Percutaneous Plating of the Proximal Humerus

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Summary: Percutaneous plating was developed in an attempt to address the issues of humeral head necrosis associated with open reduction through an extensive approach and insufficient primary stability associated with previous attempts at limited exposure with minimal internal fixation. Our minimally invasive approach consists of 2 separate mini-incisions. The proximal incision is a direct anterolateral deltoid-splitting approach of <5 cm that exposes the humeral head and tuberosities. The distal incision of 1 to 2 cm exposes the humeral shaft and distal part of the plate. Before plate insertion underneath the deltoid, the axillary nerve must absolutely be identified and protected to prevent entrapment. The block guide attachment to the plate cannot be safely used as it stretches directly the nerve at the distal edge. With our approach, indirect reduction techniques are needed to achieve good reduction. Ideal fracture types include 2-part surgical neck fractures, isolated greater tuberosity fractures, and all valgus-type injuries. With increased experience, indications can be extended to many 3-part fractures and some 4 parts. Good outcomes can be expected if patients are well selected.

Key Words: proximal humerus fracture—percutaneous plating—minimally invasive surgery—locking plate fixation.

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INDICATIONS

General indications for surgical treatment are when fracture instability or displacement is sufficiently great that functional impairment is likely. Even among experts, controversy exists regarding the indications for fixation. Evidence-based treatment guidelines are still lacking.[1] Previous attempts at limited exposure with minimal internal fixation lead to insufficient primary stability.[2] We developed percutaneous plating of the proximal humerus to minimize soft-tissue scarring and avascular necrosis associated with open reduction through an extensive approach yet still providing stable fixation for an early range of motion.

Fractures amenable to minimally invasive fixation are as follows.

- Displaced unstable 2-part surgical neck fractures.
- Isolated greater tuberosity fracture.
- Valgus-impacted (3- or 4-part) fractures.
- Proximal third shaft fractures.

With increased experience, varus-displaced 3-part fractures and some 4-part fractures can be tackled. However, the ability to extend this approach to a full anterolateral acromial incision as described by Gardner[3] is needed to avoid suboptimal reduction.

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The authors declare that they have nothing to disclose.

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CONTRAINDICATIONS

A minimally invasive incision should not be an excuse for poor reduction. For this reason, we caution against the use of this technique for all fractures with calcar comminution, fracture-dislocations, nonunions, and malunions.

TECHNIQUE

Patient Positioning

Our preferred setup is supine on a radiolucent table with the image intensifier placed on the opposite side. This is the ideal for multiply injured patients especially if cervical spines issues complicate head positioning or if associated fractures to the extremities need simultaneous fixation without the need to reposition. The patient is positioned in a supine position on a radiolucent table with a soft bump placed behind the patient's chest. The entire upper extremity must be draped to allow free mobility for reduction maneuvers and for optimal imaging during surgery. The setup is checked before draping with the C-arm unit brought on the opposite side to ensure complete visualization of the proximal humerus including a modified axillary view (Fig. 1).

FIGURE 1. Patient positioning supine with fluoroscopy on the opposite side.

The popular beach chair position is an excellent alternative that has the advantage of facilitating conversion to a hemiarthroplasty if the fracture is unreconstuctible. Arthroplasty requires free movement with extension of the shoulder. It also offers the best way to visualize the entire shoulder (axillary view) but only if the image intensifier is placed parallel to the table at the patient's head on the injured side.

Surgical Approach

Our percutaneous plating technique allows the use of a standard locking plate but with limited disruption of the soft tissues. No special targeting device is needed. After proper positioning of the patient, we proceed with a deltoid-split anterolateral approach to access the humeral head (proximal window) and a separate mini-incision is made distally to access humeral shaft and distal part of the plate (distal window). Internal or external rotation with abduction facilitates exposure through these mobile windows.

