Fixation Strategies to Prevent Screw Cut-out and Malreduction in Proximal Humeral Fracture Fixation

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Fixation of proximal humerus fractures with pre-contoured, fixed angle devices has improved operative management of these difficult injuries, particularly in osteoporotic patients. However, recent data has revealed that fixation with these constructs is not without complication, particularly screw cut-out and loss of reduction. Multiple strategies have been developed to decrease complications. We offer a surgical technique combining suture augmentation of the proximal humerus with locked plate fixation utilizing short screws. Our series utilizing this technique has resulted in no patients with screw cut-out and limited patients with loss of reduction.

While locking plate constructs have shown promising results in the treatment of displaced and unstable proximal humerus fractures[1-3], the use of the this technique has not been without complications[3-5]. Described complications include malreduction, malunion, plate impingement, stiffness, and avascular necrosis of the humeral head. Recent studies evaluating the outcomes of patients treated with locking plates for proximal humerus fractures have shown that one of the most frequent complications of this technique is intra-articular penetration of the locking screw[3-5].

This article describes and illustrates a variation of the locking plate application for the treatment of proximal humerus fractures that utilizes short locking screws in the humeral head in conjunction with suture fixation to the rotator cuff. We propose that combination of shorter screws minimizes the potential for intra-articular penetration and augmentation with sutures through the rotator cuff increases fracture stability. We have performed this technique in a series of 53 patients from January 2005 to September 2008 without screw penetration or loss of fracture fixation. It is our belief that such a technique is reproducible by other surgeons and will help ensure stable fixation for fracture healing while reducing the incidence of screw penetration into the glenohumeral joint.

Surgical Technique

The patient may be positioned supine on a radiolucent operating room table or placed in the beach chair position. The semi-seated position, while not necessary, does introduce gravity which facilitates reduction of the shaft to the humeral head at the surgical neck. If a beach chair positioner is not available, the patient may be placed in a semi-seated position on a regular operating room table. Initially, the patient is positioned supine and the table is rotated 180 degrees such that the patient's head is placed at the foot of the table and the shoulder rests on the radiolucent footplate. In the supine position, a bump is then placed at the medial border of the scapula which serves to protract the scapula and facilitates glenohumeral extension during the procedure. The head of the table is then elevated to 30 to 45 degrees, and the table is reflexed, allowing for slight flexion at the waist and knees creating a beach-chair position. For poly-trauma patients with spine precautions, a supine position may be utilized as well. The head is secured and the endotracheal tube is moved to the contralateral side. A pillow is placed under the knees for comfort and to minimize neural tension. The entire table is rotated approximately 75 to 90 degrees so that the operative shoulder is moved further from anesthesia. This is done to facilitate positioning of the surgeon and assistants, as well as for image intensifier. Image intensifier is positioned at the head of the bed. Prior to prepping and draping of the patient's shoulder, neck, and arm, fluoroscopic images are obtained to confirm visualization with the image intensifier (Figure 1). Full anesthetic relaxation allows for less traumatic retraction of the deltoid and minimizes dynamic forces upon the fracture fragments during reduction.

A 3rd generation cephalosporin is administered thirty minutes prior to incision. In cases of true penicillin or sulfamethoxazole allergies, clindamycin or vancomycin can be utilized. A deltopectoral exposure is used for exposure of the proximal humerus. The bony landmarks of the clavicle, acromion, scapular spine, and coracoid process are outlined and marked. The planned line of incision is injected with local anesthetic containing epinephrine to limit superficial bleeding, as a dry operative field is imperative throughout this procedure. An anterior incision is made in line with the deltopectoral groove. The incision is started just above the coracoid process and continued distally in an oblique manner to the deltoid insertion through the deltopectoral groove. Shoulder abduction and external rotation of 30 to 45 degrees during the approach relaxes

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Figure 1. Preoperative radiograph of an unstable 2-part proximal humerus fracture. There is fracture site comminution with varus angulation and a reversal of the greater tuberosity to humeral head relationship.

the deltoid and facilitates exposure.The deltopectoral interval is then deepened with retraction of the pectoralis major medially and the deltoid laterally.The cephalic vein is routinely retracted laterally as a rich venous plexus enters the vein through the deltoid. However, when taken medially, the vein is subjected to less traumatic force with deltoid retraction. Often, in acute cases, the deltopectoral interval and clavipectoral fascia are traumatized and the dissection of the vein may be carried out to either side of the interval depending on the surgeon's preference and zone of soft tissue injury.

