An Original Study

Minimally Invasive Plate Osteosynthesis for Proximal Humerus Fractures: Functional Results of Treatment

Gregory T. Altman, MD, Robert A. Gallo, MD, Kenneth G. Molinero, DO, Matthew T. Muffly, BS, and Leonardo Mascarenhas, MD

Abstract

Proximal humeral fractures can safely and effectively be treated with minimally-invasive plate osteosynthesis (MIPO). Twenty-one patients treated with MIPO for 2-, 3-, and 4-part proximal humerus fractures were treated at a mean 6.8 days (range, 1-24 days) after injury and followed for a mean of 24 months (range, 5-38 months). All fractures healed by 8 weeks postoperatively, with reductions "good" in 18 (86%) of patients and "fair" in 3 (14%). There were no infections or nerve or vascular injuries. One patient had loss of reduction that healed but required hardware removal. The neck–shaft angle was measured intraoperatively and at final follow-up, with mean (SD) of 139º (9.3; range, 123º-156º) and 138º (8.9; range, 123º-159º), respectively. Mean (SD) displacement from the most superior aspect of the humeral head articular surface to the top of the greater tuberosity was 4.3 (10) mm. Mean (SD) active range of motion was 143º (35.04; range, 80º-180º) for forward flexion, 118º (46.8; range, 45º-180º) for elevation, and 33º (19.2; range, 10º-65º) for external rotation. The mean Disability of the Arm, Shoulder, and Hand (DASH) score was 25.95 (range, 0-80). Excluding patients with associated injuries, a statistically significant difference ($P<.05$) was found in the DASH scores for those patients with greater tuberosity displacements between 3 mm and 8 mm and those patients with greater tuberosity displacement greater than 8 mm inferior to the articular surface. Clinical outcomes depended upon reduction of the greater tuberosity, which is facilitated by the MIPO technique.

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Minimally invasive plate osteosynthesis (MIPO) has become increasingly popular in the management of fractures.[1-5] This technique "bridges the gap" between percutaneous and standard open methods by parlaying the advantages of each and eliminating many of the disadvantages. Through limited soft-tissue dissection, MIPO can minimize additional trauma to an already injured region while providing fixation rigid enough to allow for early motion.

After performing a cadaveric study to assess the safety of the technique,[6] we applied MIPO techniques to patients with proximal humerus fractures that required operative fixation. The goal of this study was to assess the healing rate, functional outcome, and potential short-term complications of MIPO for the treatment of proximal humeral fractures. We hypothesized that MIPO is a safe technique that allows for prompt fracture healing and return to nearly normal function.

Materials and Methods

After institutional review board approval was granted, we retrospectively reviewed the cases of patients who had sustained proximal humerus fractures and been treated at our level I trauma center between January 2006 and October 2007. Our criteria for surgical fixation included

Figure 1. A 49-year-old study patient with displaced shortened proximal humerus fracture.

Figure 2. Intraoperative radiographs show a “good” reduction with minimal displacement.

Figure 3. A-74-year-old study patient with a displaced proximal humerus fracture.

proximal humerus fractures with either or both (a) surgical neck displacement of more than 1 cm and/or 45° of angulation and (b) greater tuberosity displacement of more than 5 mm. Patients with minimally displaced fractures involving the greater tuberosity and/or the surgical neck were treated nonoperatively.

During the enrollment period, 36 patients were treated for proximal humerus fractures. Fifteen of these patients did not undergo percutaneous treatment. Of these, 9 were older patients who underwent stable closed reduction in the operating room while being treated for another fracture; 2 had proximal humerus fractures extending to the shaft and were treated with an extensile anterolateral approach; 2 had an irreducible anterior dislocation requiring a deltopectoral approach; 1 underwent a failed closed reduction; and 1 was elderly, had poor bone quality, and was treated with hemiarthroplasty.

The other 21 patients (14 women, 7 men; mean age, 55.6 years; range, 23-76 years) had proximal humeral fractures treated using MIPO. Five of these patients had ipsilateral upper extremity fractures. Mechanisms of injury were falls (15 patients) and motor vehicle collisions (6 patients). Of the 21 patients, 8 had type IIA fractures (2 type IIA1, 1 type IIA2, 5 type IIA3), 8 had type IIB fractures (6 type IIB1, 2 type IIB2), and 5 had type IIC fractures (1 type IIC1, 3 type IIC2, 1 type IIC3) according to AO (Arbeitsgemeinschaft für Osteosynthesefragen) guidelines.[7] Alternatively, according to the method described by Neer,[8] 9 patients had 2-part fractures (8 surgical neck, 1 greater tuberosity), 11 patients had 3-part fractures (all greater tuberosity and surgical neck), and 1 patient had a 4-part fracture (surgical neck, greater tuberosity, lesser tuberosity). All but 3 patients underwent the MIPO procedure within 2 weeks of injury (mean, 6.8 days; range, 1-24 days).

