Early Outcomes of Proximal Humerus Fracture Fixation With Locking Plate and Intramedullary Fibular Strut Graft

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Abstract

Proximal humerus fractures are commonly encountered in elderly patients. Surgical treatment demonstrates high complication rates, including varus construct collapse and screw cutout. In this study, the authors evaluate the clinical outcome of locking plate fixation with intramedullary fibular strut graft augmentation as a primary surgical treatment in the prevention of early collapse and screw cutout. A total of 9 patients were evaluated. Surgery was performed for displaced proximal humerus fractures between April and December 2011. Patients were either class 2, 3, or 4, according to Neer classification. Mean patient age was 75.4 years. Preoperative and immediate, 6-week, and 3-month postoperative radiographs were evaluated. Head-shaft angles were measured to assess for varus collapse and displacement. Range of motion, complication rates, and functional recovery were also evaluated. Patients underwent open reduction and internal fixation with placement of an intramedullary fibular strut graft. Fixation was achieved with a Philos plate (Synthes, Oberdorf, Switzerland). Reduction and fixation were evaluated with radiographs. Passive exercises and range of motion were allowed immediately postoperatively, and all patients achieved active abduction and forward flexion 6 weeks postoperatively. Shoulder radiographs taken 12 weeks postoperatively revealed no loss of reduction or screw cutout. The introduction of the locking plate has improved outcomes. The addition of an intramedullary strut graft has shown improved preliminary results. Maintained reduction was observed in all 9 patients in the early postoperative period, and good functional motion was achieved. No incidence of screw cutout was recorded.

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The authors have no relevant financial relationships to disclose.

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Received: January 6, 2014; Accepted: January 30, 2014; Posted: September 9, 2014. doi: 10.3928/01477447-20140825-60
Proximal humeral fractures account for approximately 4% to 5% of all fractures. They are the second most common upper-extremity fracture and the third most common fracture, after hip fractures and distal radial fractures, in patients aged older than 65 years. Up to 75% of the patients are women, and it is postulated that these fractures are related to osteoporosis.

Fortunately, the majority of proximal humeral fractures are either nondisplaced or minimally displaced and can be treated with sling immobilization and physical therapy, with good results attained. Approximately 20% of displaced proximal humeral fractures will require operative treatment. Many surgical techniques have been described, but no single technique is recommended to be the standard of care. This broad range of techniques, including transosseous suture fixation, closed reduction and percutaneous fixation, open reduction and internal fixation, and hemiarthroplasty, have been described with varying degrees of success. Locked-plate technology and the use of osteobiologics play an increasingly important role in the treatment of displaced proximal humeral fractures, with both in vitro and clinical studies displaying improved outcomes compared with conventional techniques.

Various devices for internal fixation have unpredictable results at best, especially in patients with osteopenic bone and comminuted fractures. Several complications have been described in association with these techniques, including implant failure, loss of reduction, fracture nonunion or malunion, impingement syndrome, and osteonecrosis of the humeral head.

Faraj et al studied 131 consecutive operated patients with displaced proximal humerus fractures and reported results after 2-year follow-up. Ninety-two (70%) patients were interviewed. The overall complication rate was 39.1% (36/92), excluding the 39 patients not interviewed. The most frequently occurring complications were hemorrhage (3.3%), dislocation of the caput humeri and/or tuberculum majus (2.2%), persistent pain (3.3%), loss of reduction and screw cutout (6.5%), plate break out (6.5%), subacromial impingement (11.9%), frozen shoulder (3.3%), rotator cuff rupture (1.1%), and infection (1.1%). Of the entire group of patients originally included in the study, almost 1 in 3 (29%) was reoperated due to one of the abovementioned complications.

In a study by Owsley and Gorczyca, 19 (36%) of 53 patients with displaced proximal humerus fractures treated surgically had complications. Screw cutout with intra-articular displacement was noted in 12 (23%) patients, substantial (more than 10°) varus displacement in 13 (25%), and osteonecrosis in 2 (4%). These radiographic signs of complication occurred in 12 (57%) of 21 patients older than 60 years and in 7 (22%) of 32 patients younger than 60 years ($P=.0015$), demonstrating poorer results when in patients older than 60 years. The most significant complication was screw cutout, which occurred in 9 (43%) of the 21 patients older than 60 years.