Next, the clavipectoral fascia is released. Often, this is disrupted from the initial trauma. Dissection is then carried out in a single layer between the subacromial and subdeltoid spaces. A Cobb or Key elevator and moist sponges may be swept superiorly under the coracoacromial ligament, subacromial space, and subdeltoid space laterally. The coracoacromial ligament may be partially or completely released. Similarly, the coracohumeral ligament is released. The long head of the biceps brachii tendon is then identified at its position medial to the pectoralis major insertion on the humerus. The pectoralis does not typically need to be released. However, if left in situ, the long head of the biceps brachii can be a source of pain, and we routinely tenodese it at the time of plate fixation. As the biceps is traced superiorly, the transverse humeral ligament is released with a knife or electrocautery and as the tendon courses superiorly, it is used to define the rotator cuff interval. After the rotator interval is released to the base of the coracoid process, the long head of the biceps is released from the supraglenoid tubercle and superior glenoid labrum. The lesser tuberosity and subscapularis tendon lie medial to the biceps tendon, and the greater tuberosity and supraspinatus tendon insertion are lateral to the biceps. Heavy nonabsorbable sutures are placed in the subscapularis, supraspinatus, and infraspinatus tendons at the myotendinous junction. Temporary traction sutures are often necessary to help mobilize the tendons to obtain better suture purchase more medially. The bone quality in these patients is typically poor, and sutures should be placed in the stronger rotator cuff tendons rather than through the soft, metaphyseal bone of the tuberosities. We find that unlocked horizontal mattress sutures are adequate.Traction sutures should be placed in the tendinous insertions to hold and reduce fragments securely to the plate (Figure 2). We have found that extension of the blunt dissection posterolaterally along the subdeltoid recess affords adequate exposure without disruption of the tendinous insertion at the deltoid tuberosity.

A low-profile, precontoured, peri-articular, locking plate with angular stable screws and suture eyelets is then selected to provide fixation of the fracture. Prior to plate application,

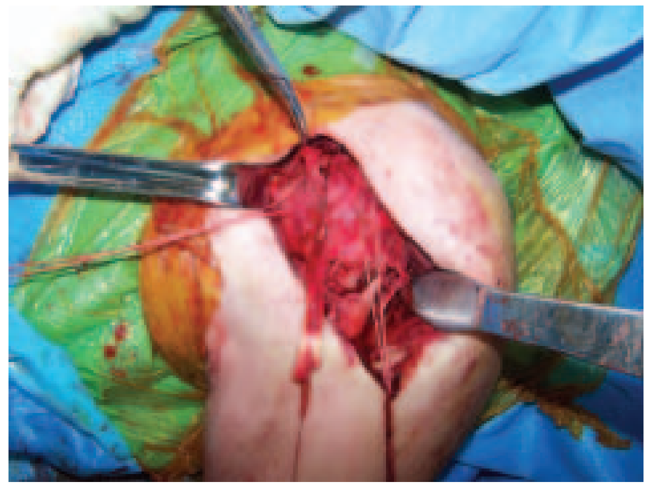

Figure 2. Deltopectoral exposure revealing the long head of the biceps brachii, which is released from the supraglenoid tubercle. Stay sutures are placed in the supraspinatus, infraspinatus, and subscapularis tendons to aid in fracture reduction. The fracture is exposed well lateral to the bicipital groove. The deltoid and pectoralis tendon insertions may be left completely intact, even in long fractures extending into the humeral shaft.

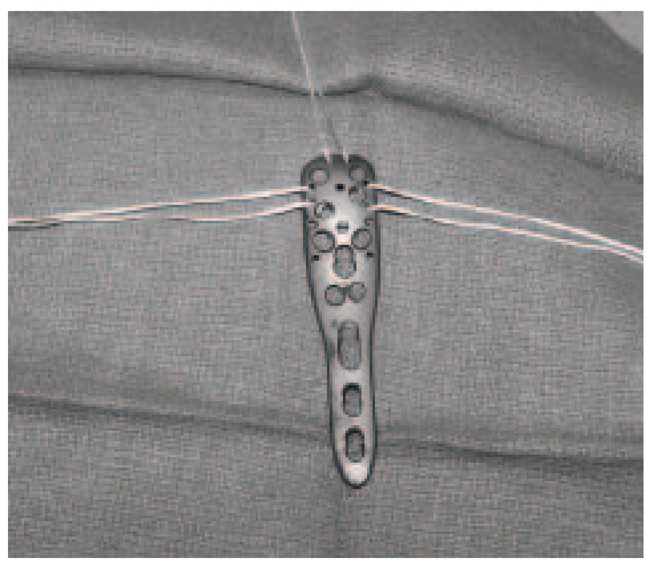

Figure 3. A short, locking pre-contoured plate is prepared with sutures placed through the eyelets of the plate superiorly (supraspinatus tendon), anteriorly (subscapularis) and posteriorly (infraspinatus). It is often difficult or impossible to place suture through the plate once it is applied to the humerus.

