5 Points on
Locking Plate Fixation for Proximal Humerus Fractures

Scott D. Pennington, MD, and Xavier A. Duralde, MD

Proximal humerus fractures are the third most common fractures in the elderly[1] and may pose complex reduction and fixation problems for surgeons. New surgical techniques and locking plate technology can provide consistently good results for these complex fractures.[2]

Most proximal humerus fractures are minimally displaced or nondisplaced and stable, and thus amenable to nonsurgical management.[3] Over 80% good and excellent results have been cited with closed management of these minimally displaced fractures.[4] Multiple fixation techniques are available for the treatment of displaced fractures, including suture fixation,[5] percutaneous pins,[6,7] nonlocking plates,[8] intramedullary rods,[9] and locking intramedullary rods.[10] Although each technique has significant complications, the myriad of fixation devices exemplifies the absence of a gold standard. Several recent short and midterm studies have demonstrated the efficacy of proximal humerus locking plate fixation.[2,11-13]

Surgical management of displaced proximal humerus fractures is challenging because of biological and biomechanical factors. Fracture fragments are subject to the unopposed pull of the muscles attached to them. Multiple deforming forces act on fracture fragments; the resulting displacement depends on fracture configuration.[14] The humeral shaft is pulled medially and is internally rotated by the pectoralis major, producing a typical valgus and anteriorly angulated deformity at the surgical neck of the humerus. The supraspinatus and infraspinatus tendons produce an external rotation moment on the greater tuberosity that often displaces posteriorly and medially or even superiorly depending on the tuberosity portion involved. The subscapularis tendon rotates the humeral head internally if the greater tuberosity detaches, as is seen in 3-part proximal humerus fractures. In contrast to the lower extremity, the humerus is subject to distraction forces from the weight of the arm that tend to create gapping in fractures of the proximal shaft.

The proximal humerus has a rich but tenuous blood supply.[15] The anterior humeral circumflex artery is a branch of the axillary artery and becomes the arcuate artery as it travels up the bicipital groove to supply blood flow to the anterior humeral head. The posterior humeral circumflex artery supplies blood to a small portion of the posteroinferior humeral head. The anterior humeral circumflex artery supplies about two-thirds of the blood flow to the humeral head,[16] and recent studies have demonstrated the importance of the medial periosteum to humeral head perfusion.[3] Fractures that damage the vessels that supply the principal blood flow to the humeral head or significantly disrupt the medial periosteum may result in humeral head avascular necrosis even if adequate bony fixation can be obtained acutely. Surgical techniques that further damage this blood supply increase the chance of avascular necrosis.

The rising incidence of osteopenia in the elderly population[17] is directly related to the increase in proximal humerus fractures. This same osteopenia challenges the ability to achieve stable internal fixation. Fixation to the shaft of the humerus is relatively reliable, as a longer plate can always be used in cases of poor bone quality. Bicortical fixation is not an option in the articular fragment of these fractures, as screws cannot penetrate the articular surface without severely damaging the glenoid.[18] Proximal fragment fixation, therefore, has always been the challenge in the management of proximal humerus fractures.

The ideal form of fixation for proximal humerus fracture, then, is one that neutralizes the deforming forces created by the various tendon insertions, does not further disrupt the somewhat tenuous blood supply, and obtains stable fixation in osteoporotic bone even in a situation in which bicortical fixation is not an option. Through its design, the periarticular locking plate has increased the orthopedic surgeon's ability to achieve these goals.[19]

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The surgeon can use a variety of fixation options to manage fractures that require open reduction and internal fixation (ORIF). Increasing use has been noted in the literature for suture anchor fixation,[20] locking plates,[21] locking rods,[10] and percutaneous pins with cortical fixation.[22] Decreasing use has been reported with wires and isolated sutures, nonlocking rods, conventional plates, and nonlocked pins.[23] The results of humeral head replacement depend on greater tuberosity healing, which unfortunately is not reliable.[24] The reverse total shoulder prosthesis is indicated in cases of severely comminuted 3- and 4-part fractures in elderly patients, especially in cases of preexisting cuff deficiency.[25] Locking plates discussed here are generally indicated in 2-part surgical neck of humerus fractures (Neer classification), 3-part fractures, and 4-part fractures. These same fracture patterns have been successfully treated with percutaneous pins and locking rods.