Proximal Incision

From the anterolateral corner of the acromion, a direct anterolateral longitudinal incision is made to a maximum of 5 cm in-line with the middle of the humeral head. The subcutaneous tissue is incised, and the deltoid fascia is visualized and transected parallel to the underlying deltoid muscle fibers. The deltoid muscle fibers are bluntly split until the underlying subdeltoid bursa is exposed and incised (Fig. 3). Pulling down on the bursa with a finger from top to bottom creates a band of tissue like a "piano cord" that may be mistaken for the nerve. Blunt finger dissection is required to elevate the deltoid muscle from the proximal humerus identifying the fracture but especially the axillary nerve. The average distance from the lateral edge of the acromion to the axillary nerve is 7 cm (range, 6.2 to 8.5 cm).[4] This cord-like band is first located in the posterior aspect of the wound as it exits the quadrangular space and then runs on the undersurface of the deltoid around the humerus as it supplies the deltoid muscle. If scarring or hematoma prevents palpation of the nerve, the surgeon should consider extending the incision and directly identifying the nerve using the extended lateral deltoid-splitting approach.

Distal Incision

The distal incision is made at the deltoid tuberosity in-line with the proximal incision and needs to be centered over the distal 3 screw holes. Correct location of the second window is done with the help of the locking plate used as a template over the skin. This incision should be wide enough to allow the insertion of your finger for inspection (Fig. 2). The subcutaneous tissue and deltoid musculature are bluntly dissected. This incision is safe and well below the course of the axillary nerve.

Reduction Techniques

The key to minimally invasive surgery is the ability to obtain acceptable reduction using indirect reduction techniques. As many surgeons have emphasized, normal anatomy is not crucial to normal function in the shoulder. However, optimizing stability by achieving adequate medial support is essential to prevent loss of reduction.[5] Varus reduction also correlated with failure and should be avoided.[6] Knowledge of the deforming forces on the fracture fragments must be understood to use appropriate reduction maneuvers. Coronal

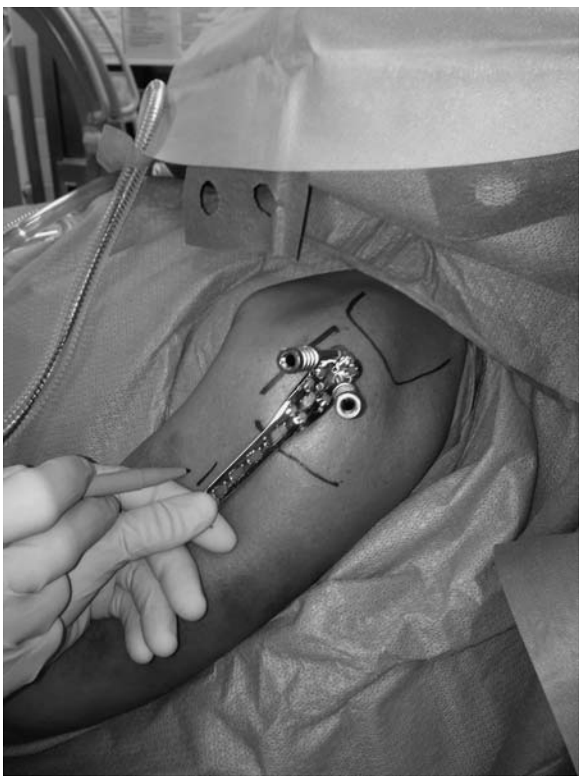

FIGURE 2. Templating the correct location of the incisions with the help of the locking plate.

FIGURE 3. Direct anterolateral deltoid split incision as the proximal window.

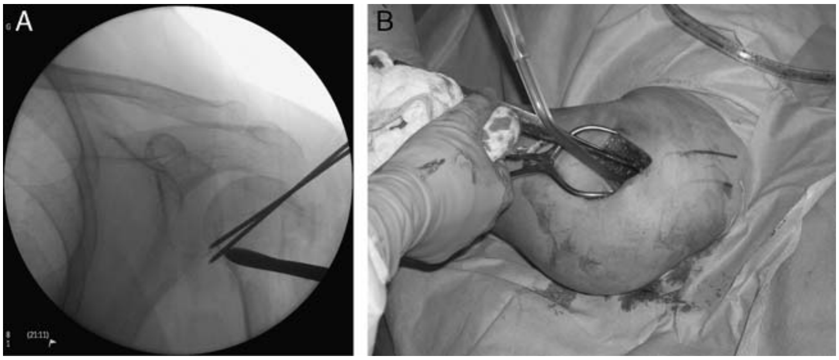

FIGURE 4. A, Clinical picture of a Cobb elevator introduced in the proximal window for indirect reduction. B, The humeral head is lifted over the shaft to attain medial calcar stability.

displacement of the proximal humerus fracture is crucial and more relevant than the numbers of parts.