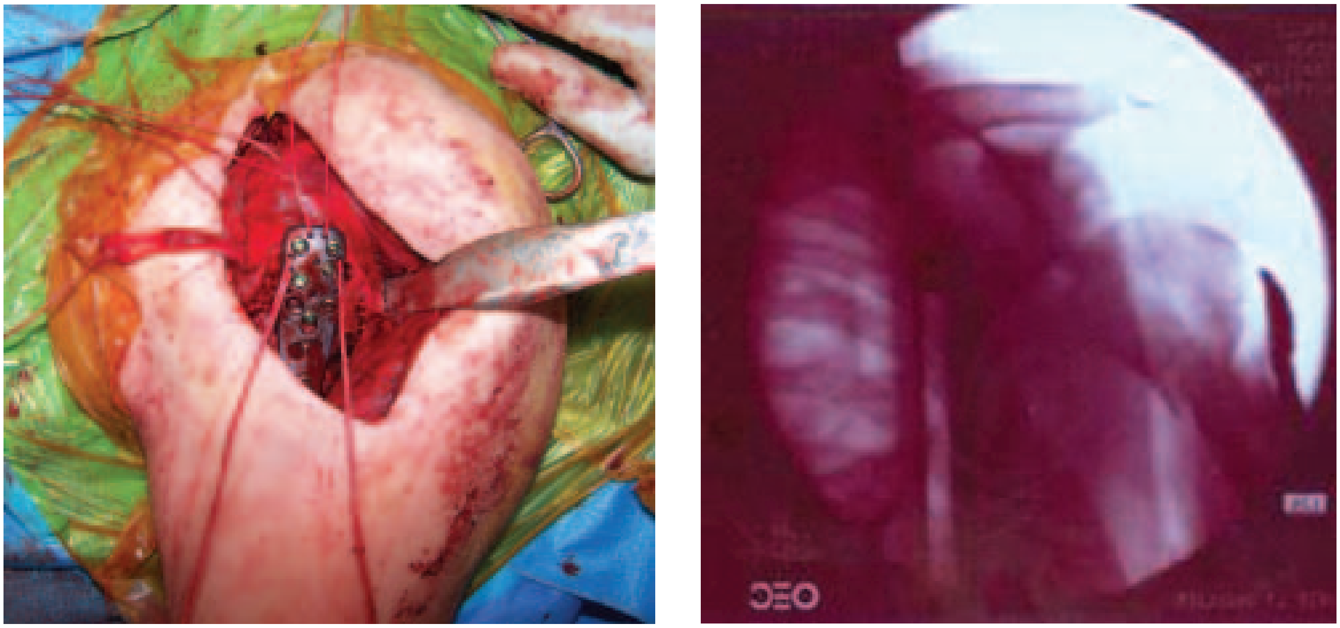

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Figure 4. (A) The plate is initially secured to the humeral shaft with a non-locked, bicortical screw through the diaphyseal portion of the plate. Sutures through the rotator cuff and through the plate are seen. The plate is positioned lateral to the bicipital groove. (B) Plate height is checked fluoroscopically. The varus malangulation will be corrected using the rotator cuff sutures to reduce the proximal humerus to the plate and humeral shaft using an indirect reduction technique.

separate sutures are passed through the eyelets of the plate (Figure 3). Ideally, a superior suture is placed for the supraspinatus tendon, an anterior suture for the subscapularis, and a posterior suture for the infraspinatus tendon. The plate is applied to the proximal humerus lateral to the biceps tendon to limit avascular necrosis. Similarly, during reduction of the surgical neck, cortical reduction and alignment can be performed with exposure staying lateral to the bicipital groove and under the deltoid recess. Care should be taken to avoid medial dissection which entails detachment of the pectoralis major tendon and risks injury to the posterior humeral circumflex artery.

A provisional reduction of the surgical neck can be held with Kirschner wires and confirmed with image intensifier, as well as by direct inspection. The tuberosities are reduced via the traction sutures with minimal manipulation of the metaphysis to prevent further fracture comminution. The plate can be secured to the humeral head and/or the shaft using K-wires, a provisional fixation pin, or a small fragment screw. The initial screw should be diaphyseal, bicortical, and non-locking. This allows compression of the plate against the humeral shaft and allows subsequent reduction of the tuberosities to the shaft via the plate. By using an oblong hole in the plate, the plate may be moved caudal or cephalad as needed. It is critical to not reduce the fracture in internal rotation as this will limit the patient's ability to regain functional external rotation postoperatively. To ensure this, reduction and plating are performed with the arm in 30 degrees of external rotation. The positioning of the plate is then evaluated using fluoroscopy to ensure appropriate placement such that the plate is not too proximal so as to impinge on the coracoacromial arch with shoulder abduction. Similarly, the plate should not be positioned too distal such that fixation into the head would be limited (Figure 4).