In this article, we offer technical advice for using the proximal humerus locking plate to optimize management of these fractures.

1 Locking plates have increased the indications for ORIF of proximal humerus fractures

Numerous deforming forces, vulnerable blood supply, and poor bone quality have limited the success of previously available treatment options in the management of certain proximal humerus fractures. Compression plates, percutaneous pins, and intramedullary rods typically have been recommended for the treatment of displaced 2-part surgical neck fractures and 3-part fractures in patients with good bone quality—for example, patients younger than 65 years and without risk factors for osteoporosis, such as chronic corticosteroid use. Poor bone quality presents a challenge to percutaneous pin fixation and can result in pin migration because of poor purchase.[22] Proximal fixation remains the principal challenge for intramedullary nails.

In conventional compression plating, stability is achieved by the compression produced by the screw between the bone and the plate. This construct allows the fracture to be reduced to the plate by the screw but also compromises the periosteal blood supply beneath the plate. There is no stout interdigitation between plate and screws that can lead to toggling if bone quality is poor. This construct does not provide angular stability to counteract rotational deforming forces, such as the pull of the rotator cuff (**Figures 1A, 1B**).

By contrast, in the locking plate construct, the screws, which are threaded, go into the plate and "lock" into place to create a fixed angle between screw and plate.[16] This provides angular stability and does not allow the plate to be compressed to the bone, protecting the periosteum beneath the plate. The screws are typically placed in a diverging or converging pattern so that a traction force on the fixed bone is resisted by all the bone behind the screw, not just the bone around the screw threads.

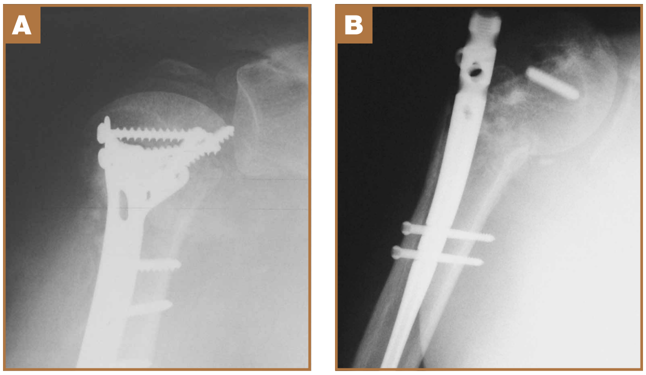

Figure 1. (A) Humeral head valgus collapse following traditional compression plating. (B) Varus collapse and loss of fixation following intramedullary nailing.

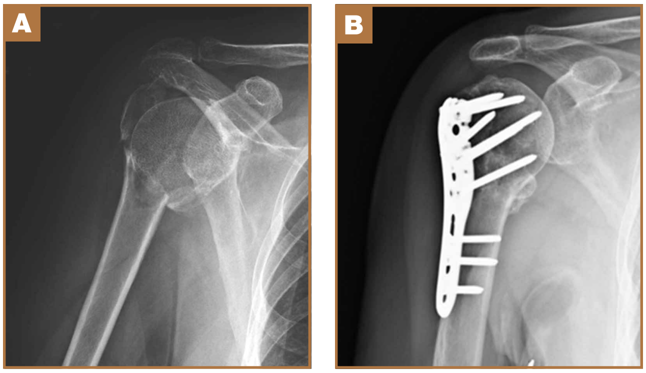

Figure 2. (A) Comminuted 3-part surgical neck of humerus fracture. (B) Anatomic alignment and union obtained with locking plate fixation.

