

Fixed-angle Locked Plating of Two-, Three-, and Four-part Proximal Humerus Fractures

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The video that accompanies this article is "Locked Plating for Proximal Humeral Fractures," available on the *Orthopaedic Knowledge Online Website*, at <http://www5.aaos.org/oko/jaaos/surgical.cfm>

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Proximal humerus fractures are relatively common, accounting for 5% to 9% of all fractures.¹⁻³ These fractures can pose a challenge for the treating orthopaedist because of the generally osteoporotic nature of bone in the elderly and the relative deforming forces of the surrounding muscles. Fractures are classified according to the Neer criteria, and treatment is often guided by the relative displacement of the anatomic fragments. Nondisplaced fractures have historically been treated conservatively, with generally good outcomes.⁴ Displaced fractures with angulation of the articular surface $>45^\circ$ and displacement of the major segments >1 cm have been treated surgically, as have fractures with substantial valgus impaction, all with mixed results.⁵⁻²³

Surgical techniques have included percutaneous fixation, standard plate-and-screw fixation, intramedullary fixation with rods or pins, the use of tension bands with and without plates or rods, standard plate modification into blade plate constructs, and hemiarthroplasty.⁴⁻²³ Many of these alternative open techniques were developed because of the high failure rates noted initially with standard plating. The inherent difficulties with internal fixation have led several authors to recommend hemiarthroplasty for the treatment of most three- and four-part humerus fractures.^{5,9,19,24,25} However, locked plates allow for more secure fixation in compromised bone, thereby possibly leading to reduced incidence of failure of internal fixation. Newer plates also incorporate suture eyelets

that further enhance the fixation construct and resist deforming muscular forces. Additional investigation is necessary, but early results with locked plate fixation for the treatment of proximal humerus fractures have been encouraging. It is anticipated that this technique will provide another potentially viable alternative to prosthetic replacement for the treatment of these difficult injuries.

Indications and Contraindications

The indications for fixed-angle locked plating are evolving. We contend that open reduction and internal fixation (ORIF) with a locked plate is ideal for displaced two-part surgical neck fractures, two-part anatomic neck fractures in the patient younger than age 40 years, three-part surgical neck fractures with involvement of the greater or lesser tuberosity, and most four-part fractures (Figure 1). Fracture-dislocations are usually associated with high-energy injuries. These injuries are more prone to complications, especially devascularization of the dislocated head fragment. As a result, fracture-dislocations are generally excluded from the treatment algorithm. Instead, they are approached on a case-by-case basis. ORIF is generally reserved for persons younger than age 40 years in an effort to save the head and avoid prosthetic replacement. In our practice, fracture-dislocations with complete denuding of all attached soft tissues are usually managed with hemiarthroplasty regardless of patient age. A two-part

surgical neck fracture with $>30^\circ$ of varus malalignment of the head relative to the neck-shaft angle is a relative indication for fixed-angle locked plating. Such plating is done to avoid the risk of tuberosity impingement with shoulder abduction and the resultant loss of motion.²⁶

Contraindications to ORIF with a locked plate include nondisplaced or minimally displaced fractures, most head-splitting fractures, and patients who are unable to tolerate a surgical procedure because of underlying comorbidities. Relative contraindications

include anatomic neck fractures in the elderly and comminuted fractures with extension into the proximal metaphyseal bone segment.

Surgical Technique

A thorough history and physical examination are essential in all patients being evaluated for surgical intervention. The surgeon should obtain preoperative radiographs, including true anteroposterior shoulder, scapular lateral, and axillary views (Figure 2). In tolerant patients, internal and external rotation views of the humerus also may be helpful. Computed tomography is not often necessary, but it can prove beneficial in the more comminuted fracture when tuberosity size and position are difficult to ascertain on standard radiographs. Magnetic resonance imaging has not proved very beneficial because most proximal humerus fractures do not have an associated rotator cuff tear.

