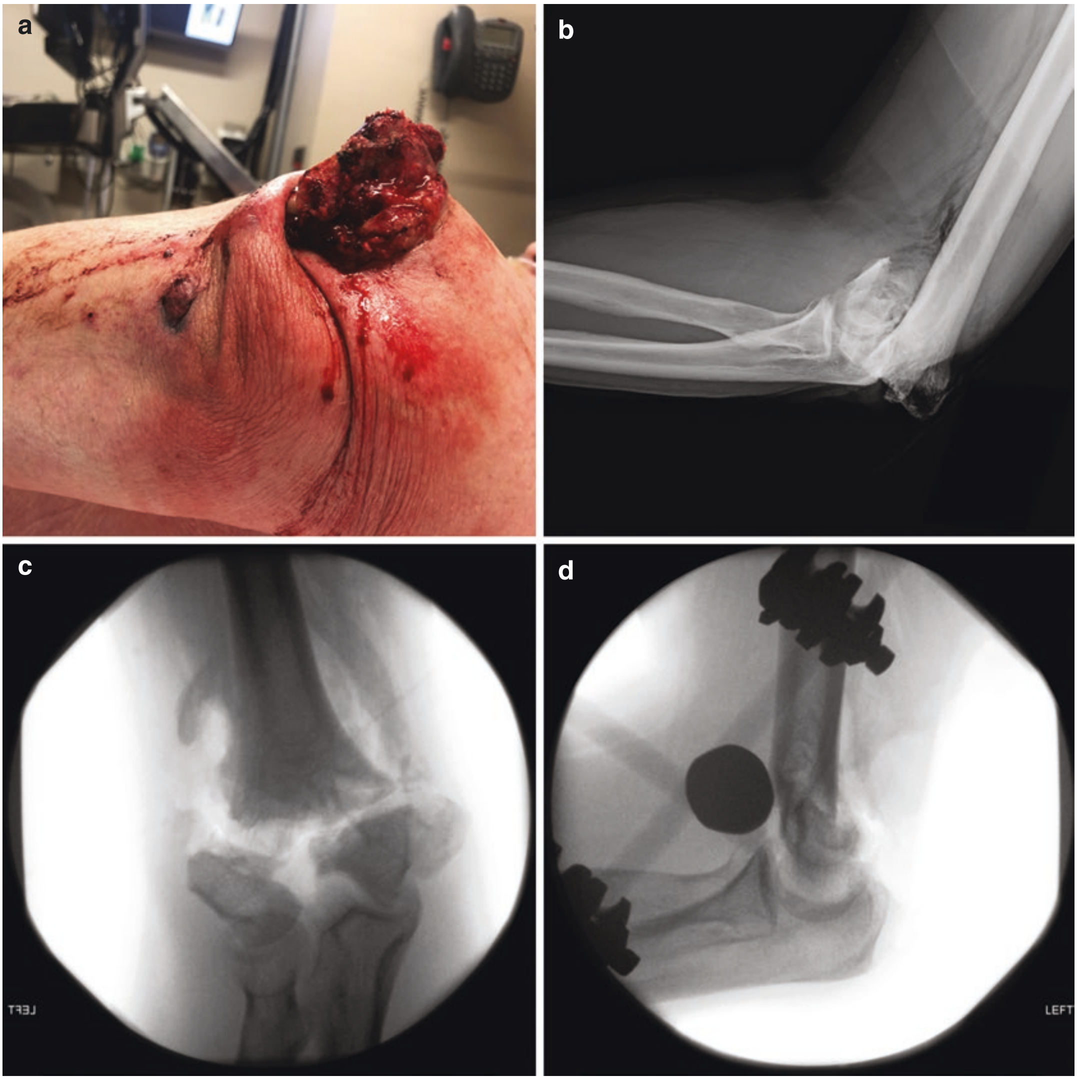

Fig. 2.2 (**a**) Photograph of an open distal humerus fracture. (**b**) Lateral plain film of the initial injury demonstrating open component of fracture. (**c**) AP intraoperative fluoroscopy of the same fracture. (**d**) Lateral intraoperative fluoroscopy after external fixator placement

Additionally, a careful assessment of the skin integrity around the injury is crucial for determining fixation timing, as open fractures or patients with acute threatened skin may benefit from application of external-fixation initially prior to definitive open reduction and internal fixation (Fig. 2.2). It is also vital to have a clear discussion with patients preoperatively, because these fractures are at high risk for nonunion, malunion, soft tissue complications, and hardware complications, and many patients require additional surgical intervention. Even patients who successfully avoid major complications can have persistent range of motion loss and/or post-traumatic arthritis.