To minimize these complications, fixed-angle implants, such as the Philos plate (Synthes, Oberdorf, Switzerland), were used. They are precontoured to the anatomy of the lateral aspect of the proximal humeral metaphysis and aid internal fixation by securing an anatomic reduction with angular stability. A recent biomechanical analysis in which blade-plate fixation was compared with locking plate fixation for the treatment of proximal humeral fractures indicated potential advantages in association with the locking plate.

Sudkamp et al reported 187 patients with acute proximal humerus fractures who were treated with open reduction and internal fixation. Locking proximal humeral plates was used and evaluated on clinical outcomes and radiological healing. Sixty-two complications were encountered in 52 (34%) of 155 patients at 1-year follow-up. Twenty-five (40%) complications were related to incorrect surgical technique and were present at the end of the operative procedure. In this situation, the most common complication, noted in 21 (14%) of 155 patients, was intraoperative screw perforation of the humeral head. Twenty-nine (19%) patients had an unplanned second operation within 12 months after the fracture. Although the reported complication rate was 34%, a similar figure to that reported in other studies, they included intraoperative events that can be rectified immediately and may occur regardless of patient age, bone quality, or fracture type. Of note was the reduction in the number of unplanned repeat surgeries when compared with other treatment modalities.

The current authors believe that several factors contribute to the early failure of this surgical technique and that the addition of an intramedullary graft is a relatively simple step in achieving improved outcomes in patients identified to be at risk of implant failure. The objective of this study was to describe the improvement in clinical outcomes and radiological union with the addition of an intramedullary strut graft.

**Materials and Methods**

All patients were admitted and underwent surgery between April and December 2011. Patients with displaced Neer type 2, 3, or 4 proximal humeral fractures were included if they were older than 60 years and provided written informed consent preoperatively. These fractures either met the indications for operative treatment as outlined by Neer (i.e., angulation of the articular surface of more than 45° or displacement of more than 1 cm between the major fracture segments) or were unstable when tested with passive motion with use of an image intensifier. Nondisplaced stable fractures and fractures with minimal...
displacement and adequate stability, as well as fractures involving only the greater or lesser tuberosity, were not considered for treatment with internal fixation. Exclusion criteria included open fracture, pathological fracture, pseudoarthrosis, previous operative treatment of the proximal part of the ipsilateral humerus, concomitant ipsilateral fracture of the distal part of the humerus or the elbow joint, and polytrauma with an Injury Severity Score higher than 16. Also excluded were patients with existing disorders having a relevant effect on the healing process, such as multiple sclerosis or paraplegia, and patients with a posttraumatic brachial plexus injury or peripheral nerve palsy. Patients with comorbidities such as diabetes, known osteopenia/osteoporosis, and polypharmacy were not excluded because they represent the target population in this treatment technique.

The Philos plate is a fixed-angle implant designed for the fixation of proximal humeral fractures. It is contoured to the anatomy of the lateral aspect of the proximal humeral metaphysis and the proximal part of the humeral diaphysis. It works as an internal fixator by securing anatomic reduction with angular stability. The screw configuration of the locking screws in the humeral head is multidirectional. In the shaft, either locking or nonlocking screws may be inserted into combination holes. Additional smaller holes can be used for the fixation of sutures or wires, allowing for the reattachment of the greater or lesser tuberosities in cases of comminuted fractures to neutralize the tension forces of the rotator cuff muscle. Several other implants afford similar design specifics, and this implant was selected to reduce variables in the study design.