Anesthesia

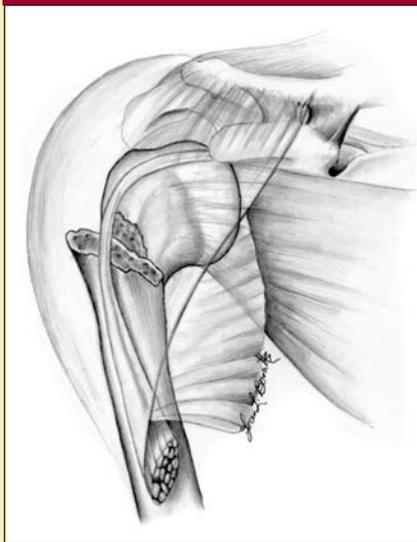
The patient is given an interscalene block, which reduces the amount of general anesthetic required intraoperatively and substantially minimizes postoperative pain. The endotracheal tube should be taped and secured on the lip contralateral to the side of surgery so as

not to interfere with the surgical field and to avoid inadvertent dislodgement during retractor placement.

Positioning

A systematic approach to patient positioning is crucial for good intraoperative fluoroscopy. We use a regular surgical table with a radiolucent footplate. The table is rotated 180° so that the patient's head is at the foot of the bed, and the shoulder rests on the radiolucent footplate (video, 3:06). Most tables are rated for 300 lb and can safely accommodate patients in this position. Once the patient is under general anesthesia, the patient's bottom is placed at the break of the table, and the head is elevated 30° (modified beach-chair position). A pillow is placed under the knees for comfort and to minimize neural tension. All prominences are well padded. The head is often supported on a jelly doughnut and taped in place with 2-in silk tape. The bed is then rotated 90° relative to the anesthesiologist. The large C-arm is positioned parallel to the patient at the head of the bed, thereby avoiding interference with the anesthesiologist (Figure 3). This simplifies the use of fluoroscopy and allows an unobstructed view of the shoulder intraoperatively with minimal repositioning of the C-arm. Imaging

Figure 1

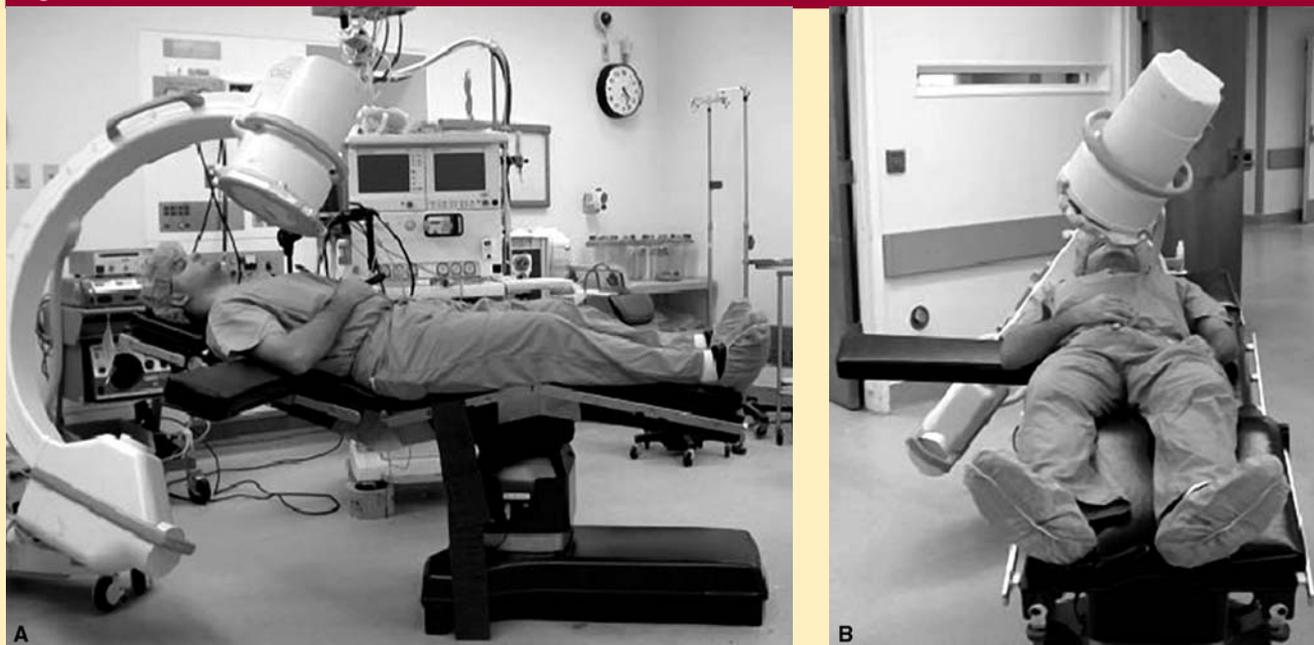


Two-, three-, and four-part proximal humerus fractures according to the Neer classification.