2.5 Anesthesia and Positioning

Anesthesia is general and may include an interscalene or supraclavicular block, however, this may confound early postoperative examination and we do not use peripheral nerve blocks in patients with pre-operative nerve symptoms.

The patient is positioned lateral decubitus with the operative arm flexed over a radiolucent arm board (Fig. 2.3). This position allows for intraoperative flexion, extension, pronation, and supination as needed, while also stabilizing the proximal humerus.

Fluoroscopic imaging should be verified prior to prepping and draping to ensure the positioning is logistically conducive to intraoperative imaging during reduction and fixation. We typically use a plexiglass arm holder for the down (nonsurgical) arm to avoid interference with imaging.

Fig. 2.3 Patient in lateral decubitus with operative arm draped over an elevated radiolucent arm board stabilizes the humerus while allowing for intraoperative flexion, extension, pronation, and supination as needed

2.6 Tips, Pearls, and Lessons Learned

2.6.1 Olecranon Osteotomy

Using an olecranon osteotomy allows the most complete exposure to the articular surface, up to 57% of the surface, and therefore lends itself to complex intraarticular fractures. It is helpful to have a low threshold for this approach when preoperative CT reveals a complex fracture pattern with articular involvement. We prefer to use a cannulated 6.5 mm screw with a washer for fixation of the osteotomy. The guidewire can be placed and the screw may be tapped and placed until nearly down to confirm length and stability prior to osteotomy. Starting your pin slightly dorsally in the tip of the olecranon can avoid translation of the osteotomy dorsally (Fig. 2.4). The screw may then be removed and saved, which makes fixation straightforward at the end of the case.

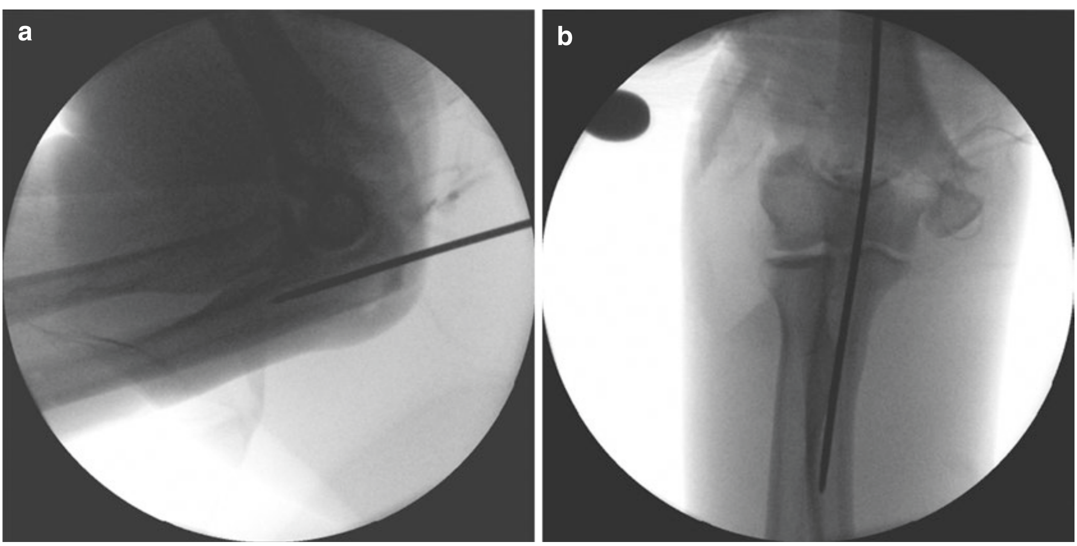

Fig. 2.4 (**a**) Lateral fluoroscopic view of predrilling for the olecranon osteotomy. A starting point at the dorsal aspect of the tip of the olecranon helps avoid dorsal translation of the fragment. (**b**) Confirmatory AP view during predrilling. The tip of the screw should begin to engage the radial cortex of the ulna