Varus-type Fracture

The proximal window allows access and is used to assist reduction of the tuberosities and humeral head. The humeral head and shaft reduction is the first step whether the greater tuberosity is involved or not. The humeral shaft always assumes a position of anteromedial displacement under the influence of the pectoralis major with the humeral head assuming a retroverted position. As described for closed reduction, longitudinal traction with posterior directed force is applied to the arm to reduce the anterior apex deformity. To aid reduction, a small Cobb elevator (or a Hohmann retractor) is introduced in the fracture site anterolaterally between the overlapping fragments and tilted downwards correcting the translational displacement like a "shoehorn manoeuvre" to lift up the head over the shaft (Fig. 4). Placement of a Hohmann retractor anteromedial to the shaft may also help offset the deforming adduction force created by pectoralis major. Adequacy of the reduction is verified using the C-arm fluoroscopy. Overreduction into slight valgus is desired (Fig. 5). Once the reduction is achieved with good medial calcar contact, a K-wire can be inserted anteriorly from the shaft into the head (or from head to shaft) to temporarily stabilize the head-shaft fracture.

With the head-shaft segment reduced, the greater tuberosity fragment, if present, is the next step in the reduction sequence. The displaced fragment is found posterosuperior to the humeral head due to the external rotation and abduction

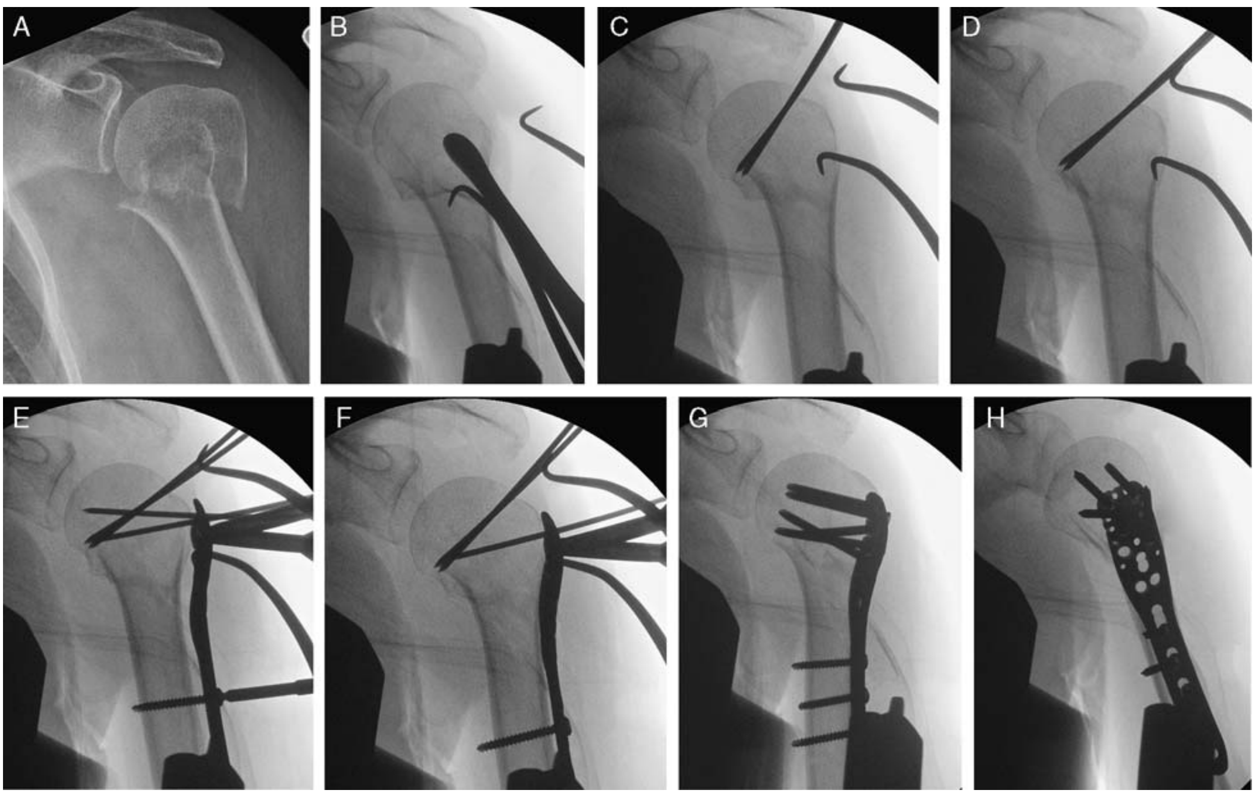

FIGURE 5. Step-by-step reduction sequence of a 2-part fracture.