Figure 2



Preoperative anteroposterior (A), axillary (B), and scapular Y-view (C) radiographs of a four-part proximal humerus fracture in a 66-year-old man.

Figure 3

Side (**A**) and front-on (**B**) views of patient positioning for intraoperative fluoroscopy for proximal humerus fracture fixation. (Reproduced with permission from Badman B, Mighell M, Drake G: Surgical technique with fibular strut allograft and fixed angle locked plating. *Tech Should Elb Surg* 2006;7:95-101.)

should be obtained before prepping the patient. If necessary, the patient should be repositioned so that a good image can be obtained ([AOA video, 3:06-4:50](#)).

Approach

A standard deltopectoral approach is used for exposure of the proximal humerus. The cephalic vein is routinely taken medially to prevent inadvertent injury during retractor placement. Gelpi retractors are placed initially to assist subcutaneous exposure, and the subdeltoid space is developed. After release of the subdeltoid space, a Browne deltoid retractor (Innomed, Savannah, GA) is carefully placed under the muscle to facilitate exposure. A second Mayo stand may be used so that the arm can be placed into an abducted posture to minimize the deltoid tension. Doing so also avoids the need for an assistant to hold the arm. The clavipectoral fascia is identified and released.

The subcoracoid space is developed next, and the axillary nerve is

identified by gentle palpation at the inferior margin of the subscapularis muscle. If necessary, up to 25% of the lateral conjoint tendon may be released off the lateral tip of the coracoid to facilitate exposure. To minimize inadvertent stretch of the musculocutaneous nerve, the surgeon should avoid placing self-retaining retractors under the conjoint tendon.

The biceps tendon is palpated deep to the pectoralis major muscle. Often, fracture hematoma can obscure normal landmarks; thus, using this as a reference can assist in orientation. The biceps may be interposed in the fracture fragments and may require mobilization. Care should be taken to avoid excessive disruption and cauterization through the bicipital groove in an effort to preserve the ascending branch of the anterior circumflex humeral artery. This branch is located laterally in the groove and is the primary blood supply to the head fragment. Preoperative discovery of a fracture-dislocation should alert the surgeon

that the anatomy may also be greatly distorted. As such, great care must be taken during dissection.

When the articular segment is dislocated and stripped of all soft-tissue attachments, hemiarthroplasty is the treatment of choice. The rotator interval can be opened by following the course of the biceps tendon to its attachment at the superior margin of the glenoid. Initial attempts are made to preserve the tendon for use as a landmark for proper plate placement. However, if the biceps tendon is frayed or appears to be at risk of rupture, a subpectoral tenodesis can be performed after definitive fixation. This will eliminate a potential source of pain and prevent the possibility of postoperative rupture.

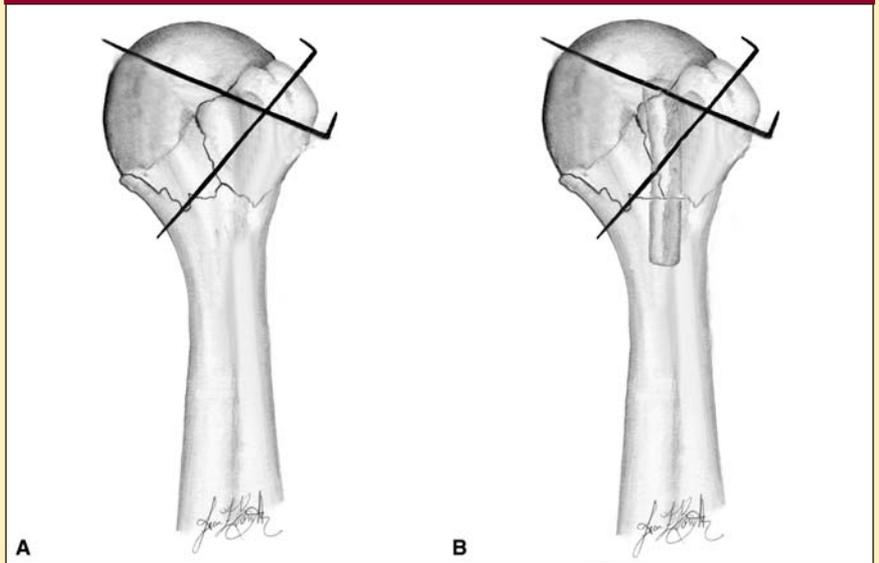
The pectoralis is not routinely released; rather, 20% of its upper border may be cut to facilitate exposure ([AOA video, 4:54-6:40](#)). In the event of a fracture-dislocation, the head is generally located anterior and medial to the glenoid along the glenoid neck. In certain circumstances,