Indirect reduction techniques are employed to reduce the head to the shaft by using the sutures in the rotator cuff to gain control of the head. Alternatively, the humeral head may be reduced or stabilized by manipulation with blunt elevators or joysticks such as Kirschner wires or Schanz pins. In osteoporotic bone, the use of elevators or joysticks can be problematic due to the poor bone quality and further fragmentation at the site of application of these reduction tools.

Once reduced, fixation into the head is limited to five or more short (32-38 mm), fixed angle screws augmented with suture fixation of the rotator cuff (which has control of the head) directly to the plate (Figure 5). This is done in order to prevent cut-out and intra-articular penetration of the screws. In addition, this can lead to decreased operative time. If the long head of the biceps tendon was released, it can be tenodesed to the pectoralis major and the rotator cuff interval. Upon completion of fracture fixation, range of motion and glenohumeral stability is assessed. Full passive motion comparable to the contralateral shoulder should be present.

A layered closure is performed and may be done over a medium Hemovac drain per surgeon's preference. As inferiorly placed drain holes tend to drain, we prefer a more superior drain hole out through the deltoid laterally within 5 cm of the acromion to prevent iatrogenic injury to the axillary nerve. Plain radiographs are obtained prior to leaving the operating room. Post-operatively, patients are placed in a sling for comfort only and are encouraged to begin pendulum exercises immediately after surgery as well, so that they can brush their teeth and perform non-load bearing activities as soon as possible.

Clinical Summary

From January 2005 until September 2008, we (SM, FPT, GRH) treated 53 proximal humerus fractures that presented to our Level I trauma center with an open reduction and internal fixation technique that utilized a locking plate in combination with both short humeral head screws and suture fixation of the rotator cuff to the plate. The average patient age was 59 years (range, 21 to 101 years). The right limb was involved in 34 cases. Thirty-eight patients were female. Neer classification was performed for all fractures; there were 17 two-part fractures, 28 three-part fractures, and 8 four-part fractures. In all cases, patients were treated with a proximal humeral fixed angle plate applied through a deltopectoral incision with short (32-38mm) locking screws placed into the humeral head and augmented suture fixation of the rotator cuff to the plate. All patients had clinical and radiographic follow-up for a minimum of 6 months (range, 6 months to 3 years) and an average of 16 months, where they were evaluated for potential complications. Of the patients reviewed in this series, none were found to have intraarticular screw penetration. Two patients had an asymptomatic varus malunion. Neither patient had penetration of the humeral head with screws and refused further surgery. Additionally, 5 patients were treated for limited postoperative range of motion (defined as active forward glenohumeral motion <120 degrees), but had no evidence of plate impingement or screw penetration. In this small group of patients, the mean pre-release active forward elevation was 95 degrees, which reached 150 degrees postoperatively.

Discussion

Proximal humerus fractures account for approximately 4% to 5% of all fractures[6]. While these fractures do occur in young individuals primarily as a result of high-energy trauma, the majority of fractures occur in the elderly population especially in those with osteoporosis. Approximately 85% of proximal humerus fractures are minimally displaced or stable and can be successfully treated with conservative management and early motion[7-10]. The remaining 15% of fractures are displaced or unstable and require surgical intervention because of poor results with non-operative treatment[8, 11, 12]. Various operative techniques have been suggested for these fractures including tension band sutures, intramedullary devices, Kirschner wires, plates, and prosthetic replacement[13]. There currently are no clear guidelines as to optimal treatment of displaced or unstable proximal humerus fractures as most of these techniques have been associated with some degree of complications including hardware failure, osteonecrosis, nonunion, malunion, hardware migration, rotator cuff impairment, and impingement syndrome[4, 5]. Traditionally, however, it has been shown that plate and screw fixation offers the best chance for stable fixation in multi-fragmented fractures[14]. With the advent of locking plate designs, torsional and bending stiffness, and load to failure are increased. With the use of supplemental non-absorbable suture fixation to the plate, the security of the tuberosities is additionally increased.