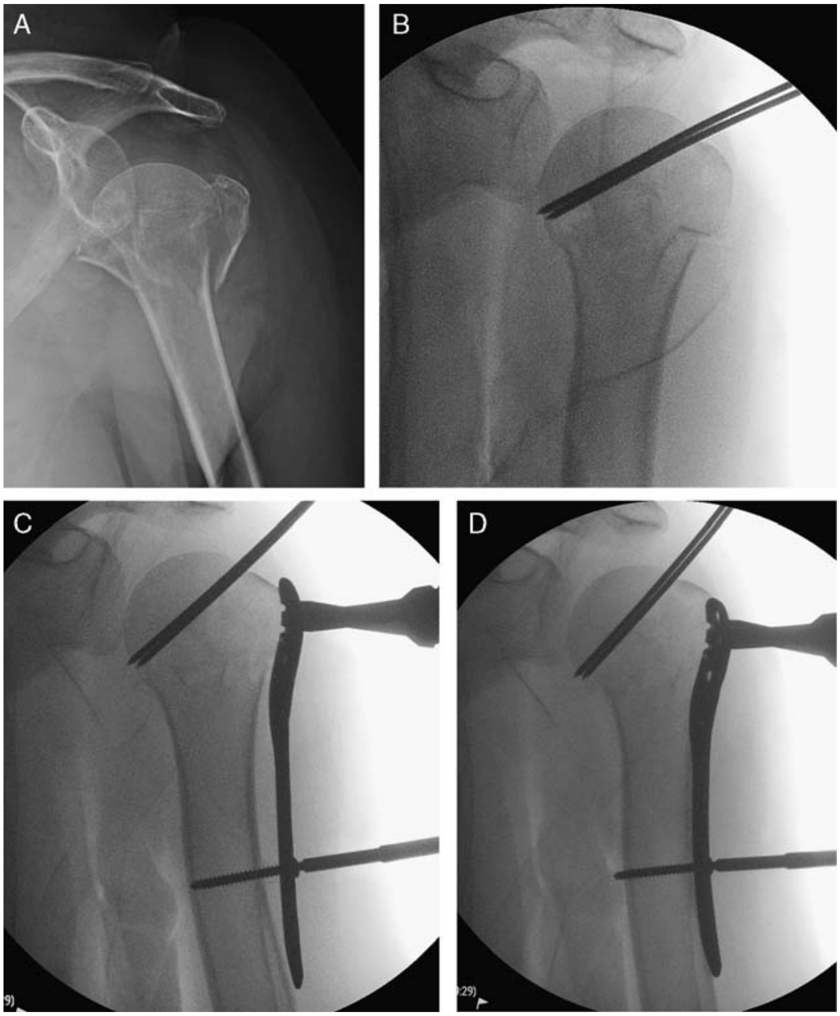

FIGURE 6. Valgus-type fracture reduction technique with plate used as a reduction tool.

imposed by supraspinatus, infraspinatus, and teres minor. External rotation and abduction of the arm is needed during this reduction technique. The greater tuberosity is caught with a Kocher forceps and pulled forward into the proximal window. Provisional sutures are useful in the cuff to help control and manipulate this fragment back to its space. It is then held with provisional K-wires directed away from future plate placement. We always secure the rotator cuff attached to the greater and lesser tuberosity fragment with nonadsorbable fiberwire sutures before plate insertion.

Valgus Type

A valgus-impacted fracture is reduced by applying a medial force to the superior-lateral aspect of the humeral head using the medial soft tissues as a hinge. Precaution is needed to maintain the intact medial soft-tissue attachment often found between the humeral head and shaft. Several instruments can be used such as a blunt dissector but after disimpaction, we usually prefer using our thumb for gentle elevation of the articular fragment onto the glenoid surface template. Once the humeral head is reduced to 130 degrees of head-neck angle, the greater tuberosity is pulled out from the posterior aspect of the shoulder and brought back into its bed, after which it serves to maintain reduction of the humeral head. Valgus alignment should be slightly underreduced at this point. High-density sutures are then added to secure the greater tuberosity.