there may be a large Hill-Sachs defect of the humeral head fragment after it is impaled on the anterior rim of the glenoid. In this situation, all releases should be performed first, including release of the pectoralis major tendon and lateral conjoined tendon as well as release of the subcoracoid and subdeltoid spaces. A key elevator or a Cobb elevator can be used to assist in prying and relocating the head fragment back into the joint. Overzealous pulling on the fragment should be avoided, to prevent inadvertent injury to the neurovascular structures lying in close proximity. When a diminished radial pulse is noted on preoperative assessment in a patient with a fracture-dislocation, it may be prudent to have a vascular surgeon immediately available at the time of fracture relocation should a vascular injury be encountered.

Fracture and Tuberosity Preparation

The overall anatomy of the fracture is identified. To mobilize the fracture fragments, a Krackow stitch is placed with a no. 2 FiberWire (Arthrex, Naples, FL) in the substance of the subscapularis. If the lesser tuberosity is a free fragment, the suture should be placed at the tendon-bone interface. Additional sutures are placed in the substance of the infraspinatus and supraspinatus or around the tendon-bone interface of the greater tuberosity if this is also a separate fragment ([AO video, 7:43-8:01](#)). The suture fixation in the cuff can then be used to mobilize the humeral head and tuberosities. These sutures will also aid in manipulation, compression, and reduction of the fracture and will ultimately help counter the natural deforming forces of the rotator cuff after they are tied to the fixed plate. To expose the shaft, the arm is taken off the Mayo stand and extended. All fracture hematoma is removed, and the canal is irrigated.

Figure 4



A, Provincial pinning of the humeral head and greater tuberosity with 2-mm Kirschner wires. **B**, Fibular strut allograft placed intramedullary for the patient with a large metaphyseal void. This helps support the head fragment.

Fracture Reduction

After adequate removal of fracture debris, the head is reduced into proper anatomic alignment. A finger can be placed through the rotator interval into the joint to assist with proper orientation. Typically, the head fragment falls into varus positioning. With the assistance of a key elevator, the head can be elevated back into proper alignment ([AO video, 8:06-8:21](#)). Typically, after elevation of the head fragment, a large metaphyseal void will exist as a result of the overall fracture comminution. In this situation, we routinely use a bulk structural allograft (ie, tricortical iliac crest graft, fibular cortical allograft) to help buttress the head fragment and prevent loss of reduction postoperatively. The graft is placed intramedullary within the shaft of the proximal canal, and the shaft is reduced as the head is impacted onto the prominent allograft. Next, a 2-mm Kirschner wire (K-wire) is placed through the upper margin of the head fragment, and the wire is driven through the articular cartilage into the glenoid to help maintain reduction of the head. Al-

ternatively, the humeral head can be pinned to the humeral shaft to help maintain reduction. The wire is bent to avoid interference with the application of the plate. Fluoroscopy is used to confirm proper head positioning. If it is unacceptable, the wire is removed, and the head is manipulated and pinned again until acceptable reduction is established.