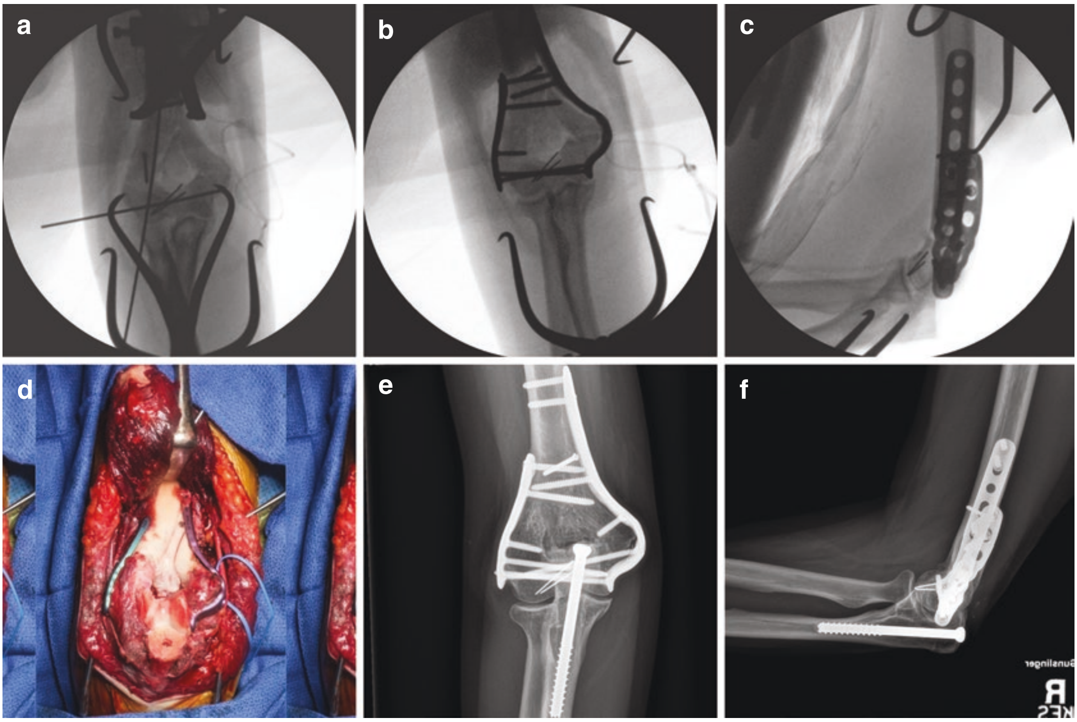

Fig. 2.5 (**a**) Reduction of articular fragments achieved with Kirschner wires and clamps. (**b**) AP intraoperative image of parallel plate fixation. (**c**) Lateral intraoperative fluoroscopy of parallel plate technique. (**d**) Intraoperative photograph. A vessel loop protects the transposed ulnar nerve. The olecranon is retracted superiorly with sutures, providing excellent visualization of the articular surface. (**e**) Postoperative AP image of the same fracture with final olecranon osteotomy screw fixation. (**f**) Lateral radiograph of final fracture fixation

2.6.2 Order of Reduction

In the majority of cases, reconstruction of the articular surface should be the first priority in fixation, using the intact radial head and ulna as a reference for articular alignment. Provisional fixation may be achieved with smooth Kirschner wires (Fig. 2.5a). In cases with severe articular comminution, the Kirschner wires may be used in addition to traditional plate and screws for definitive fixation (Fig. 2.5e).

2.6.3 Intraoperative Mobility Assessment

After reduction and before closing, range the elbow through full flexion, extension, pronation, and supination in order to assess the functional mobility of the joint after articular reconstruction. Many patients will go on to develop stiffness or face functional challenges, and ensuring appropriate alignment and restored joint mechanics intraoperatively is key for setting the patient up for functional success.

2.7 Difficulties Encountered

As stated above, reduction and fixation is best completed beginning with the articular surface distally, moving in a stepwise fashion towards the proximal fragments. The goal is to convert a complex articular fracture into a simple articular fracture by anchoring articular fragments to either the medial or lateral column before moving to proximal fixation. These distal fragments act like the keystone in an arch, providing intercondylar stability. Fragments that are too small may be removed. If the remaining articular surface is deficient, causing narrowing of the intercondylar width, autograft or allograft iliac crest bone graft may be used to bridge the gap and restore anatomic width.

