

Outcomes of Open Reduction and Internal Fixation of Proximal Humerus Fractures Managed With Locking Plates

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Abstract

We conducted a study to evaluate the outcomes and complications of open reduction and internal fixation (ORIF) of 2-, 3-, and 4-part proximal humerus fractures using a standard management protocol with locking plates.

Of 72 patients with acute proximal humerus fractures managed with ORIF and locking plates, 63 were available at the minimum follow-up of 1 year and met the inclusion criteria. At each follow-up, radiographs were reviewed for healing, hardware failure, osteonecrosis, shoulder range of motion, and DASH (Disabilities of the Arm, Shoulder, and Hand) scores; any complications were recorded.

Mean age was 62 years and mean follow-up was 19 months. There were 12 two-part fractures, 42 three-part fractures, and 9 four-part fractures. Thirteen patients had complications. Mean shoulder forward elevation was 135°; patients with complications had a significantly lower mean forward elevation ($P = .002$). DASH scores were significantly lower in patients without complications than in those with complications ($P = .01$).

Although excellent outcomes can be achieved when locking plates are used to manage proximal humerus fractures, complications are possible. Physicians must weigh the functional outcome data when considering management options for these types of injuries.

The proximal humerus fracture is the second most common fracture of the upper extremity and represents approximately 5% of all fractures.^{1,2} Most proximal humerus fractures are minimally displaced or stable, and can be successfully managed nonoperatively. In 15% to 20% of cases however, the fracture

pattern is displaced, unstable, and may disrupt the vascular supply to the humeral head. Operative management is indicated for these cases but can pose a difficult challenge for surgeons.^{3,4}

Use of locking plates, which has become increasingly common in managing complex fracture patterns, maximizes fracture stabilization by minimizing the peak stresses at the bone-implant interface.⁵ Despite the increasing popularity of using locking plates in proximal humerus fracture management, the literature on functional outcomes is still evolving, and the few clinical studies that have been conducted have revealed that the procedure is not without complications: osteonecrosis of the humeral head, fixation failure, infection, stiffness, and impingement. Some complications, such as screw penetration and implant breakage, seem unique to the implant.^{3,6-10} It is always important to critically assess such new technology because, in recent years, the pendulum has swung back toward open reduction and internal fixation (ORIF) for displaced 2-, 3-, and 4-part proximal humerus fractures.

We used radiographic and standardized functional measures to evaluate the outcomes of ORIF of 2-, 3-, and 4-part proximal humerus fractures using a standard management protocol, a proximal humerus locking plate (Synthes, Paoli, Pennsylvania), and soft-tissue–friendly techniques. We also examined the incidence of complications of this management option.

MATERIALS AND METHODS

This prospective analysis was performed on a consecutive series of patients who presented to our affiliated institutions with a displaced, unstable proximal humerus fracture, and were treated with ORIF with a standardized treatment algorithm using a locking plate. The 5-year study period ran from February 2003 to January 2008. The study received institutional review board approval at all the institutions where patients were treated.

Patients were included in the study if they were older than 18 and had an acute fracture caused by a low-energy mechanism. Patients with nonunions, malunions, and fractures resulting from a primary or metastatic tumor were excluded. All fractures were classified according to the Neer and Orthopaedic Trauma Association (OTA) systems.^{11,12} Demographics such as age, sex, fracture

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date, fracture type, and medical comorbidities, were gathered from patient records. Operative data, including patient position, surgery duration, blood loss, number of screws used, and intraoperative complications, were extracted from hospital records.

All patients had ORIF performed through a standard deltopectoral approach under the supervision of 1 of 7 fellowship-trained shoulder or trauma surgeons. The fracture fragments were mobilized indirectly with nonabsorbable sutures placed through the rotator cuff tendons adjacent to the displaced tuberosity fragments. The humeral head was elevated and reduced through a lateral cortical window, and the defect was grafted with either cancellous chips or calcium phosphate cement. The medial cortex of the fracture fragments was anatomically reduced, as were the tuberosities, and then the locking plate was applied to the lateral aspect of the humeral shaft, just lateral to the bicipital groove. All proximal locking screws were placed in a unicortical fashion, through an external guide, and intraoperative fluoroscopy (ie, anteroposterior internal and external rotation and axillary views) was used to confirm that the screws were within the humeral head, the goal being 5 to 10 mm short of subchondral bone. The screws placed in the distal shaft, a combination of locking and nonlocking screws, were bicortical. How many screws to use and where to position them within the proximal and distal segments were left to the discretion of the treating surgeon. Finally, the nonabsorbable braided sutures were tied down to the plate after plate and screw placement.