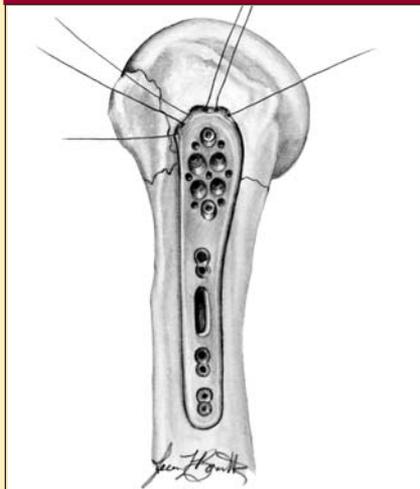
Once the humeral head is correctly positioned in the joint, the tuberosities are brought beneath the head to buttress the articular segment. The traction sutures in the front and back of the rotator cuff are used to assist in reduction of the tuberosities. The shaft is then reduced to the proximal segment and provincially held in place with a 2-mm K-wire. The overall alignment is verified with fluoroscopy. If there is a large greater tuberosity fragment, another K-wire can be placed through the posterior shoulder below the posterolateral acromion and into the tuberosity to help maintain reduction (Figure 4, A) ([AO video, 9:20-9:35](#)). The tuberosities are then reduced around the allograft (Figure 4, B) ([AO video, 8:28-9:16](#)). In situations of

Figure 5



Commonly used proximal humerus locking plates. **A**, Philos plate (Synthes, Paoli, PA). **B**, S³ plate (Hand Innovations, Miami, FL). **C**, Numelock plate (Stryker, Mahwah, NJ).

Figure 6



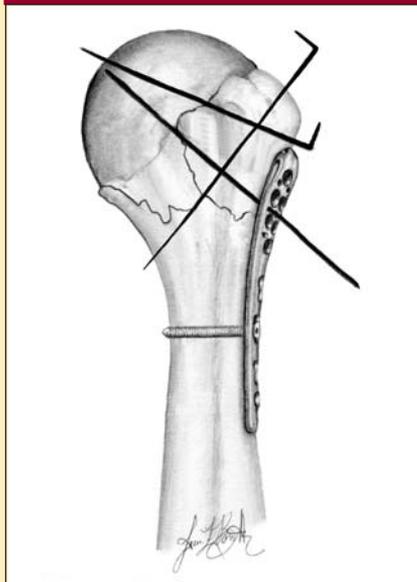
Lateral view of proper plate positioning for proximal humerus fracture. The plate is placed just posterior to the bicipital groove and 1 to 2 cm below the top of the humeral head.

extreme comminution, we strongly recommend the use of a structural allograft to fill the void that may persist. We have found this to be beneficial in maintaining postoperative alignment and preventing varus collapse of the head fragment in patients with compromised bone.

Plating

Once reduction is confirmed, an appropriately sized internal fixation plate is selected. Several locking

Figure 7



Central placement of a Kirschner wire for provisional plate fixation. The gliding hole is drilled to allow minor adjustments in plate height.

plates by various manufacturers are currently available. In our experience, design aspects important in plate selection include a low profile to minimize overhead impingement, divergent proximal locking screw options to improve fixation in the head and reduce the risk of pullout, suture eyelets on the plate that allow for stable tuberosity fixation and compression (Figure 5), and head screws that

match the anatomic neck-shaft angle of the proximal humerus. General recommendations are to position the plate just lateral to the bicipital groove, with the upper portion of the plate sitting 2 to 3 cm distal to the top of the humeral head (Figure 6) (video, 1:36-3:05; 9:40-9:49; 9:56-10:01). Most plates have a slotted gliding hole; this should be drilled first in its center to allow for minor adjustments in plate height. Typically, this shaft screw is not locking, which allows the plate to be compressed to the bone. The shaft screws generally measure 28 mm in length. The implant height is confirmed under fluoroscopy. Most plates have separate K-wire holes that allow for provisional head fixation. We most commonly use the S³ plate (Hand Innovations, Miami, FL), which is positioned appropriately when the provisional K-wire passes through the center of the humeral head (Figure 7) (video, 10:10-10:49; 11:19-11:28). The remaining proximal screw holes are then drilled and tapped through the cortex, and the appropriately sized screws are inserted while maintaining reduction of the tuberosity fragments. We prefer to hand-tap the head screw holes because it provides better tactile feedback when the tip encounters the thin cortical shell of the head. This prevents inadvertent