In the setting of significant metaphyseal comminution, which may prevent supracondylar compression and anatomic reconstruction, a humeral shortening osteotomy maybe used to allow better bony apposition. It is key to ensure anatomic alignment, rotation, and geometry of the distal humerus are maintained when using a supracondylar osteotomy. It is helpful to mark rotation with electrocautery prior to the osteotomy. The distal humerus can tolerate up to 2 cm of shortening without sacrificing elbow biomechanics [3].

2.8 Key Procedural Steps

2.8.1 Exposure and Approach

Incision is midline posterior, which allows exposure of both columns via full-thickness fasciocutaneous flaps, dissecting to the triceps tendon. For rare single column injuries, a direct medial or lateral incision may be used. The single incision posterior approach has been shown to have better outcomes than a two-incision approach [4]. We typically begin by transposing the ulnar nerve. First, release the nerve from the cubital tunnel, ensuring you have about 6 cm mobilized both proximally and distally to the epicondyle. Tag the nerve with a vessel loop, and elevate a subcutaneous flap above the flexor pronator mass for transposition. Be sure to release Osborne's ligament and the fascia of the flexor carpi ulnaris, both areas of potential ulnar nerve impingement. A thorough decompression and transposition at that beginning of the case will allow the nerve to be protected through the remainder of the case (Fig. 2.5d).

In extra-articular fractures, or fractures with a simple articular split with extraarticular cortical reads, a paratricipital approach may be used. We do this by elevating the anconeus and triceps between the intermuscular septae, exposing the posterior humerus. If the fracture extends intraarticularly, windows on either side of the elevated triceps may be used.

For more complex intercondylar fractures of the distal humerus, we have a low threshold to perform an olecranon osteotomy. We begin by predrilling, tapping, and placing a 6.5 cannulated screw with a washer. This can be seated down until it is nearly contacting to ensure appropriate length. An anteroposterior (AP) fluoroscopy image will demonstrate the screw beginning to engage the radial cortex of the ulna (Fig. 2.4b). This gives outstanding fixation. By initiating a starting point that is on the dorsal aspect of the tip of the olecranon, dorsal translation of the fragment can be avoided.

Working through the medial and lateral windows of the triceps and posterior humerus, we visualize the bare area of the trochlea. This is the location where the osteotomy should exit, and should be visualized (rather than identified by fluoroscopy). A very small chevron osteotomy can be made with a thin saw, and the last 20% should be finished with an osteotome. Reflection of the osteotomy will allow excellent visualization of the distal humerus. We use sutures in the triceps to hold the osteotomy retracted proximally (Fig. 2.5d).

2.8.2 Fixation

Fixation follows the key principles listed in Sect. 2.1, beginning with the articular surface. Remove and save any fragments that are too small for Kirschner wire fixation, as these may be used for bone graft once stripped of cartilage. Kirschner wires may be used to fix articular fragments together until the articular surface is recreated. After pinning the articular surface, the distal construct including the articular surface can then be reduced to the shaft. In most cases, this is held in place with 0.062 K-wires, which can provisionally hold the reduction until plate application (Fig. 2.5a). We typically apply the plate to the most stable column first. Compression can be applied with pointed reduction clamps (and held compressed with locking screws) or with compression through the plate. Larger fragments, particularly extraarticular pieces, can be fixed together with lag screws.

In some cases of profound comminution or bone loss of one column, it may be advantageous to fix one column first, in order to restore alignment to the joint. Careful compression of the columns to ensure bone contact is critical if this technique is employed. We prefer to reduce the joint first, and compress to the supracondylar humerus.

When there is profound supracondylar comminution, supracondylar shortening can allow compression and stabilization of the articular segment. This can be done with minimal functional compromise to the arm. We have a low threshold for use of this technique, particularly in the elderly, or in open fractures. Steps are similar to those above, with removal of spikes of supracondylar bone to allow stable compression of the repaired articular surface to the distal humerus. The olecranon tip and coronoid tip should be inspected through an arc of motion to ensure they do not engage the humeral cortex. In most cases, recreation of the olecranon and coronoid fossa are necessary to ensure impingement free ROM.

We use parallel plating for the vast majority of distal humerus fractures. This technique provides rigid support to the articular surface through interdigitating screws, while providing supracondylar compression. Precontoured periarticular plates designed with tightly grouped distal screw holes allow multiple long screws to pass through the articular fragments (Fig. 2.5e, f). All plates should ideally be slightly under contoured in order to compress across the metaphyseal fracture. Plate length should allow placement of at least three screws proximal to the metaphyseal fracture both medially and laterally, with the plates ending at different heights proximally to avoid stress riser creation [5].