Final reduction of the residual valgus is accomplished with the use of an anatomically contoured plate to buttress the humeral head. The plate is used as a reduction tool to push on the greater tuberosity in the defect optimizing its stability (Fig. 6). Through the distal window, a conventional 3.5-mm screw or a push-pull device is tightened slowly to bring the diaphysis in close contact with the plate. The length of this screw needs to be long enough to catch the far cortex and should be exchanged for a shorter one later on. The plate may slide on the diaphysis in the sagittal plane during this indirect reduction technique. Adding a K-wire (or a second cortical screw) in a distal hole will prevent rotation.

Plate Insertion

During plate insertion, care is taken to keep the plate directly along the bone to prevent trapping the axillary nerve under the plate. The *first step* is to identify the axillary nerve and to protect it from entrapment by positioning the surgeon's finger on the nerve during insertion of the plate on the proximal humerus (Fig. 7). If the nerve is not palpated, a separate deltopectoral approach or an extended anterolateral acromial should be used. Futhermore, the attachable insertion guide

FIGURE 7. During plate insertion, the surgeon's finger protects the axillary nerve to avoid entrapment.

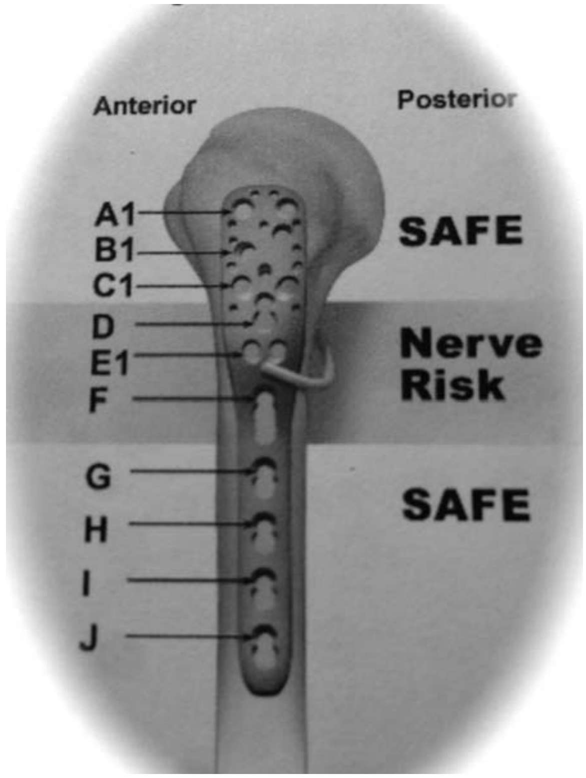

FIGURE 9. Safe zones for screw insertion to prevent nerve injury.

block cannot be safely used because the distal edge impinges directly on the axillary nerve when insertion is percutaneous (Fig. 8). Our preferred implant is a 5-hole Synthes (Paoli, Pennsylvania) 3.5-mm locking compression plate proximal humerus plate. Two 3.5-mm locking screw sleeves are anchored into the proximal holes to perform as a handle to aid with insertion. Similar low-profile, precontoured, locking plate with multiple screw options can also be used. Plates with targeting devices are available to facilitate distal screw insertion but are quite bulky and limit the access to fingers (tactile inspection).

FIGURE 8. Threaded locking guides are preferred and used as a handle for insertion. Caution against the use of the Block guide attachment that causes stretching of the nerve.

The plate is positioned on the proximal lateral humerus with the inherent angulation of the plate sitting at the inferior portion of the greater tuberosity. To prevent acromial impingement, the plate should sit at least 5 mm lower than the greater tuberosity. To control the articular fragment, 2 joysticks (2-mm K-wires) are inserted starting medial to the greater tuberosity getting purchase in the articular fragment. Once satisfactory plate placement is attained, the proximal fracture fragments are provisionally fixed by placing K-wires or a fully threaded cancellous screw through any one of the proximal humeral head screw holes and into the humeral head.