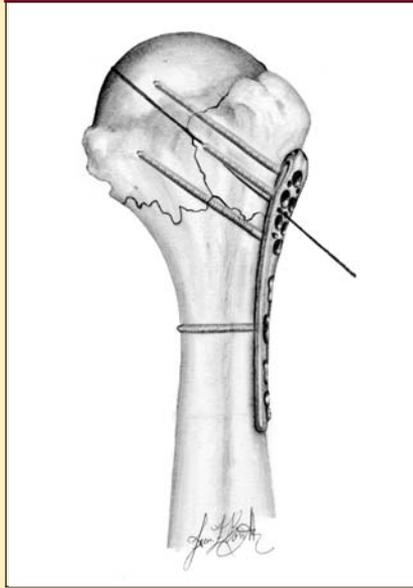
articular penetration, which can occur when using power tools (Figure 8) (video, 11:28-12:25; 12:27-12:38; 13:03-13:16).

Fluoroscopy may aid in appropriate screw sizing. With the S³ system, screws and pegs are offered for fixation of the head fragment. In general, screws are only used when treating an anatomic neck fragment in which purchase in the bony segment is critical for fixation. Otherwise, smooth pegs are preferred because of the danger of the hardware penetrating the joint if the head collapses into varus. We feel that a smooth peg would inherently cause less damage to the joint than would a threaded screw. The peg also provides a greater surface area for the head segment to rest on and can theoretically provide better support, similar to the way rebar reinforces concrete.

Tuberosity Fixation

Tuberosity fixation to the plate is the most critical step in providing overall fracture stability. Much like the principles used with shoulder hemiarthroplasty, fixation of the tuberosities to the plate helps counter the deforming forces of the contracting rotator cuff musculature. In our opinion, the high failure rate noted with traditional fixation was likely the result of the unopposed pull of the rotator cuff and, to some extent, the absence of fixed-angle screws. Although fixed-angle screws alone may be sufficient to counter these forces in young healthy bone, most proximal humerus fractures occur in patients with compromised bone. By themselves, unicortical locking screws may not provide rigid enough fixation to prevent pullout and fracture displacement.²⁷ Avoidance of tuberosity failure and ultimate fracture failure necessitates that the pull of the rotator cuff be counterbalanced via heavy suture or tape passed through the tendons or, preferably, is passed around the tendon-bone interface of the tuberosities and tied to the plate. Plates with suture eyelets at

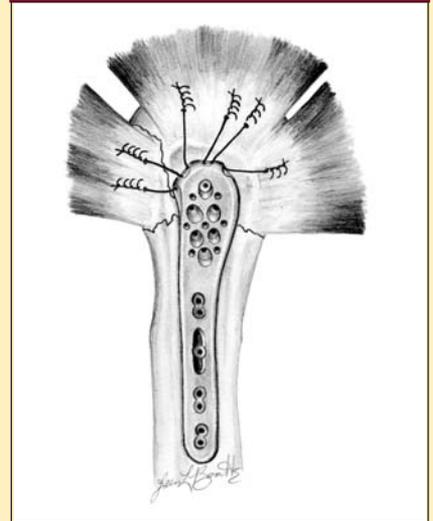
Figure 8



Humerus locking plate with proximal head screws sequentially inserted. In general, the most proximal central screw is inserted first, followed by the proximal anterior, proximal posterior, distal central, distal anterior, and distal posterior screws.

the proximal portion are advantageous in this regard for facilitating fixation. Some plates require that the sutures be passed through the eyelets before applying the plate to the bone. This can be time-consuming. Instead, we recommend the use of a plate that allows for sutures to be passed after the plate is secured to the bone. The FiberWire sutures that were previously placed through the subscapularis, supraspinatus, and infraspinatus are passed through the eyelets and secured to the plate (Figure 9) (video, 13:24-13:48; 14:12-14:21). We prefer to place at least two sutures through the posterior cuff and two sutures in the subscapularis. The remaining shaft screws are then drilled, and the appropriately sized screws are placed (video, 14:25-14:49). After tuberosity fixation, the arm is rotated to assess fracture stability, and final fluoroscopic imaging is obtained. It is critical to obtain orthogonal views during imaging to ensure that all

Figure 9



Lateral view of the proximal humerus demonstrating Krackow sutures passed through the rotator cuff and tied to the plate through the suture eyelets.

screws are appropriately sized (video, 14:52-15:09). The rotator interval is closed with a no. 2 Ethibond suture (Ethicon, Somerville, NJ) or FiberWire, and the wound is closed in standard fashion. Closure of the rotator interval is critical to avoid instability.