All patients were followed for at least 2 months after clinical and radiographic evidence of complete fracture union. Mean overall follow-up after fracture fixation was 24 months (range, 5-38 months). Outcome was determined at final follow-up and was judged using radiographic and clinical parameters.

Radiographs obtained in both anteroposterior and axillary projections were assessed for fracture union and reduction quality. A fracture was considered a “union” once there was no longer any evidence of incomplete fracture healing (cortical discontinuity). Reduction quality was graded according to the criteria outlined by Kristiansen and Kofoed[9]: With a “good” reduction, the fracture is corrected to a position of minimal displacement, according to Neer (Figures 1, 2); a “fair” reduction is improved with bony apposition between the fragments (Figures 3–5); and with a “poor” reduction the fragments are unchanged or worsened.

Functional outcomes were quantified with measurements of active range of motion (ROM) and use of a validated outcome tool, the Disability of the Arm, Shoulder, and Hand (DASH) questionnaire.[10-12] Active ROM was tested with forward elevation, elevation in the plane of scapula, and external rotation with the arm at 0° of abduction. The DASH questionnaire is often used to determine the overall disability resulting from an upper extremity injury.

Surgical Technique

Initial patient setup was focused on facilitating fluoroscopic imaging of the extremity. A radiolucent Jackson table was our operative bed of choice. The patient was positioned with the lateral edge of the torso on the affected side aligned with the edge of the bed. A folded blanket was placed beneath the affected shoulder to pro-

Figure 4. Intraoperative radiograph shows a "fair" reduction with some retroversion of the humeral head.

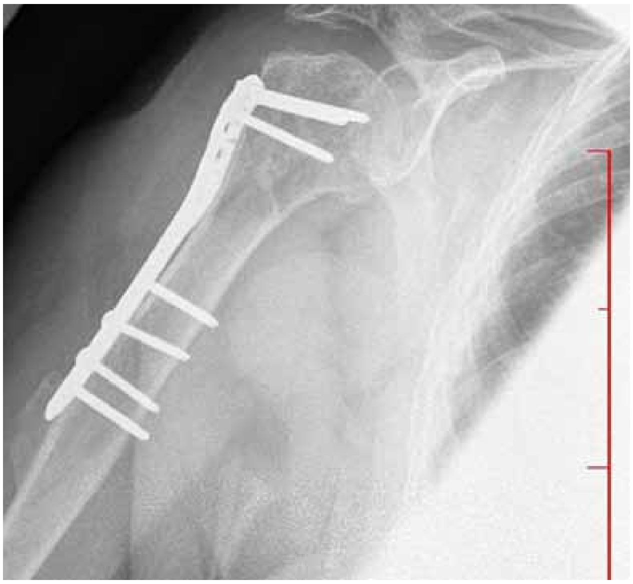

Figure 5. Intraoperative radiograph shows a "fair" reduction with some retroversion of the humeral head.

duce a semilateral position. The affected extremity was placed on a radiolucent arm rest. The full-sized C-arm fluoroscopy machine was moved into the surgical field from the contralateral side and perpendicular to the long axis of the patient (Figure 6). The ability to obtain biplanar images—facilitated by the steps outlined earlier—was confirmed before preparation and draping of the surgical site.

After the usual preparation and draping, a longitudinal surgical incision was created slightly distal to the lateral edge of the acromion and extended distally 3 cm (Figure 7). In the sagittal plane, this incision was positioned in the center of the humeral head. More deeply, the deltoid musculature was split parallel to its fibers to

Figure 6. Biplanar imaging and a semi-lateral position.