After surgery, all patients participated in a postoperative therapy protocol, which was similar across patients. Isometric deltoid, biceps, and triceps strengthening exercises were started immediately on postoperative day 1. Patients were placed in a sling and were encouraged to perform passive range-of-motion (ROM) shoulder exercises the first 4 to 6 weeks after surgery until there was radiographic evidence of fracture healing. Patients then began active ROM exercises in a formal physiotherapy program.

Patients were evaluated 1, 6, 12, 26, and 52 weeks after surgery. For each patient, the treating surgeon and an independent researcher determined active ROM, pain, and discomfort levels. Patients were followed for a minimum of 12 months; when clinically indicated, follow-up was continued beyond 12 months. Any complications noted at follow-up visits were documented. Functional outcomes were measured with the DASH (Disabilities of the Arm, Shoulder, and Hand) questionnaire at 6 and 12 months. Higher scores indicate lower function and more-adverse symptoms, while lower scores indicate higher function and less-adverse symptoms.¹³⁻¹⁵

Radiographic imaging consisted of the standard shoulder trauma series: anteroposterior, scapular Y, and axillary views taken before and during surgery and at follow-up visits. All radiographs were evaluated for fracture healing, hardware position, anatomical alignment, and evidence of postoperative osteonecrosis (Figure 1). A single observer determined the head-shaft angle for each patient in accordance with a method described in the literature.¹⁶ Line a-b was drawn from the superior border to the inferior border of the articular cartilage of the humeral head, and then line c-d was drawn perpendicular to a-b. The angle between line c-d and a line bisecting the humeral shaft was determined to be the head-shaft angle (Figure 2).¹⁶

Patient data were statistically analyzed to determine associations between variables and outcomes/complications. Tests for significance were conducted, the *t* test for continuous variables and the Fischer exact test for categorical variables. All tests were 2-tailed and differences were considered significant when $P < .05$.

RESULTS

Of the 72 consecutive patients with a proximal humerus fracture managed with ORIF at our institutions, 63 (88%) had the minimum follow-up of 12 months and met criteria for inclusion in the study. The other 9 patients were excluded because they did not have acute fractures or had nonunions or malunions. Mean follow-up for the



Figure 1. Radiographic imaging of a 3-part fracture treated with locked plate in a 60-year-old female. From left to right: preoperative anteroposterior (A) and axillary (B) views demonstrate an OTA class C2 proximal humerus fracture and a postoperative anteroposterior view after ORIF (C).

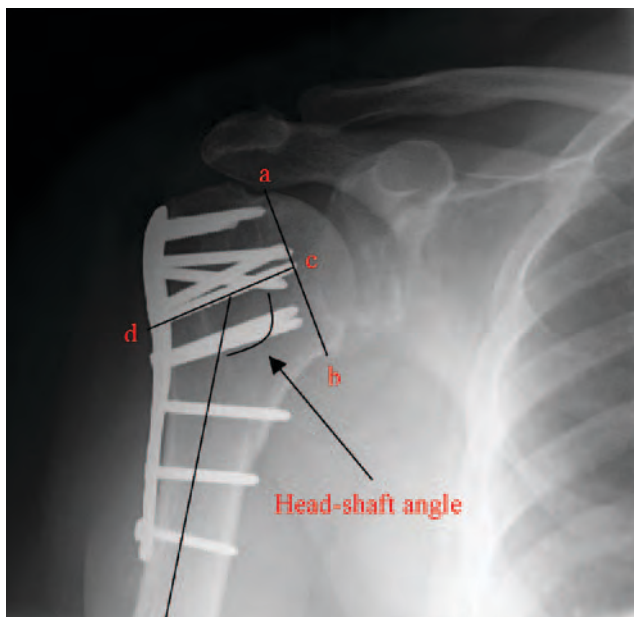


Figure 2. Head-shaft angle is measured by drawing a line (a-b) from the superior to inferior border of the articular cartilage of the humeral head and then a line (c-d) perpendicular to this. The angle between this line (c-d) and a line bisecting the humeral shaft was determined to be the head-shaft angle.

cohort was 19 months (range, 12-64 months). Sixty-three acute fractures were identified in 63 adults (19 men, 44 women). Mean age was 62 years (women, 64 years; men, 57 years). According to the Neer system, there were 12 two-part fractures (19.0%), 42 three-part fractures (66.7%), and 9 four-part fractures (14.3%). According to the OTA system, there were 16 type A fractures (25.4%), 19 type B fractures (30.2%), and 28 type C fractures (44.4%) (Table I).