Postoperative Management

The patient is placed in a shoulder immobilizer. Frequently, a patient is admitted 1 to 2 days postoperatively for pain relief and for 24 hours of intravenous antibiotics. The immobilizer is strictly used for 2 to 4 weeks postoperatively, depending on intraoperative assessment of fracture stability. For stable two-part fractures with secure fixation, we often discontinue the immobilizer at 2 weeks and allow gentle pendulum and active-assisted forward elevation with the contralateral extremity. Three- and four-part fractures are usually kept rigidly immobilized for 4 to 6 weeks, with elbow and wrist range of motion encouraged. For all fracture types, formal therapy with a therapist is not

Pearls

- The patient's head should be placed at the foot of the operating table, with the head in 30° of elevation. This allows for better fluoroscopic imaging and easier fracture reduction ( **video, 15:34-16:56**).
- The fluoroscope is placed at the head of the bed, parallel with the operating room table. Good imaging should be ensured before prepping the patient.
- A second Mayo stand may be used to help support the arm and assist with fracture reduction.
- Adequate releases of the subdeltoid and subcoracoid space should be performed. Release of up to 25% of the lateral conjoined tendon and the upper border of the pectoralis major tendon can be done to facilitate exposure.
- A Browne deltoid retractor (Innomed) is vital in assisting with retraction of the deltoid and passing the sutures around the tendon-bone interface of the greater tuberosity.
- For three- and four-part fractures, the rotator interval should be released to the level of the glenoid.
- Krackow sutures should be placed in the subscapularis and infraspinatus tendons with a heavy suture, preferably a no. 5 or no. 2 FiberWire. If the tuberosities are detached fragments, the sutures should be placed around the tendon-bone interface. This allows for control of the fracture and substantially assists with reduction.
- The head is typically in the varus position, and the surgeon should use a key elevator to help reduce it into proper alignment.
- Once the head is reduced, one or two 2-mm K-wires should be passed through the upper portion of the head fragment into the glenoid to maintain proper reduction. The K-wire should be bent 90° to keep it out of the way for the remainder of the surgery.
- The surgeon should ensure that the fracture is reduced before plate application.
- The first screw placed should be in the gliding hole of the plate to allow for minor adjustments in implant height after fluoroscopic imaging. This screw is placed in compression and should be non-locking.

Pitfalls

- The biceps tendon should be identified. Devascularization and mobilization of the tendon should be avoided, unless it is entrapped in the fracture site. When possible, the surgeon should preserve the ascending branch of the anterior circumflex artery, which lies at the lateral edge of the bicipital groove. When there is significant degeneration of the biceps tendon, a subpectoral tenodesis can be performed. However, the surgeon should make every effort to keep the tendon until the plate is attached to assist with proper plate positioning.
- For a patient with compromised bone quality in which a large metaphyseal void exists after elevation of the humeral head, the surgeon should consider the use of a tricortical iliac crest graft or a fibular cortical allograft placed intramedullary in the proximal canal of the shaft. This allows for structural support of the articular head segment and reduces the risk of postoperative varus collapse.
- The greater tuberosity in an elderly patient is often a thin wafer of bone, making it nearly impossible to allow for adequate screw purchase. For this reason, heavy suture should be placed around the tendon-bone junction. The suture should be secured to the plate to allow for adequate fixation.
- The deforming forces of the muscular cuff should be counterbalanced by securing the tuberosities to the plate via heavy suture (no. 2 or no. 5 FiberWire) passed through the tendon-bone interface of the subscapularis, supraspinatus, and infraspinatus using a Krackow stitch. This will help avoid fracture subsidence and potential postoperative failure.
- The surgeon should avoid manufacturer plates that require passing of the tuberosity sutures before the plate can be secured to the humeral shaft.
- An internally rotated view of the shoulder with the arm abducted should be obtained to ensure that the posterior screws are not too long.
- To prevent early failure and allow for adequate wound healing, physical therapy should not be started too early.

begun until at least 4 to 6 weeks postoperatively, at which time passive- and active-assisted range of motion activities are initiated. Unassisted active motion is allowed at 8 weeks postoperatively or when callus formation is first noted radiographically (Figure 10). Strengthening is instituted in the last phase of therapy, typically beginning at 12 weeks.