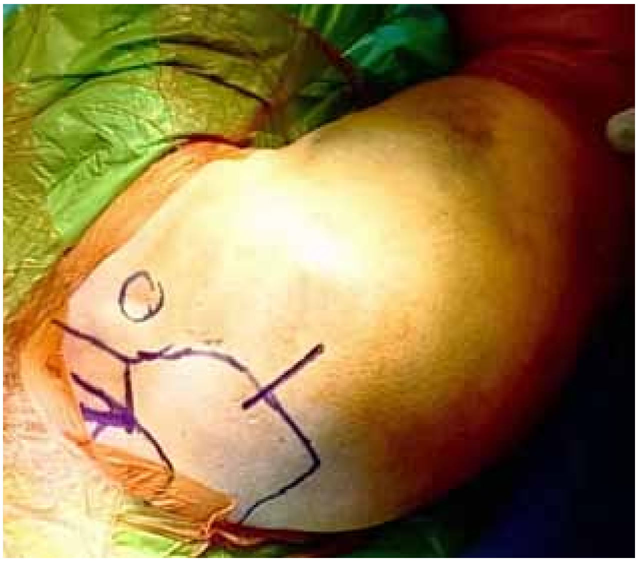

Figure 7. A longitudinal surgical incision was created slightly distal to the lateral edge of the acromion and extended distally 3 cm.

expose the underlying subdeltoid bursa and the proximal edge of the greater tuberosity (Figure 8).

The fracture was reduced by several methods. Often, manual manipulation of the fragments followed by axial compression of the fracture was sufficient for adequate reduction. When this method was insufficient,

Figure 8. Two incision percutaneous approach.

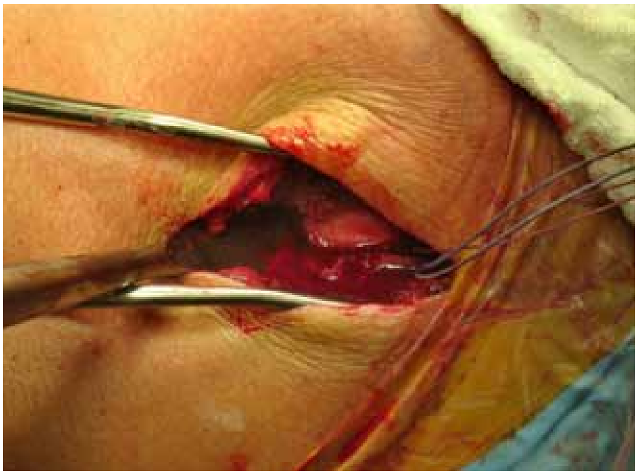

Figure 9. A traction suture into the rotator cuff tendons and/or placement of an elevator facilitated the reduction.

placement of a traction suture in the rotator cuff tendons and/or placement of an elevator facilitated the reduction (Figure 9). Once the head–shaft segment had been reduced, the greater tuberosity fragment, if present, could be manually reduced. The displaced piece was palpated posterosuperior to the humeral head because of the external rotation and abduction afforded by supraspinatus, infraspinatus, and teres minor. The tuberosity was held into its reduced position by the plate or by a provisional Kirschner wire (K-wire) (Figure 10). The K-wire should be directed away from future plate placement. In another reduction technique, K-wires were placed into the articular segment and used as joysticks to restore the neck–shaft angle. After confirmation with fluoroscopy, the reduction was stabilized with K-wires into the glenoid (Figures 11, 12). When the fracture reduction could not be maintained because of inadequate assistance or fracture instability, K-wires were inserted anteriorly from the shaft into the head to temporarily stabilize the fracture.

After adequate reduction was obtained, the plate was inserted safely between the bursa and the greater

Figure 10. The tuberosity can be held into its reduced position by the plate or with a provisional Kirschner wire.

Figure 11. Preoperative radiograph shows the initial injury with an impacted articular segment.

tuberosity before the plate was advanced distally on the humerus. The axillary nerve was identified easily by inserting an index finger into the wound and curling it distally; the nerve, which runs transversely 5 cm distal to the lateral edge of the acromion, was readily palpable on the undersurface of the deltoid. The axillary nerve was protected manually as the deltoid was elevated and the plate slid distally beyond the fracture site. If any soft-tissue resistance was appreciated before the distal tip of the plate reached the deltoid insertion, the plate was removed and reinserted. Standardized orthogonal fluoroscopic images, including true anteroposterior and trans-scapular lateral views of the shoulder, confirmed correct plate position.