**Surgical Technique**

Surgery is performed with the patient in the beach-chair position on a radiolucent table with use of either the deltopectoral or deltoïd-splitting approach. The fracture is reduced and provisionally stabilized with threaded Kirschner wires. This reduction is evaluated for adequacy with use of image intensification. The fibular strut graft is trimmed to fit into the medullary canal of the humeral shaft with the proximal end sitting within the humeral head, with the goal of best possible fit. The plate is positioned, with the help of a mounted aiming device, at least 8 mm distal to the upper end of the greater tuberosity and 2 mm posterior to the bicipital groove, with care being taken to ensure that a sufficient gap was maintained between the plate and the tendon of the long head of the biceps. A Kirschner wire is inserted into the proximal guide hole of the insertion guide below the rotator cuff so that it aims at the proximal joint surface. Drill sleeves are inserted and Kirschner wires placed within. A position check with the image intensifier is performed, and screw length is determined. The plate is fixed definitively with the insertion of angular stable screws into the humeral head. A final image intensifier check is performed to verify correct screw placement and length. Postoperatively, the arm is immobilized in a sling, and passive range-of-motion exercises are started within 2 days postoperatively. Controlled active mobilization with abduction and flexion beyond 90° was started 3 weeks postoperatively for all patients in the current study.

During hospitalization, the demographics and baseline characteristics of the patients were recorded. Fractures were classified according to the AO system on the basis of plain radiographs and intraoperative fracture visualization. Scheduled follow-up evaluations were performed 3, 6, and 12 weeks postoperatively. At each follow-up visit, the patients were examined and interviewed with regard to pain, mobility, and strength.

True anteroposterior and transscapular Y-view radiographs were obtained postoperatively and at each follow-up visit. Evidence of fracture healing was evaluated, and radiographic measurements were performed. In particular, head-shaft angle was measured at each phase to determine whether varus or valgus collapse had occurred. Humeral head screws were also evaluated to determine whether screw cutout had developed (Figure 1).

**RESULTS**

Nine patients with acute unstable proximal humeral fractures were included in the study and were managed with open reduction and internal fixation with a locking (fixed-angle) proximal humerus plate. Mean patient age was 75.4 years (range, 62-86 years). The patients included 7 (77.8%) women and 2 (22.2%) men. Proximal humeral fractures were caused by a low-energy injury in 8 (88.9%) patients and a high-energy injury in 1 (11.1%) patient. The dominant arm was injured in 6 (66.7%) patients. All of the fractures were displaced according to the Neer criteria. Average time from injury to surgery was 4.3 days. The deltopectoral approach was used 5 cases and the deltoïd-splitting approach in 4. There was no difference between the 2 approaches with respect to outcomes and complication rates. Additional sutures were used to stabilize the greater or lesser tuberosity in all cases. Mean operative time was 130 minutes (range, 90-155 minutes), with no...
significant difference between type A, B, and C fractures. No patients were lost to follow-up at 3 or 6 weeks postoperatively.

Six weeks postoperatively, mean forward flexion was 87° (range, 70°-95°), mean abduction was 85° (range, 70°-95°), mean external rotation was 31° (range, 25°-40°), and mean internal rotation was 40° (range, 25°-45°). No evidence of superficial or deep infections was observed, and no unplanned readmissions were recorded. Radiological assessment of head-shaft angles immediate postoperatively and 3 and 6 weeks postoperatively showed no significant progression of varus angulation ($P=.395$ and $.611$, respectively) (Table; Figure 2). There was no evidence of screw cutout in any patient by 6-week follow-up. Callus formation was not observed.

At 12-week follow-up, all 9 patients had radiological evidence of callus formation with maintenance of head-shaft angles. Range of motion had improved to a mean forward flexion of 109° (range, 95°-130°), mean abduction of 107° (range, 100°-130°), mean external rotation of 41° (range, 35°-45°), and mean internal rotation of 55° (range, 40°-65°).

**DISCUSSION**

For union in osteoporosis-related fractures of the humerus, stable fixation is required. However, standard plating techniques have been associated with failure rates as high as 70%.26,27 In designing a stable construct, several techniques with variable outcomes have been described, including screw augmentation with polymethylmethacrylate, tension banding of the rotator cuff with extramedullary plates or intramedullary nails, bone grafting with autograft struts, standard plate modification into a blade plate construct, and hemiarthroplasty.6-12 Despite promising results in several studies, results were not easily reproduced in other centers and, at times, increased morbidity was observed.

The addition of an autograft has been suggested to improve union.6-8,10 However, donor-site morbidity has significantly contributed to patient dissatisfaction.28-30 Common donor sites include cancellous bone or cortical grafts from the tibia, fibula, ribs, or ilium. Cortical grafts provide immediate structural stability and improved bone stock; however, difficulty in procurement and donor-site morbidity (eg, fractures and chronic pain29,30) have resulted in their infrequent use.