Mean forward elevation ROM for all treated patients was 135° at final follow-up. Mean forward elevation ROM was significantly less in patients with complications, compared with patients without complications ($P = .002$; 111° vs 142°, respectively). In addition, mean external rotation was significantly less in patients with complications than in those without ($P = .029$; 32° vs 44°, respectively). Radiographic assessment demonstrated that all 63 acute fractures united by 3 months after surgery. Mean head-shaft angle at union was 130°. There was no statistical difference in sex, age, fracture type, screws in humeral head, or head angle between

Table I. Patient Demographics (n = 63)

Patient characteristic		P-value*
Age (years)	62.1 (13.6)	.14
Gender (% women)	69.8	.14
Smoking (% yes)	11	.58
OTA Class		.79
A	25%	
B	30%	
C	44%	

*Statistical significance of patient parameter versus complication occurrence

patients with and without complications. However, patients with complications had significantly poorer functional outcomes and their DASH scores were significantly higher than the scores of patients without complications ($P = .01$; mean, 36.7 vs 19.6; standard deviation, 28.5 vs 19.1) (Table II).

DASH outcome scores were overall less favorable for the 13 patients (20.6%) with postoperative complications, but varied somewhat among individual patients (Table III). A 58-year-old man developed significant postoperative heterotopic ossification. ROM was severely diminished by the heterotopic bone in the deltoid musculature and at latest follow-up, the patient was able to forward-elevate only to 60°. However, he was pain-free and working as a train conductor again. DASH function score was 9.2.

Another patient, a 48-year-old man with a history of alcoholism and seizure disorder, had early implant failure. Operative management was delayed 20 days to optimize the patient’s medical condition. Fracture fixation failed after only 10 days, when the humeral head pulled off the shaft. Reverse shoulder arthroplasty was indicated, but because of poor compliance, resection arthroplasty was required. The patient’s functional outcome was, not surprisingly, poor (DASH score, 95.8).

Three patients had acute postoperative infections. A 61-year-old woman had a wound infection, secondary to a *Staphylococcus epidermidis* infection, that required irrigation, drainage, and intravenous antibiotics. Despite the infection, the fracture and the incision healed, the implant was retained, and the patient was freed of signs of infection (DASH score, 42.2). Another patient, a 61-year-old man, had a displaced greater tuberosity

Table II. Patient Outcomes (n = 63)

Patient Outcome	Complication	No Complication	Combined	P-value*
No. of head screws	6 (0.28)	5.7 (0.13)	5.8 (0.12)	.351
DASH	36.7 (7.9)	19.6 (2.7)	23.2 (2.8)	.013
Forward elevation	111.2 (7.5)	141.8 (4.4)	135.4 (4.1)	.002
External rotation	31.9 (6.4)	44.3 (2.3)	41.7 (2.3)	.029
Head-shaft angle	128.2 (4.1)	131.2 (1.6)	130.1 (1.5)	.410

*Statistical significance of patient outcome vs. complication occurrence

Table III. Complications and Select Patient and Surgical Variables

Patient	Gender	Age	Smoker	Neer Classification	DASH Score	Complication Type
1	F	83	N	3-part	90.8	Screw cutout, osteonecrosis
2	M	58	N	4-part	9.2	Heterotopic ossification
3	M	61	N	4-part	29.2	Greater tuberosity malunion, post-operative infection
4	M	46	Y	3-part	95.8	Hardware failure
5	F	71	N	3-part	40.5	Screw cutout
6	F	69	N	3-part	45	Screw cutout
7	F	61	N	3-part	42.2	Postoperative infection
8	F	74	N	3-part	34.2	Screw cutout
9	M	57	N	4-part	36.7	Postoperative infection
10	M	61	N	2-part	12.5	Screw cutout
11	M	80	N	2-part	6.9	Screw cutout
12	F	68	N	2-part	8.6	Screw cutout
13	F	81	N	2-part	25	Osteonecrosis

fragment on computed tomography 1 week after surgery and required revision for reduction and fixation. The postoperative course was further complicated by a wound infection (*Enterococcus* species) that required intravenous antibiotics and hardware removal with irrigation and debridement. DASH score after these interventions was 29.2. The third patient, a 57-year-old man, had an infected postoperative hematoma that required irrigation and debridement. Wound cultures grew levofloxacin-sensitive *Pseudomonas* and *Enterococcus* species, and the patient was successfully treated with a course of oral antibiotics. Hardware remained intact and DASH score at final follow-up was 36.7.