We routinely used a Synthes LCP proximal humerus plate (Synthes, Paoli, Pennsylvania). This plate was provisionally secured using either 2 K-wires or 2 drill bits (Figure 13). Each screw was prepared using standard AO technique and fluoroscopic guidance (Figure 14). An incision of 1.5 cm was made centrally over the distal 2 screw holes to facilitate screw preparation and placement. We attempted to fill the majority of locking screw

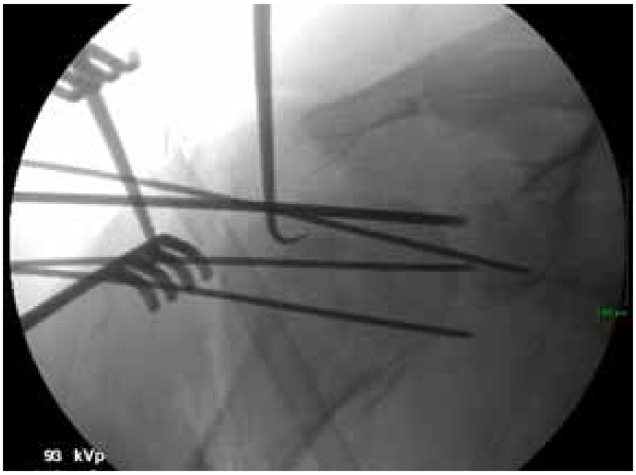

Figure 12. The articular segment was elevated using 2 Kirschner wires as joysticks. Once the reduction was confirmed under fluoroscopy, 2 Kirschner wires were used to stabilize the articular segment to the glenoid.

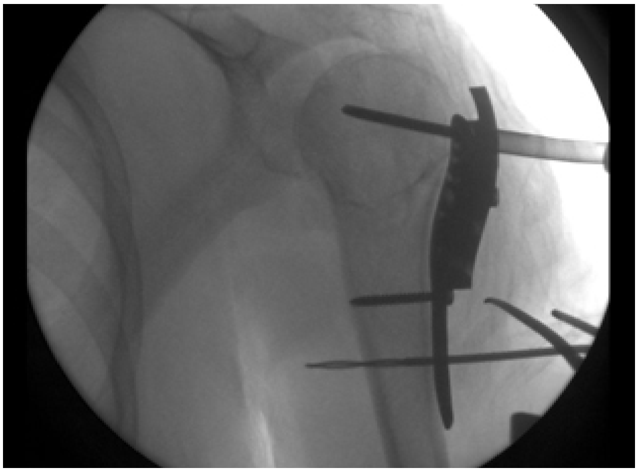

Figure 13. After insertion, the plate was provisional fixed to the proximal and distal fragments using drill bits.

holes into the humeral head proximally and place at least 3 bicortical screws into the distal fragment. We avoided placing screws within the vicinity of the axillary nerve, as this area usually correlates with the flare of the plate. The proximal aiming guide was used for placement of the 2 most superior screws. This provided enough stability to abduct the arm, thus protecting the axillary nerve and allowing for safe placement of the more distal screws. As proximal diaphyseal screws and distal screws in the guide pose a high risk for injury to the axillary nerve, we avoid placing screws in this area. A combination of locked and unlocked screws was used for each construct, depending on bone quality and screw position. Plate position and screw size were reassessed fluoroscopically and readjusted as necessary. Calcium phosphate cement (Norian; Synthes, Paoli, Pennsylvania) was used to augment fixation when bone stock was intraoperatively deemed to be of poor quality (Figure 15).

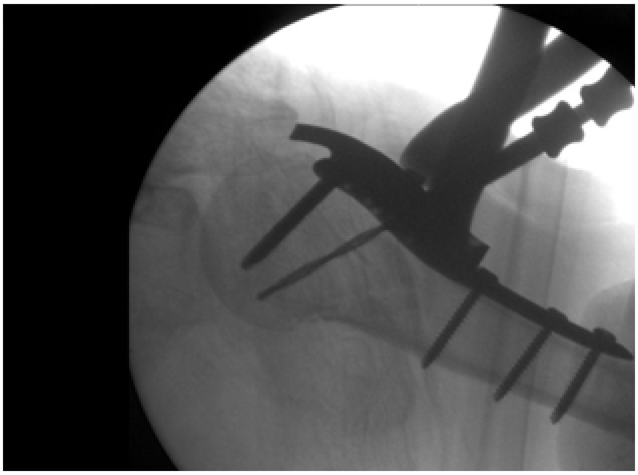

Figure 14. Proximal and distal screws were prepared and inserted through larger proximal and smaller distal lateral incisions.