Definitive Plate Fixation

Readjustment or fine-tuning the humeral head position is still possible at the point with the K-wires fixed in the articular fragment. Spending a few more minutes to dial out any residual varus is crucial. Tactile verification through both incisions and fluoroscopy must be used to confirm the plate position on the shaft and lateral surface of the head before proceeding to definitive fixation. Incorrect placement of the plate to far anteriorly on the humeral head and residual apex anterior angulation are common pitfalls to remember. With a deltoid-splitting approach, the plate should sit on the lateral surface and not the usual anterolateral surface close to the bicipital groove recommended for the deltopectoral approach.

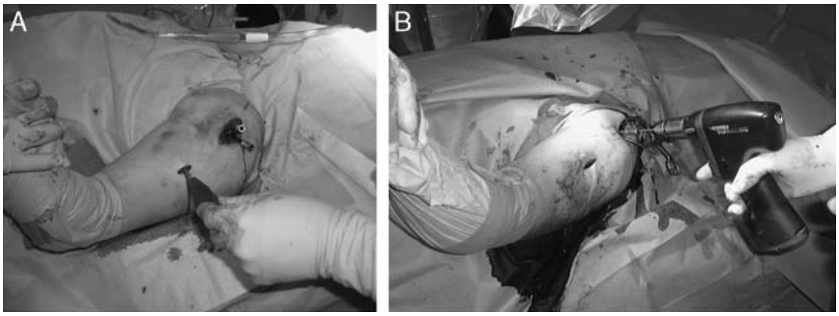

FIGURE 10. A, Definitive fixation with locking screws proximally. B, Cortical screws distally.

The *second step* to prevent axillary nerve injury is to fix the plate with screws positioned in the safe zone as determined by the anatomic study of Smith and colleagues. The most proximal 6 holes (A, B, C) and 4 most distal screws (those distal to the slot hole) pose little danger to the axillary nerve (Fig. 9). In the proximal window, a minimum of 4 locking screws are inserted and tightened sequential. Additional screws should be added in osteopenic bone with shorter screw length to allow settling of the fracture (Fig. 10A). Abduction of the arm offers better visualization through this mobile window especially for the screw in row D. In the distal window, three 3.5-mm conventional screws that usually measure 26 to 28 mm are used to secure the plate distally. In osteopenic bone with thin cortices, one 3.5-mm locking screw may be added to protect the cortical screws from shear forces (Fig. 10B).

The most common pitfall with the use of locking plates in the proximal humerus is that screw penetration can be easily missed at the time of surgery. To prevent the severe morbidity of such a complication, we recommend (Fig. 11) the following.

(1) Exceptional vigilance while placing subchondral head screws using fluoroscopic imaging throughout a full range of motion. Every screw needs to be verified one by one, especially the divergent screws in the third row.
(2) Tap drilling to enhance proprioceptive feedback and to avoid damage to the subchondral bone. In osteopenic bone, we drill the proximal cortex and then use the depth gage