Two particular fracture patterns that once presented such a fixation challenge are 3-part fractures in elderly patients with poor bone quality and 4-part impacted fractures, which involve significant crushing of metaphyseal bone. Previously recommended treatment included use of a humeral head replacement (HHR) to address the common problem of fixation failure. The outcomes of HHRs, however, are unreliable, often limiting function to below shoulder level.[26] In contrast, the proximal humerus locking plate has demonstrated reliable healing rates in these fracture patterns.[27-29] We have used such fixation even in rheumatoid patients on maintenance corticosteroid therapy, without loss of fixation (**Figures 2A, 2B**).

2 This surgery can be safely and effectively performed through a deltopectoral approach

The deltopectoral approach to the shoulder is a standard "workhorse" approach surgeons are very comfortable with. In the treatment of proximal humerus fractures,

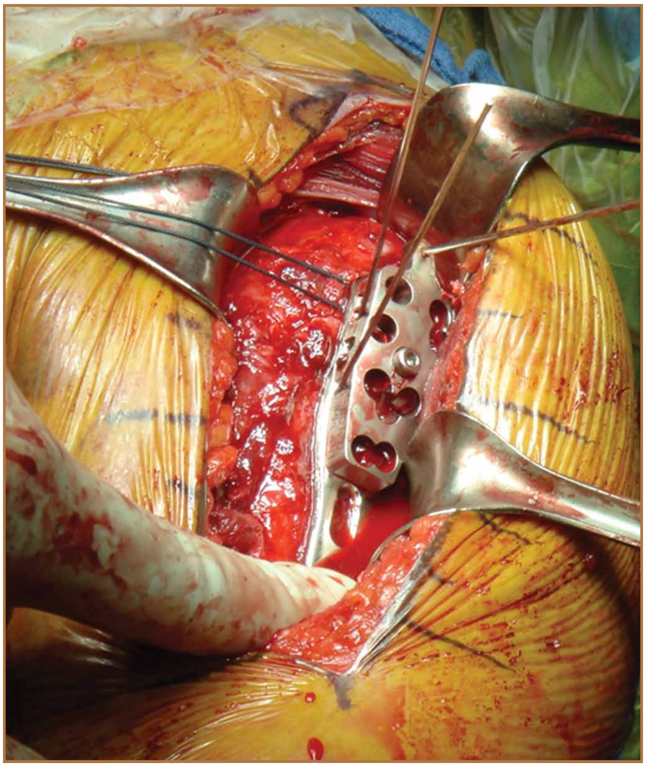

Figure 3. Heavy braided polyester suture is used as traction suture to hold the proximal humerus in internally rotated position to allow easy application of the plate to the humerus lateral to the bicipital groove.

it offers multiple advantages. There is no need to dissect any vascular structures, so it does not further compromise fracture healing. It does not weaken the deltoid by violating its origin or insertion. Last, it does not put the axillary nerve at risk, as occurs in deltoid muscle-splitting approaches.

The challenge of using this approach is that the locking plate must be placed lateral to the bicipital groove, and the deltopectoral approach leads to the anterior humeral shaft. The fracture does not allow the proximal fragments to be controlled by rotation of the humeral shaft. The solution is to control the proximal fragments with heavy sutures placed in the subscapularis and infraspinatus tendons and use these sutures to rotate the proximal humerus. Medial traction placed on the infraspinatus tendon suture helps with fracture reduction in 3- and 4-part fractures. Once the proximal portion of the fracture has been reduced and temporarily fixed with sutures, medially directed traction on the infraspinatus tendon suture internally rotates the proximal humerus and exposes the lateral aspect of the greater tuberosity to the surgeon to allow easy application of the plate posterior to the bicipital groove (**Figure 3**). We typically use a No. 5 braided polyester suture and have an assistant across the table apply the traction. The plate is placed directly on top of this suture. After final plate application, this suture can be either cut or tied to the subscapularis suture to reinforce proximal fixation of the tuberosities.

3 Adequate reduction maneuvers are necessary before plate application

In contrast to compression screws, locking screws do not assist in fracture reduction. We use a single compression screw when applying the locking plate. After the plate is well fixed to the proximal humeral segment, the compression screw is placed through the plate into the humeral shaft to reduce the shaft to the humeral head. All other screws are locking screws. Therefore, fractures that involve the tuberosities and humeral head must be reduced and temporarily fixed before plate application. The 3 following reduction strategies, *lever, derotate,* and *elevate,* are required to achieve this goal.