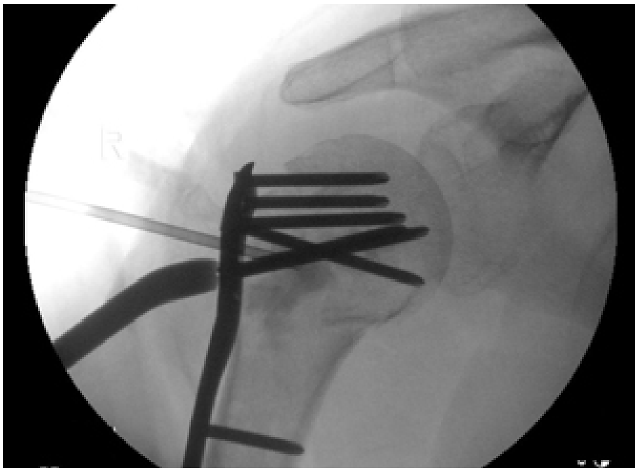

Figure 15. Percutaneous injection of calcium phosphate cement.

Before wound closure, the axillary nerve was palpated to ensure that the nerve was not ensnared by a screw or trapped beneath the plate. The deltoid fascia and subcutaneous tissues were repaired with a nonabsorbable suture, and the skin edges were reapproximated with staples or a running subcuticular stitch. A sterile dressing was applied with the extremity placed into a sling. Each patient began pendulum exercises immediately after surgery and started physical therapy using a standard shoulder protocol.[13,14]

Results

We evaluated all patients within 8 weeks after injury and found complete fracture healing, according to clinical parameters (no tenderness or crepitance at fracture site) and a radiographic parameter (bridging callus on at least 3 of the 4 cortices). Overall reduction was “good” in 18 patients (86%) and “fair” in 3 patients (14%). In 1 patient (4%), the reduction worsened during the postoperative

Figure 16. A 61-year-old female study patient with a 4-part proximal humerus fracture and ipsilateral open supracondylar humerus fracture.

Figure 17. She was treated with MIPO proximally and traditional open reduction and internal fixation distally.

period and required hardware removal after fracture healing (Figures 16–18). Mean (SD) neck–shaft angle of each humerus was 139° (9.3°; range, 123°-156°) during surgery and 138° (8.9°; range, 123°-159°) at final follow-up; mean difference between these measurements was 0.4°. All patient data fell within 2 SDs of the mean.

In addition, for each patient, displacement of the greater tuberosity was measured on final follow-up radiographs. Mean (SD) displacement from the most superior aspect of the humeral head articular surface to the top of the greater tuberosity was 4.3 (10) mm. There was 1 outlier with superior displacement of the tuberosity by 10.3 mm; all other patient data fell within 2 SDs of the mean.

Figure 18. During healing, reduction was lost and she developed impingement. The plate was removed after healing of the fracture, but significant functional limitations persisted over one year.

Clinically, there were no infections, nerve or vascular injuries, or cases of avascular necrosis. Thirteen patients had minimal blood loss (<50 mL), and the other 8 patients had mean blood loss of 197 mL (range, 75-500 mL). For each patient, we assessed ROM during follow-up visits. Mean (SD) active ROM was 143° 35.04°; range, 80°-180°) for forward flexion, 118° (46.8°; range, 45°-180°) for elevation in the plane of the scapula, and 33° (19.2°; range, 10°-65°) for external rotation at 0° of abduction. All patient data fell within 2 SDs of the mean.

The DASH questionnaire was administered to 21 patients. Mean DASH score was 25.95 (range, 0-80) and tended to correlate with both fracture type and reduction quality. Mean scores were 20.6 (range, 2.4-44) for patients with type A fractures, 23.2 (range, 2.5-65.8) for type B, 30 (range, 5.3-74) for type C, 26.2 (range, 2.5-65.8) for 2-part, 17.3 (range, 2.5-34.3) for 3-part, and 74 for the sole 4-part. In addition, mean scores were 21.9 (range, 2.5-65.8) for "good" reductions and 35.5 (range, 28.3-44) for "fair" reductions. Patients with isolated proximal humerus fractures had a mean score of 19.5 (range, 2.5-44), whereas the 5 patients with concomitant upper extremity fractures had a mean score of 36.6 (range, 2.5-74).

DASH scores were then used to evaluate clinical outcomes with respect to amount of greater tuberosity displacement. A previous anatomical study found the top of the greater tuberosity to be a mean of 8 mm below the most superior portion of the articular surface.[15] Park and colleagues[16] suggested reduction of fractures with 3 mm of displacement of the greater tuberosity in patients engaging in overhead activities. Given these 2 studies, a displacement range of 3 mm to 8 mm was determined to be the acceptable range for normal displacement of the greater tuberosity. Using these parameters, the patient data were divided into 3 groups: displacement between 3 mm and 8 mm (group A); displacement of less than 3 mm, including superior displacement of the greater tuberosity (group B); and displacement of more than 8 mm (group C). With 6 patients with associated injuries excluded, mean DASH scores for each group were then compared to see if there was clinical significance based on amount of greater tuberosity displacement. Group A had 9 patients with a mean DASH score of 11.8; group B had 3 patients with a mean score of 7.9; and group C had 3 patients with a mean score of 30.6.