In vivo studies with cadaveric specimens have concluded the improved strength of fixation with intramedullary strut graft augmentation. Mathison et al11 found that the addition of the graft increased the failure load of the constructs
by 1.72 times and the initial stiffness of the construct by 3.84 times. They studied 6 pairs of embalmed specimens, with each pair having 1 humerus repaired with locking plate fixation and the other humerus repaired with plate fixation and intramedullary fibular allograft. The constructs were tested in bending to determine the relative movement between the humeral head and the shaft under bending loads and the failure loads of both constructs. Osterhoff et al. studied the effect of an intramedullary augmentation with fibular graft. Twenty composite analog humeri were tested. In one arm (n=10), fixation was achieved with an anatomically formed locked plate, and in the other arm (n=10), the same fixation was performed with an additional fibular graft inserted in the intramedullary canal. Active abduction was simulated for 400 cycles, and fragment gap distance was measured, thus determining intercyclic motion, fragment migration, and residual plastic deformation. The addition of a fibular graft led to 5-times-lower intercyclic motion, 2-times-lower fragment migration, and 2 times less residual plastic deformation. Screw pullout, cut-through, and implant failure were not observed.

Bae et al. showed that construct displacement was significantly less with strut graft augmentation. Seven pairs of human cadaveric humeri were grouped into either locking plate alone or locking plate with fibular strut graft. Cyclical loads of between 10 and 80 N at 5 Hz were applied for 1,000,000 cycles. Immediately after cycling, an increased axial load was applied at a rate of displacement of 5 mm per minute. They concluded that all maximum failure loads and measures of stiffness in the augmentation group were significantly higher than those with only the locking plate (P=.024 and .035, respectively). With only locking plate fixation, varus collapse and plate bending were seen.

Currently, the common technique for surgical treatment of proximal humeral fractures involves the use of a fixed-angle device in the form of a modified standard plate, a site-specific blade plate, or an anatomic proximal humeral locking plate. Biomechanical testing has proven that the locking plate is superior in torsional rigidity and stiffness compared with a blade plate for 2-part proximal humeral fractures. With the increased stiffness and reduced motion at the fracture site, an improved mechanical environment may enhance healing. In the current series, no displacement or varus collapse was noted in any patient by 12-week follow-up and physiotherapy. The authors believe that this favorable outcome was achieved by producing a stiffer construct in osteoporotic bone via the addition of an intramedullary cortical allograft. The advantages of the allograft strut are that it provides added bone stock to improve fixation and that its use avoids the complications associated with donor-site morbidity from autograft harvesting. Wright demonstrated that screw fixation in the proximal humerus is the weakest region biomechanically in a cadaver humerus. Previous authors have reported that cavitary defects encountered in proximal humeri are an indication to abort fixation and to proceed with prosthetic replacement. In this instance, the strut contributes as a void filler, allowing for improved fixation, added bone stock, support of the head fragment, and an overall better mechanical environment favorable for bone healing. Migration of the graft is minimized with passage of the screws through both native cortices and the intramedullary graft. This further strengthens the construct.

The current authors recognize that use of allografts poses an inherent risk of disease transmission. With stricter screening processes and the avoidance of unprocessed fresh-frozen grafts, their use is safe, with only 1 report of hepatitis C transmission from a processed graft. No documented reports of HIV transmission were found.

**CONCLUSION**

Displaced proximal humeral fractures have been discussed extensively, with various techniques described to achieve successful reduction and union. Variable results, some with devastating complications, have been described, in particular varus collapse and screw cutout resulting in revision surgery or replacement. In the treatment of displaced osteoporotic proximal humerus fracture, primary fixation with an intramedullary fibula allograft provides a safe and reliable way of achieving stability and stiffness. A study involving a larger cohort and clinical outcome assessments must be performed with longer follow-up periods to determine whether successful union can be accomplished with concomitant improvement in clinical outcomes. Early results from this series of strut graft augmentation are promising and have significantly reduced the complications encountered in elderly patients with reduced bone density.

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