Outcomes

The treatment of proximal humerus fractures with fixed-angled locked plating still warrants caution because of the lack of comparable data with other treatment methods. However, several recent studies have been encouraging. In a three-part fracture model, Weinstein et al²⁸ found that the locking plate provided better torsional fatigue resistance and stiffness than a blade plate. Edwards et al²⁹ noted that a locking plate was far superior to a proximal humerus nail in regard to both varus bending and torsional stability. Given that most proximal humerus fractures fail because of rotational and bending moments, such added stability could potentially prevent many of the failures noted with other implant types.³⁰

Recently, several authors have presented short-term results, with mixed outcomes. Kettler et al³¹ reported on 225 fractures treated with the Philos plate. One hundred and seventy-six patients were available for review. Complications resulting from technical error included 24 screw perforations (11%), 8 implant dislocations (4.5%), and 25 cases (14%) of initial malreduction of the head and tuberosities. Other complications included loss of reduction with secondary screw perforations in 14 cases (8%), two infections, two hematomas, partial osteonecrosis in 9 cases (5%), and complete osteonecrosis in 5 (3%). Björkenheim et al³² reported their early clinical experience of 72 patients treated with the Philos proximal humerus locking

plate. At 1-year follow-up, two nonunions were noted, and three patients developed osteonecrosis. Forty-eight patients had anatomic fracture healing. Nineteen fractures were noted to have mild postoperative settling; these subsequently healed in mild varus positioning. Traction sutures were used to aid in the initial reduction. However, the authors did not comment on whether they were tied to the plate to assist in maintaining the reduction. Patients in this study were started on immediate passive range of motion, with active motion started as early as 4 weeks. Fankhauser et al³³ reviewed their experience of 28 patients with 29 proximal humerus fractures treated with the locking proximal humerus plate. Twenty-four of these fractures were AO classification type B or type C. All fractures healed. Five complications were noted, with one broken plate and four instances of loss of reduction (one related to a deep infection). Two patients developed partial osteonecrosis, one after deep infection. In this series, traction sutures were incorporated into the plate, but active motion was initiated as early as 2 weeks. The authors did not comment on the use of bone graft. Most recently, Owsley and Gorczyka³⁴ presented their series of 53 patients treated with a locking plate with a minimum follow-up of 1 year. Nineteen patients (36%) had radiographic signs of complications, with intra-articular screw cutout in 12 (23%), varus displacement in 13 (25%), and osteonecrosis in 2 (4%). A higher incidence (43%) of cutout regardless of fracture type was seen in patients older than age 60 years. While tuberosity sutures were utilized in all cases, structural allograft was not incorporated. Furthermore, the radiographic example in the article of an "acceptable" reduction of a four-part valgus impacted fracture shows clear evidence of a malaligned construct. If this was deemed acceptable in all circumstances, this could be one ex-

Figure 10



Postoperative anteroposterior radiograph of a patient who underwent locked plating for a four-part proximal humerus fracture.

planation for their relatively high failure rate.

Summary

We believe that a reproducible standard surgical technique is necessary for improved patient outcomes. Many of the plates that are currently available provide a fixed-angle device with multiple divergent screws, but more is needed than an innovative plate design to avoid complications such as loss of reduction and screw cutout. The treating surgeon must approach a proximal humerus fracture as both a bony and a soft-tissue procedure. Other surgeons have used traction sutures, but not all have commented on their incorporation into the plate. This is a critical step that should not be skipped because it allows the deforming forces of the rotator cuff to be counterbalanced and neutralized via heavy suture that is resistant to breakage and is tied to the plate. We advocate passing these sutures around the tendon-bone interface to provide a bony buttress and prevent the stitch from pulling through the soft tissue. We routinely use a structural allograft to fill the metaphyseal void that is frequently encountered after reduction of the

fragments. In so doing, the void that would usually allow for the articular humeral head segment to collapse into varus (resulting in screw penetration into the joint) is filled, enabling the graft to buttress the head segment and minimize subsidence. Ultimately, although the fixed-angle plate is a useful tool, it is not the sole factor in providing good outcomes. Basic principles of rigid fracture fixation, structural bone graft, and strong, secure soft-tissue repair should be followed.

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