Two-part surgical neck fractures—lever

The majority of 2-part surgical neck fractures occur with anterior and medial displacement of the proximal shaft because of unopposed pull by the pectoralis major tendon. In these cases, reduction is straightforward. More challenging are 2-part impacted varus fractures of the surgical neck. Significant angulation of this fracture leads to relative prominence of the greater tuberosity, impingement, and limited range of motion. Plate application without reduction on this inherently stable fracture does not benefit the patient. Reduction of this fracture without significant soft-tissue dissection is a challenge.

Reduction of varus impacted surgical neck fractures is best achieved by placing plate and screws in an appropriate position relative to the humeral head and tuberosities and then levering the plate to reduce the head relative to the shaft (**Figures 4A, 4B**). Degree of angulation of the proximal humerus relative to the shaft can be evaluated on

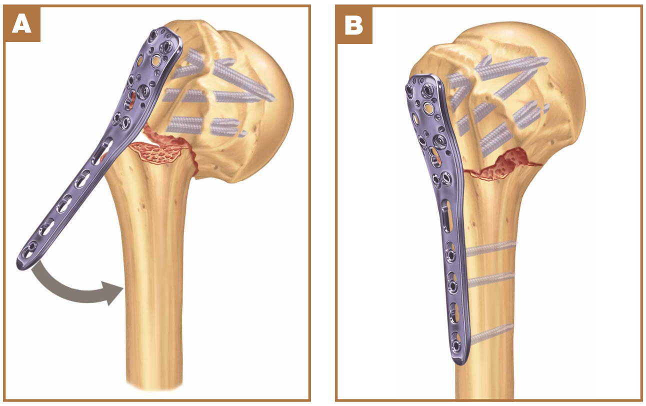

Figure 4. In varus impacted 2-part proximal humerus fractures, (A) the plate is fixed to the head fragment and is then (B) used to lever the head into reduced position relative to the shaft. Reprinted from *Journal of Shoulder and Elbow Surgery*, vol. 19, issue 4, Xavier A. Duralde and Lee R. Leddy, The results of ORIF of displaced unstable proximal humeral fractures using a locking plate, pages 480–488, Copyright 2010, with permission from Elsevier.

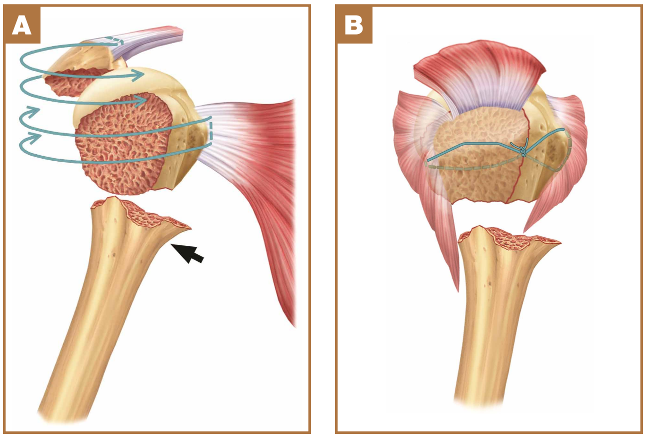

Figure 5. (A,B) In 3-part proximal humerus fractures, sutures are used to derotate and reduce tuberosities to each other, and the plate is then applied. Reprinted from *Journal of Shoulder and Elbow Surgery*, vol. 19, issue 4, Xavier A. Duralde and Lee R. Leddy, The results of ORIF of displaced unstable proximal humeral fractures using a locking plate, pages 480–488, Copyright 2010, with permission from Elsevier.

preoperative radiographs and intraoperative fluoroscopy. After adequate fixation with at least 5 divergent locking screws in the head has been obtained, the plate is used as a "crowbar" to lever the humeral head and reduce the head to the shaft. The first screw placed in the shaft, a compression screw, facilitates this reduction, and the other screws in the shaft are locking screws.