Discussion

Treatment of proximal humerus fractures has been revolutionized by locked plating.[17-25] Previous instrumented fixation methods, including rods, nails, pins, and plates and screws, were often limited by inadequate purchase into the humeral head.[26-28] Locked plating provides more rigid fixation into the metaphyseal bone[29-34] and consequently allows for earlier mobilization, which theoretically decreases postoperative stiffness.

Before the advent of locked plating, minimally invasive techniques were limited to extra-articular diaphyseal or metaphyseal fractures or nondisplaced articular fractures amenable to isolated screw or pin fixation. Locked plating not only has afforded more effective stabilization of fractures with poor cortical bone, such as metaphyseal fractures or osteoporotic fragility fractures, but has allowed plating of these fractures through smaller incisions.[35]

Locked plating has prompted a growing trend toward obtaining stable fracture fixation through minimally invasive techniques. As the axillary nerve is consistently 5 cm to 7 cm distal to the lateral edge of the acromion,[36] percutaneous plate fixation is ideally suited to fractures involving the proximal humerus. Through the proposed incision, the axillary nerve can be palpated easily and protected. With these precautions, MIPO may be safer than other techniques, such as humeral nailing and percutaneous pinning, in which screws or pins may be blindly inserted adjacent to the axillary nerve.[37-40]

Evidence suggests that minimally invasive techniques also pose less risk to the vascular supply of the humeral head. In a cadaveric study of MIPO, Gardner and colleagues[41] demonstrated preservation of the humeral head arterial supply, which included the ascending branch of the anterior humeral circumflex vessel and an unnamed posterior branch, when the plate was placed in the "bare spot" on the proximal lateral region of the humerus. Several clinical studies have corroborated the benefits of minimally invasive vs standard open techniques in limiting incidence of avascular necrosis of the humeral head.[42,43]

Another advantage of this technique is the ability to obtain a "good" reduction of the greater tuberosity. Several authors have indicated that attaining anatomical reduction of the greater tuberosity is important to the ultimate outcome after proximal humeral fractures.[44-46] Previously, we advocated a 2-incision technique, a standard deltopectoral plus a small lateral incision, to facilitate fracture reduction and fixation.[47] Our clinical success with the 2-incision technique prompted our performing MIPO through a lateral incision. Given the high rate (86%) of "good" reductions in this series, we feel that this technique, which provides ample exposure to the greater tuberosity, allows for reduction of all fracture fragments. Patients with associated injuries were excluded, and there was shown to be a statistically significant (P = .05) difference in DASH scores between patients with greater tuberosity displacement within the normal range (group A) and patients with greater tuberosity displacement more than 8 mm inferior to the articular surface (group C).

In a clinical series on the effectiveness of MIPO for the treatment of proximal humerus fractures, percutaneous plating techniques were used, all fractures were 2- or 3-part valgus impact fractures, and all healed within 6 months without loss of correction or injury to neurovascular structures.[48] A recently published report documented shoulder abduction of more than 140° in 82.4% of 17 patients and bony union in all but 1 patient within 6 months of surgery.[49] In our series, there was no correlation between ROM and age, surgery delay, fracture type, or reduction quality. Although all patient data in our series fell within 2 SDs of the mean, the poorest ROM outcomes were found in patients with associated injuries, heterotopic ossification, or loss of reduction.

Patients in this series were followed for a mean of 24 months (range, 5-38 months). Two patients were followed for only 5 and 7 months, but all others were followed for at least 15 months, and maximum follow-up was 38 months. We were in contact with all patients through fracture healing. In cases of shorter follow-up, outcomes may have worsened after final follow-up, but previous reports have demonstrated that functional outcomes continue to improve 1 and 2 years after proximal humerus fractures are treated.[50-52] Our study results show that adequate functional results, as evidenced by acceptable DASH scores and ROM, can be achieved several months after MIPO for proximal humerus fractures.

Our study provides additional support for use of MIPO techniques in the treatment of proximal humeral fractures. Patients in our series regained a high level of functioning within a short period. Although still in its infancy for the treatment of proximal humeral fractures, MIPO offers a promising solution for a fracture that is often difficult to manage.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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