Screw penetration into the glenohumeral joint after fracture collapse was the most frequent complication in this study. Seven patients (11%) had screws that penetrated the humeral head. Five of the 7 had these screws removed (ROM and symptoms improved significantly); the other 2 were asymptomatic and did not require hardware removal. One patient who underwent screw removal, a 74-year-old woman with significant glenoid wear caused by intra-articular screw penetration, subsequently had shoulder arthroplasty. Mean DASH score for the 5-patient subgroup was 29.8 (range, 6.9-90.8).

Two patients in our series had osteonecrosis. One had concomitant screw penetration but did not require reoperation. ROM was limited to 30° of external rotation and 90° of forward elevation, and her DASH outcome measure (90.8) was in the high range for the subgroup of patients with screw penetration. The other patient's only complication was radiographic signs of osteonecrosis without complete head collapse. The screws fixing her implant buttressed the subchondral bone but did not penetrate the articular surface. DASH score at final follow-up was 25, and the patient was relatively symptom-free, with pain only at the extremes of motion.

DISCUSSION

Overall, our patients who had proximal humerus fractures managed with locking plates had good outcomes. First,

mean shoulder forward elevation ROM was 135°, which is better than that obtained with hemiarthroplasty and is comparable to that obtained with other forms of osteosynthesis. Second, the incidence of osteonecrosis in our series (2 patients, or 3%) was much lower than what has been reported historically with other forms of fixation. Osteonecrosis is a much-feared complication of proximal humerus fractures managed with operative fixation, because of the tenuous blood supply to the humeral head.

Early results of using locking plates in the management of displaced proximal humerus fractures have shown that this technology compares quite favorably with hemiarthroplasty and older fixation techniques. In our study, patients treated with locking plates had mean forward elevation of 135° and mean external rotation of 42°. Operative fixation with preservation of native anatomy has provided ROM superior to that obtained with hemiarthroplasty. Pain relief, however, has been more variable.

In a study of patients with hemiarthroplasties and long-term follow-up (5 years minimum), Antuna and colleagues¹⁷ found mean forward elevation of only 100° and mean external rotation of only 30°. Dietrich and colleagues¹⁸ compared locking plate osteosynthesis with hemiarthroplasty and reported significantly better functional outcomes with locking plate fixation. Similarly, Solberg and colleagues¹⁹ studied 3- and 4-part fractures managed with either fixed-angle plates or hemiarthroplasty and found that open repair with locking plates had better patient outcomes—especially with 3-part fractures—though the complication rate was higher.

Outcomes of locking plates are comparable to those of alternative fixation techniques. Handschin and colleagues²⁰ compared one-third tubular plates and Philos implants (Synthes, Paoli, Pennsylvania), and found no significant difference in complication rates or functional outcomes. They also observed that locking plates may be advantageous only in certain settings, such as osteoporotic bone. In another study, which compared plate osteosynthesis using angular stable screws (Philos,

Synthes, Paoli, Pennsylvania) and intramedullary nailing (Targon PH nail, Synthes, Paoli, Pennsylvania), there was no statistical difference in functional outcomes between the groups at 1-year follow-up.²¹

Although locking plates have the potential to improve management and outcomes of some complex fractures, we tried to critically evaluate our experience with locking plates by closely examining patient outcomes, particularly in the presence of postoperative complications. Thirteen patients (21%) in our series had complications and 9 patients (14.3%) required additional surgery. Screw penetration into the glenohumeral joint space was the most prevalent complication we found. This complication can arise from improper placement of hardware resulting from poor intraoperative images, screw migration, implant shifting, or collapse of the subchondral bone into the stationary hardware.²² This type of complication can require reoperation and may cause significant injury to the glenoid or humerus, leading to permanent loss of joint function.²³

In the current literature on locking plates used in proximal humerus fractures, the reported incidence of screw penetration has varied. In one study, Lill and colleagues⁸ reported that in 17% of treated patients, screws placed in the humeral head were too long. In another study evaluating fixed-angle plating of the proximal humerus, Fankhauser and colleagues⁶ found screws cutting into the humeral head in 3 of 29 patients (10%). In a series of 176 patients treated with Philos plates, Kettler and colleagues²⁴ reported 24 screw penetrations into the glenohumeral joint. Finally, in a prospective study of fixed-angle plate osteosynthesis, Helwig and colleagues²⁵ noted screw penetration has replaced secondary displacement and implant loosening as complications of using conventional plates. They reported a screw penetration rate of 13% (11/87) and an osteonecrosis rate of 10% (9/87).