Three-part proximal humerus fractures —derotate

In 3-part proximal humerus fractures, the greater tuberosity typically is displaced from the fragment containing the humeral head and attached lesser tuberosity. The unopposed pull of the subscapularis internally rotates the head fragment while the rotator cuff pulls the greater tuberosity posteriorly and medially. There is a variable amount of comminution in these cases. This deformity must be "derotated" to regain alignment. This is accomplished by placing heavy traction sutures into the infraspinatus tendon and the subscapularis tendon. The fracture is reduced by pulling medially on the greater tuberosity fragment and laterally on the lesser tuberosity fracture (**Figures 5A, 5B**). The reduction is checked fluoroscopically, and cancellous allograft is used to reestablish the normal contour of the greater tuberosity. The amount of bone graft required varies from case to case. A reduction suture is placed in figure-of-8 fashion between the tuberosities, as described by Gerber and colleagues.[30] This is typically a No. 5 braided polyester suture or a No. 2 FiberWire suture (Arthrex, Naples, Florida). The suture is tied to achieve temporary fixation of the tuberosities to each other and is checked fluoroscopically. The 3-part fracture has now been converted to a 2-part fracture. Kirschner wires are not required. The plate can now be applied to the proximal fragment directly over the reduction suture and fixed to the head in routine fashion, as previously discussed.

Impacted 4-part proximal humerus fractures—elevate

As the name indicates, in these factures the humeral head is impacted down onto the shaft, creating a neck–shaft angle typically of 90° with outward displacement of the tuberosities. As in the case of 3-part fractures, the fracture line between the tuberosities occurs just posterior to the bicipital groove. Significant crushing of the metaphyseal bone has occurred. Reduction is obtained by elevating the humeral head through the fracture site. The tuberosities are reduced by ligamentotaxis when the humeral head is elevated. The glenohumeral joint capsule is not opened. The medial retinaculum must be intact for this technique to work, and this technique may not be effective in nonimpacted fractures in which the head has translated laterally more than 6 mm relative to the medial calcar. The intact medial retinaculum creates a stable pivot point for the humeral head to help reestablish the normal neck–shaft angular alignment. It is also a crucial source of blood supply to the humeral head and accounts for the low rate of avascular necrosis in this group despite the displacement of the greater tuberosity. The greatest challenge with this

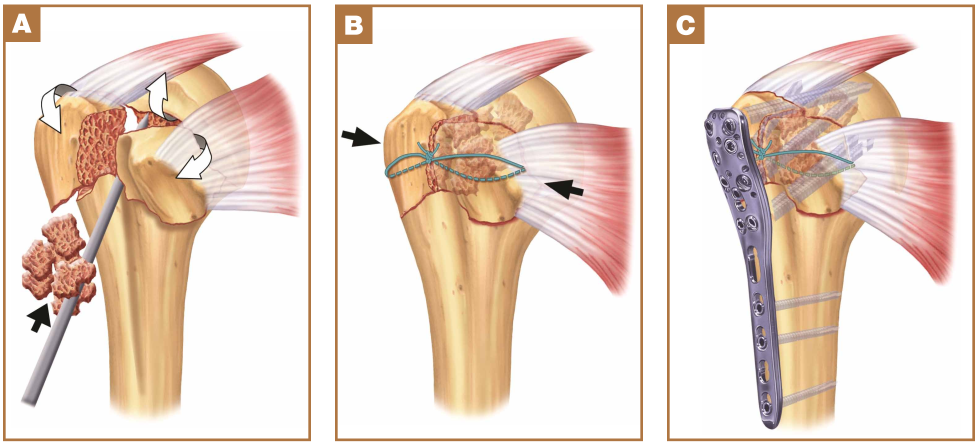

Figure 6. In impacted 4-part fractures, (A) the head is elevated, (B) bone graft is inserted into the void, (C) and the plate is then applied. Reprinted from *Journal of Shoulder and Elbow Surgery*, vol. 19, issue 4, Xavier A. Duralde and Lee R. Leddy, The results of ORIF of displaced unstable proximal humeral fractures using a locking plate, pages 480–488, Copyright 2010, with permission from Elsevier.