Fixed- and variable-angle locking devices are the latest development in plate fixation for the treatment of proximal humerus fractures. Early studies on the use of locking plates to treat proximal humerus fractures have shown promising results especially in patients with poor bone quality[1-3, 15] and consequently, many surgeons have adopted the use of locking plates for the treatment of complex proximal humerus fractures[2, 16]. The benefits of locking plate technology in the treatment of displaced and unstable humerus fractures are two fold. Locking plates do not need to be compressed for stability and therefore allow the preservation of periosteal vascularity. In addition, locking plates incorporating divergent metaphyseal locking screws are beneficial in osteoporotic bone which is frequently encountered in patients with this type of injury[17-19]. Locking plates minimize the risk of screw stripping in osteoporotic bone such that even if the screw-bone interface fails, the screw-plate interface remains intact[17, 19, 20].

While locking plate constructs have shown promising results in the treatment of displaced and unstable proximal humerus

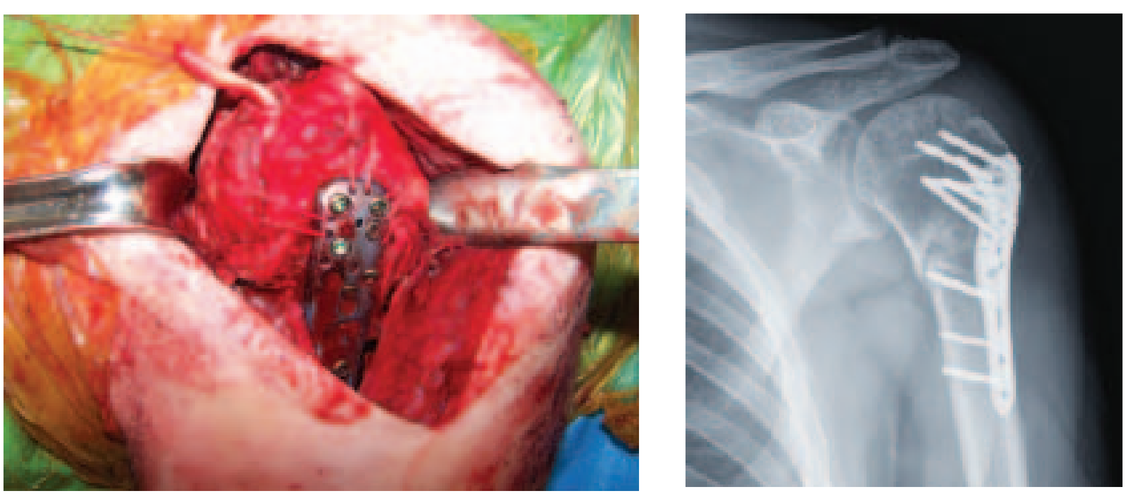

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Figure 5. (A) Proximal and distal screws have been inserted and the rotator cuff sutures are secured to the plate affording additional proximal fixation. The long head of the biceps is tenodesed using soft tissue only. The plate is positioned well lateral to the bicipital groove and inferior to the tuberosity to minimize risk of avascular necrosis and plate impingement, respectively. (B) Postreduction radiograph show four to six short (32 – 38mm) locking screws placed to eliminate the risk of intra-articular screw penetration.

fractures[1-3, 15], the use of the this technique has not been without complications[3-5]. Recent studies evaluating the outcomes of patients treated with locking plates for proximal humerus fractures have shown that one of the most frequent complications of this technique is intra-articular penetration of the locking screw[3-5]. In the study by Owsley et al, 23% of patients had screw penetration into the glenohumeral joint.The studies by Egol et al and Charalambous et al showed similar complications with 16% of patients in both studies having articular screw penetration. It was noted that this complication was more common in patients over the age of 60 in whom osteoporotic bone is more likely to be found. In these studies, the concept of obtaining subchondral screw fixation (as in load-bearing joint periarticular fractures such as femoral neck fractures) has been incorporated. We feel that this is a misuse of the locking design in proximal humerus fractures where the rotator cuff tissue integrity exceeds that of the metaphyseal bone of the humeral tuberosities. For this reason, we have used short, divergent locking screws and suture fixation to minimize the risk of varus malunion, plate failure, and intra-articular screw penetration.

In this series of 53 patients treated with our modified technique, we had 2 patients (3.8%) who had failure of fixation, but no patients who had screw penetration of the humeral head.We believe this is, in part, due to the use of short, fixed angle screws into the humeral head in conjunction with supplemental non-absorbable suture fixation of the rotator cuff to the plate. Anecdotally, the quality of fixation of the suture in the rotator cuff is felt to be superior to the fixation of the fixed angle screws into osteoporotic bone of the humeral head. It is our belief that such a technique can reduce the incidence of screw penetration into the glenohumeral joint and provide stable fixation for healing.

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