Our study results have shown that, even with meticulous placement of screws aided by intraoperative fluoroscopy, screw penetration can occur. We believe that fracture settling occurs after surgery and may lead to intra-articular screw penetration. Gardner and colleagues²⁶ emphasized the importance of reducing the medial calcar to maintain fracture reduction and prevent fracture collapse. We also believe that augmenting the fracture site with cancellous chips or calcium phosphate cement may provide structural support to limit fracture settling and possibly prevent screw penetration. In the present study, the decision to use or not use structural graft was left to the operating surgeon. Sixty-one percent of the fracture sites were augmented, including 32% with cancellous chips and 29% with calcium phosphate cement (29%). Pursuing this as an active investigation, we have found that patients treated with calcium phosphate cement showed less radiographic evidence of fracture settling and had a lower complication rate.

The rate of osteonecrosis associated with the frac-

ture pattern, or with the soft-tissue dissection needed in traditional plating, has been found to be as high as 35%.^{27,28} In our series, the incidence was relatively low; only 2 patients (3%) showed radiographic signs of osteonecrosis. This rate was consistent with the 4%-16% range reported in several other studies of proximal humerus locking plates.^{3,6,7,9,10} Investigators have noted that the relatively low rates appearing in the literature may be attributable to advantages in surgical technique and less soft-tissue stripping allowed with a fixed-angle construct.^{27,29}

In our investigation, we used DASH scores as the main measure of functional outcomes, as the DASH score is the most widely studied shoulder disability questionnaire.³⁰ The mean score for patients in our series was 23.2; scores were significantly lower, indicating better function, for patients without complications. Complications can severely affect patients' ROM, function, and satisfaction. Other investigators have reported similar findings. Owsley and Gorczyca³¹ found a mean QuickDASH score of 15 for all 34 patients in their study. Patients without radiographic evidence of complications had a mean score of 12 and patients with complications had a mean score of 22 ($P < .001$).

Our study had several limitations. The cohort included patients who were operated on by several different surgeons. Although a standard operating protocol was implemented, slight variations in surgical technique and in surgeon experience in performing a new procedure or using a new implant may have influenced study results. In addition, there was no comparison group of patients treated either nonoperatively or with an alternative device. Patients were selected for operative fixation on the basis of fracture severity, clinical indication, and radiographic presentation. Lastly, the decision to treat a patient operatively and the decision to use the Philos plate were left to the treating surgeon.

CONCLUSION

Locking plates provide reasonable fixation and stability for these fractures. The literature on functional outcomes of locking plates about the proximal humerus is continuing to develop, and it remains to be seen if this new technology is the best management option for these fractures or is merely comparable with other fixation constructs. More research is needed on the functional outcomes of using locking plates about the proximal humerus, as this relatively new technology is becoming more widely used.

AUTHORS' DISCLOSURE STATEMENT

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

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Guest Editorial

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One result of having clinics qualified to conduct high-quality research is the creation of a scientific network that provides benefits to both the centers (ie, trained and motivated personnel, increased attractiveness to other sponsors, etc.) and the AO Foundation (ie, a readily accessible network of centers where clinical research can be conducted to a known level).

While the program is currently being prepared for a global rollout, the pilot phase conducted in 25 clinics on 3 continents received very good feedback. The concept could serve as a model for other programs, on either a national or international level. Indeed, just like the American College of Surgeons set standards for levels, and provides ongoing qualification for Trauma Centers in the US, there should be no restraint to doing similarly for the evidence providers at orthopedics and/or trauma centers. Just like EBM, the idea is simple and malleable enough to be shaped for other purposes.

Although many factors may influence the results of a trial, we are duty-bound to strive to conduct these studies to the highest level possible. The creation of a strong network of EBM-trained sites which produce more and better evidence on the increasing number of different

treatment options will definitely help orthopedic surgeons in the choices they make for their patients.

In the end it is the patient who will benefit most from initiatives like this one... just as it should be.

AUTHORS' DISCLOSURE STATEMENT

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

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