reduction technique is adequate reduction of the lesser tuberosity relative to the humeral head. Direct palpation of this fragment with digital reduction through the fracture site can facilitate this step. The reduction is confirmed fluoroscopically. A large void is noted in the impaction area and must be bone-grafted to support the humeral head and tuberosities. After bone grafting, the tuberosities are fixed temporarily with a figure-of-8 suture, as described for 3-part fractures (**Figures 6A–6C**). The plate is then applied, and the proximal humeral fragment fixed to the shaft.

4 Bone grafting is crucial to the success of ORIF of proximal humerus fractures

Multiple fracture patterns about the proximal humerus are associated with comminution. After adequate reduction of these fractures, a bone defect is often present. The defect weakens the overall construct and transfers increased stress to the hardware. Medial calcar comminution can occur in 2- and 3-part fractures.[31] A large bone defect is also seen between the humeral head and tuberosities after reduction of an impacted 4-part fracture. A significant varus-deforming force is created by the rotator cuff and can lead to varus collapse if the medial calcar is not adequately restored. Joint compression forces created by the rotator cuff can similarly lead to valgus collapse of the humeral head if the metaphysis is not supported by bone graft after reduction of impacted 4-part fractures. Failure manifests as either screw cutting out from the head or as plate fracture. These complications were commonly reported in earlier series but did not occur in our series of 21 cases, in which bone grafting was routinely used.[2] In the majority of displaced proximal humerus fractures, the soft-tissue envelope is relatively intact and contains the bone graft. As a result, well-packed cancellous allograft or autograft adequately supports the reduction, and structural bone graft is not necessary.

For 2-part impacted fractures, the cancellous bone is packed at the surgical neck site through the fracture site before reduction of the head fragment to the shaft. The intact medial periosteum and retinaculum hold the graft in proper position. In 3-part fractures, the bone graft is placed between the greater tuberosity fragment and the humeral head before the reduction suture is tied between the tuberosities. In 4-part impacted fractures, the bone graft is placed into the void beneath the humeral head through the intertubercular fracture line (**Figure 7**). This last technique is similar to management of plafond fractures of the distal tibia, in which bone graft helps support the articular surface. Again, the intact soft-tissue envelope maintains the graft in place and prevents collapse of the humeral head.

In cases of severe medial calcar comminution or severe osteoporosis, use of an intramedullary fibular strut graft can be considered. With minimal trimming, this graft can be fashioned to fit snugly inside the intramedullary canal of the proximal humeral shaft. Graft protruding proximally can be trimmed to support the humeral head without distracting the fracture site. The intramedullary portion of this graft also enhances screw–plate fixation.[32]

None of these bone-grafting maneuvers requires any soft-tissue dissection, so the blood supply to the humeral head is not further compromised. The improvement in structural integrity created by this bone graft decreases the stress on the hardware and decreases the possibility of hardware fracture or screw cutout.

5 Beware medial calcar comminution and varus collapse

Varus collapse is a commonly reported complication of locking-plate ORIF of proximal humerus fractures.[31] The combination of varus-deforming forces caused by pull of the rotator cuff muscles and associated medial calcar comminution can lead to varus failure. Appropriate strategies to prevent this complication of varus collapse include maneuvers to neutralize the deforming force created by the pull of the rotator cuff tendons as well as maneuvers to reestablish support of the medial calcar. For neutralization of the pull of the rotator cuff, heavy braided nonabsorbable sutures are placed between the cuff tendons and holes in the proximal plate. This construct transfers the forces created by the cuff tendons to the plate, directly bypassing the humeral head. Sutures are placed from the supraspinatus and infraspinatus tendons to the plate (**Figure 8**).