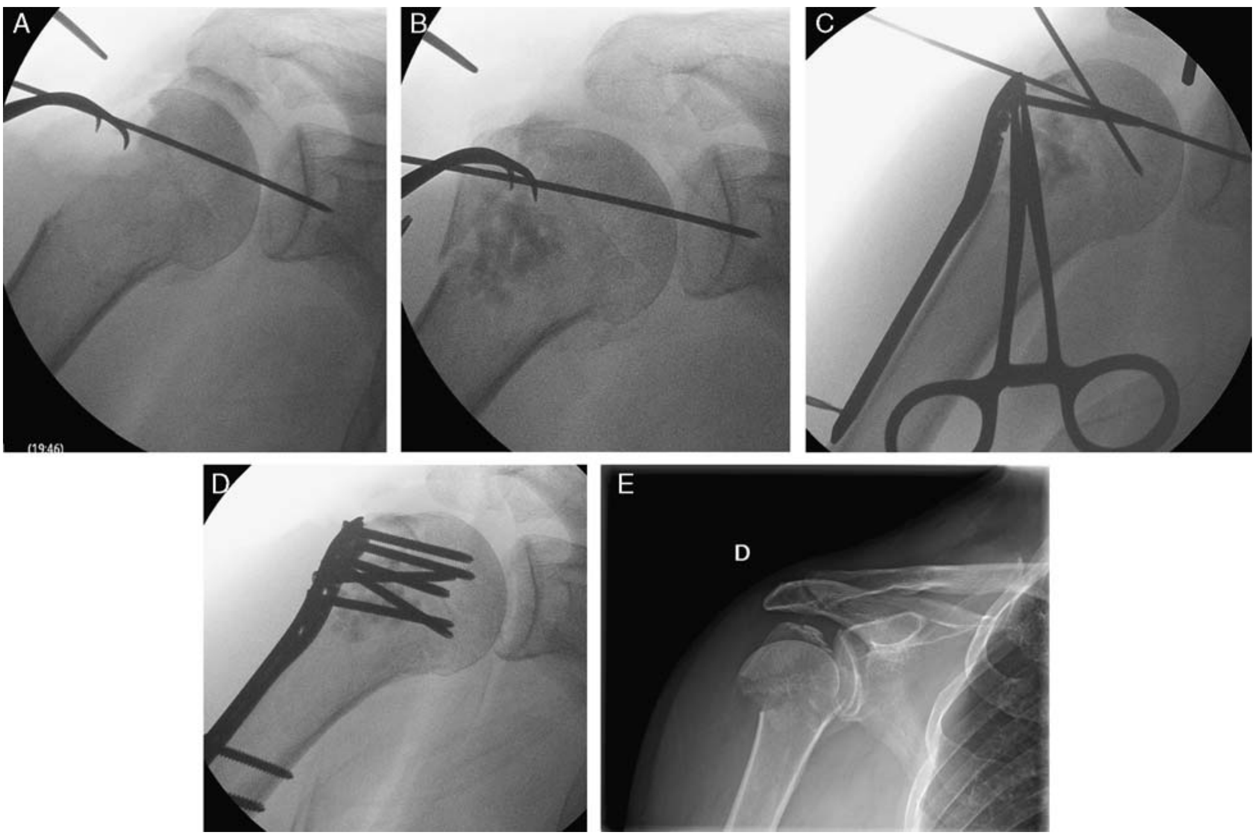

FIGURE 11. Case example of a valgus fracture type with a multitude of shorter locking screws to minimize joint perforation and screw cut-out with fracture settling during healing period.

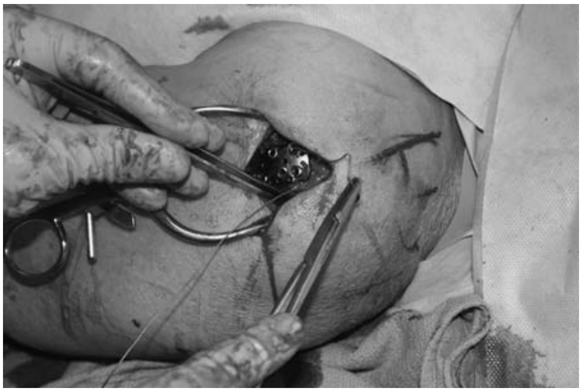

FIGURE 12. Suture augmentation.

with a twisting motion to advance up to the subchondral bone eliminating the risk of joint perforation.

(3) Shorter screws by subtracting 3 to 5 mm from the measured screw length allowing some fracture settling. Additional screws can be use to compensate for reduced stability.

(4) After surgery, fracture collapse can also lead to screw penetration. Optimizing stability by achieving adequate medial support and avoiding varus is essential (Fig. 11).

FIGURE 13. Clinical picture of a patient's scars.

Once fixation is stable, live fluoroscopy with full rotation confirms the correct placement and length of each screw. All temporary fixation devices are carefully removed and/or replaced. Tension-band sutures around both tuberosity fragments are anchored to the plate holes (Fig. 12). The deltoid fascia and subcutaneous tissues are repaired with a nonadsorbable suture, and the skin edges reapproximated with staples or a running subcuticular stitch (Fig. 13). A sterile dressing is applied, and the arm placed in a sling.

Rehabilitation Protocol

Patients are started on immediate postoperative active range of motion of the shoulder and elbow. A standardized protocol begins with pendular exercises and then active-assisted exercises until clinical and radiographic evidence of healing. At this point, the addition of strengthening and proprioception exercises is allowed which typically takes about 8 to 12 weeks.

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