Regarding plate orientation, parallel plating involves placing plates on the medial and lateral columns, with the screws oriented slightly anteriorly (Fig. 2.5). In orthogonal ("90–90" or perpendicular) plating, one plate is placed on the medial column, with a second plate on the posterolateral surface (Fig. 2.6). Biomechanical studies comparing both methods suggest parallel plating provides greater stiffness in extension, lateral bending, and torsion [6]. Ultimately fracture configuration will guide plate orientation, and both configurations have historically favorable outcomes. We use parallel plating in almost all cases, with the exception being certain supracondylar fractures with minimal intraarticular involvement.

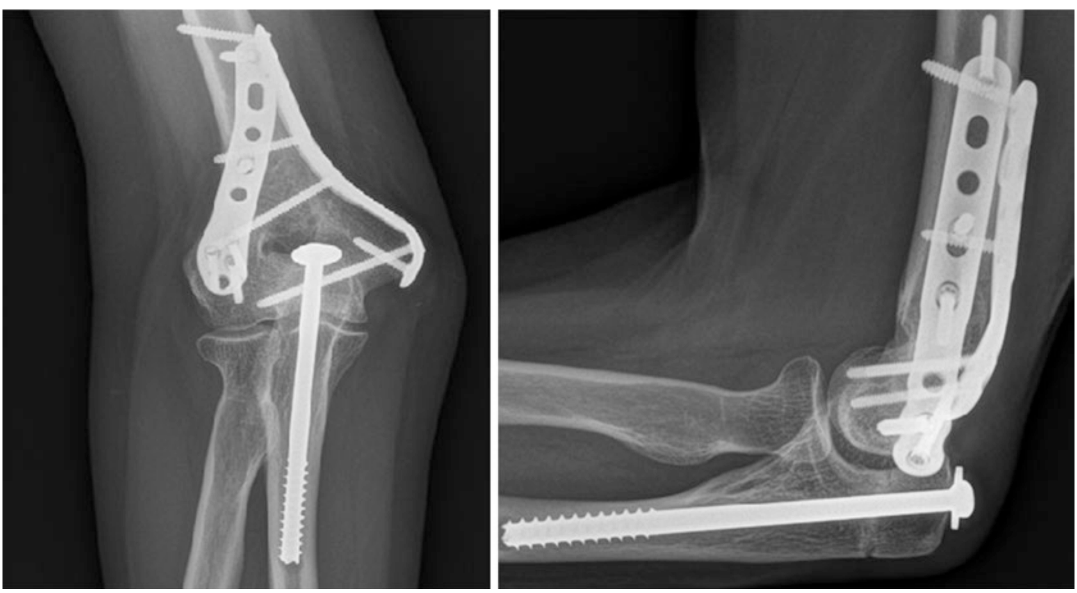

Fig. 2.6 AP and lateral plain radiographs demonstrating orthogonal, or "90–90" plating, with posterolateral precontoured plate and medial precountoured plate. This can be effective in simpler, mostly extraarticular fractures

2.9 Bailout, Rescue, and Salvage Procedures

In fractures that remain unstable despite dual plating, triple plating may be used to augment fixation in the coronal plane (Fig. 2.7) and provide a more rigid fixation construct in highly unstable or osteoporotic fractures. In cases where an anatomic reduction or stable construct may not be possible even with three plates, total elbow arthroplasty should be considered [7]. This is typically contemplated in elderly patients with intercondylar fractures. Total elbow arthroplasty (TEA) is also the gold standard in patients with inflammatory arthritis and elderly patients with poor bone quality due to osteoporosis (Fig. 2.8).