One method of calcar support has already been mentioned: placement of cancellous or cortical strut bone graft in comminution areas. Another technique involves placement of locking screws into the inferior humeral head and calcar to support this area in cantilever fashion. These particular screws are not required in all cases but are

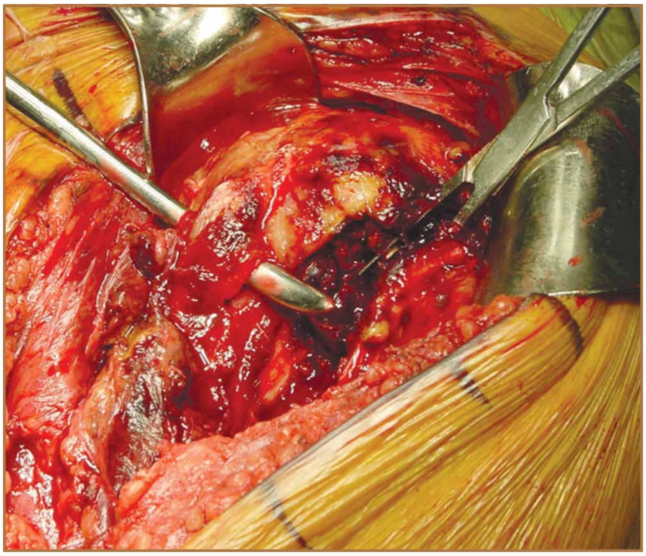

Figure 7. Bone graft is inserted through the intertubercular fracture line, which is typically just posterior to the bicipital groove.

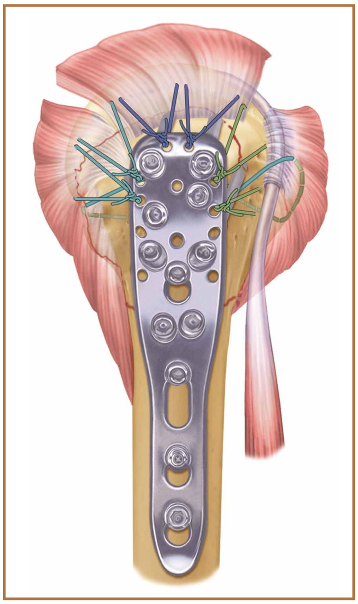

Figure 8. Varus traction forces created by the rotator cuff on proximal fragments are neutralized by sutures placed between cuff tendons and the plate. Reprinted from *Journal of Shoulder and Elbow Surgery*, vol. 19, issue 4, Xavier A. Duralde and Lee R. Leddy, The results of ORIF of displaced unstable proximal humeral fractures using a locking plate, pages 480–488, Copyright 2010, with permission from Elsevier.

Figure 9. In cases of medial calcar comminution, additional screws must be placed to support the inferior humeral head in cantilever fashion.

crucial in fractures with medial humeral calcar comminution (**Figure 9**).

Conclusion

In summary, locking plates have increased the indications for ORIF of proximal humerus fractures because they adequately neutralize the multiple deforming forces encountered, obtain adequate fixation even with poor bone quality, and can be applied without further damaging the humeral head blood supply. The principal fractures added to the list of indications for ORIF include 3-part fractures in elderly patients with poor bone quality and 4-part impacted fractures.

This surgery can be performed safely and comfortably through a deltopectoral approach, decreasing the chance of axillary nerve injury. Traction sutures in the rotator cuff tendons assist in rotating the proximal humerus to facilitate plate application posterior to the bicipital groove.

The locking plate does not assist in fracture reduction the way that compression plates do, so the surgeon must use techniques appropriate to the fracture pattern. The 3 described here are levering (for 2-part varus impacted fractures), derotation (for 3-part fractures), and elevation (for 4-part impacted fractures).

Bone grafting is crucial to the success of this procedure, as it reestablishes the soft-tissue envelope and supports the bony fragments against collapse. Bone grafting can be performed through the fracture site without further soft-tissue dissection.

Medial calcar support with neutralizing rotator cuff sutures, bone graft, and screw placement is essential to avoid the commonly described complication of varus collapse. The principles and surgical pearls discussed in this article should help the surgeon obtain excellent bony alignment, fixation, and healing of these complex fractures.

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