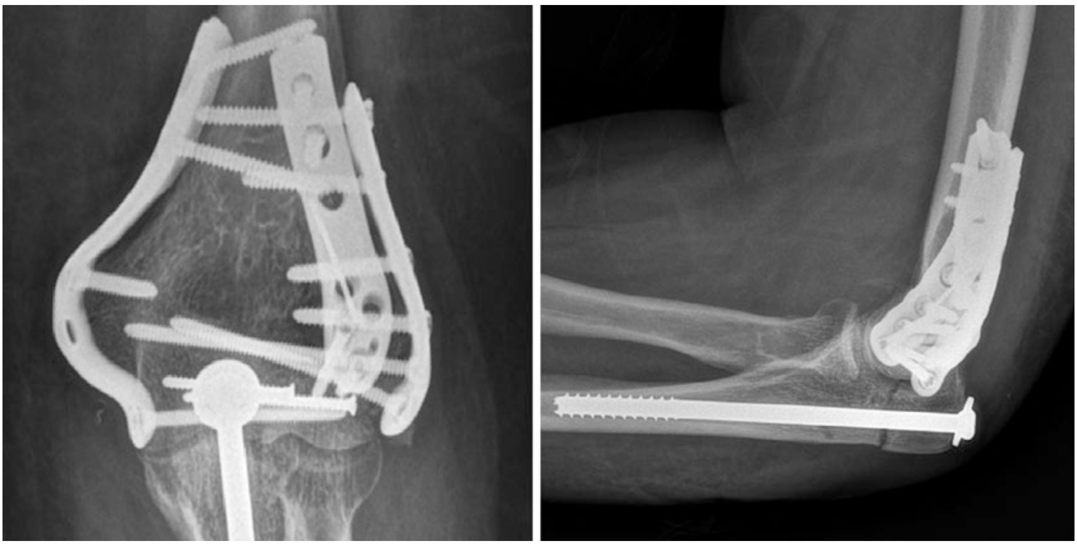

Fig. 2.7 AP and lateral views of triple plating technique, with two parallel plates and a third posterolateral plate placed perpendicular to the medial and lateral plates

Fig. 2.8 AP and lateral view of a primary total elbow arthroplasty (TEA) for distal humerus fracture in a 75-year-old woman with osteoporosis

Additionally, TEA outcomes after failed internal fixation are similar to those of primary TEA [8]. Finally, in very rare cases, elbow arthrodesis may be considered as a salvage procedure. Arthrodesis position is about 100° of flexion, neutral pronation [9].

References

1. O'Driscoll SW. Optimizing stability in distal humeral fracture fixation. J Shoulder Elb Surg. 2005;14(1 Suppl S):186S–94S. https://doi.org/10.1016/j.jse.2004.09.033.
2. Cobb TK, Morrey BF. Total elbow arthroplasty as primary treatment for distal humeral fractures in elderly patients. J Bone Jt Surg Am. 1997;79(6):826–32. https://doi.org/10.2106/00004623-199706000-00004.
3. Hughes RE, Schneeberger AG, An KN, Morrey BF, O'Driscoll SW. Reduction of triceps muscle force after shortening of the distal humerus: a computational model. J Shoulder Elb Surg. 1997;6(5):444–8. https://doi.org/10.1016/s1058-2746(97)70051-x.
4. Ozdemir H, Urgüden M, Söyüncü Y, Aslan T. Long-term functional results of adult intra-articular distal humeral fractures treated by open reduction and plate osteosynthesis. Acta Orthop Traumatol Turc. 2002;36(4):328–35.
5. O'Driscoll SW. Supracondylar fractures of the elbow: open reduction, internal fixation. Hand Clin. 2004;20(4):465–74. https://doi.org/10.1016/j.hcl.2004.07.001.
6. Schemitsch EH, Tencer AF, Henley MB. Biomechanical evaluation of methods of internal fixation of the distal humerus. J Orthop Trauma. 1994;8(6):468–75.
7. Galano GJ, Ahmad CS, Levine WN. Current treatment strategies for bicolumnar distal humerus fractures. J Am Acad Orthop Surg. 2010;18(1):20–30. https://doi.org/10.5435/00124635-201001000-00004.
8. Logli AL, Shannon SF, Boe CC, Morrey ME, O'Driscoll SW, Sanchez-Sotelo J. Total elbow arthroplasty for distal humerus fractures provided similar outcomes when performed as a primary procedure or after failed internal fixation. J Orthop Trauma. 2020;34(2):95–101. https://doi.org/10.1097/BOT.0000000000001631.
9. Koller H, Kolb K, Assuncao A, Kolb W, Holz U. The fate of elbow arthrodesis: indications, techniques, and outcome in 14 patients. J Shoulder Elb Surg. 2008;17(2):293–306. https://doi.org/10.1016/j.jse.2007.06.008.