Locked Plating of 3- and 4-Part Proximal Humerus Fractures in Older Patients: The Effect of Initial Fracture Pattern on Outcome

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Objectives: The use of locked plates in repairing osteopenic 3- and 4-part proximal humerus fractures remains controversial. The purpose of this article was to report the outcomes of open reduction and internal fixation in low-energy proximal humerus fractures treated with locked plating in patients older than 55 years and stratify risk of failure or complication based on initial radiographic features.

Design: Retrospective.

Setting: Level I Trauma Center.

Methods: Seventy patients older than 55 years undergoing locked plate fixation for Neer 3- or 4-part proximal humerus fractures were studied retrospectively. All patients had standardized, true size digital radiographs of the injured and normal shoulder in the axillary, scapular Y, and 20-degree external rotation views with a minimum of 18 months' clinical follow-up. Two groups were identified based on the initial direction of the humeral head deformity: varus or valgus impaction. There were no statistical differences between treatment groups with regard to age, sex, Neer classification, follow-up, or dislocation. Radiographic measurements included humeral head angulation, tuberosity displacement, and length of the intact metaphyseal segment. Clinical outcomes measured Constant scores (CS) using active range of motion at latest follow-up.

Results: Twenty-four patients with initial varus fracture patterns healed with an average of 16-degree varus head angulation and an overall CS of 63 at an average of 34 months' follow-up. Forty-six patients with initial valgus fracture patterns healed with an average of 6 degrees of varus angulation and an overall CS of 71 at an average of 37 months' follow-up ($P < 0.01$). Complications of avascular necrosis, humeral head perforation, loss of fixation, tuberosity displacement >5 mm, and varus subsidence >5 degrees were encountered in 19 of 24 (79%) in the varus group compared with 9 of 46 (19%) in the valgus group ($P < 0.01$). Final CSs for 3-part fractures were 65 versus 72 ($P < 0.01$) for varus and valgus groups, respectively, and 61 versus 69 ($P = 0.19$) for 4-part fractures.

Conclusions: Neer 3- and 4-part proximal humeral fractures in older patients with initial varus angulation of the humeral head had a significantly worse clinical outcome and higher complication rate than similar fracture patterns with initial valgus angulation. Two factors had significant influence on final outcome in these fracture patterns: initial direction of the humeral head angulation and length of the intact metaphyseal segment attached to the articular fragment. The best clinical outcomes were obtained in valgus impacted fractures with a metaphyseal segment length of greater than 2 mm, and this was independent of Neer fracture type. Humeral head angulation had the greatest effect on final outcomes ($P < 0.001$), whereas metaphyseal segment length of less than 2 mm was predictive of developing avascular necrosis ($P < 0.001$).

Key Words: locked plate, osteopenic, proximal humerus fracture

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Each author certifies that his or her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research and that informed consent for study participation was obtained.

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INTRODUCTION

Treatment of 3- and 4-part proximal humerus fractures in patients with osteopenia poses a difficult clinical challenge. The use of locking plates has allowed surgeons to treat a greater percentage of proximal humerus fractures with open reduction and internal fixation (ORIF) and retention of the native humeral head.[1] Outcome data suggest that if a good reduction can be obtained and maintained, ORIF patients have better clinical outcomes than patients undergoing hemiarthroplasty.[1–4] The most common cause of poor outcomes with ORIF are varus subsidence of the humeral head, screw perforation, and implant cut-out.[5,6] Unfortunately, delineating which fracture patterns within the Neer and OTA classification systems are at increased risk for subsidence or cut-out has not been clearly defined. Moreover, most series using locked implants for proximal humerus fractures do not stratify rate of failure or outcome in 3- and 4-part fractures in individuals with osteopenia.[3,6] The purpose of this article was to report the outcomes of ORIF in low-energy proximal humerus fractures in patients older than 55 years treated with locked plating and stratify risk of failure or complication based on initial radiographic features.

PATIENTS AND METHODS

A total of 70 patients' Neer 3- and 4-part proximal humerus fractures treated with locked plating at our institution between January 2002 and December 2006 were studied retrospectively. Approval from the Institutional Review Board was obtained for retrospective review of patient records and radiographs, and informed consent was obtained for all patients included in the final study groups. Inclusion criteria were low-energy 3- or 4-part proximal humerus fractures in patients older than 55 years treated with a locked plate and a minimum of 18 months clinical and radiographic follow-up. Three fellowship-trained orthopaedic trauma surgeons were involved in the surgical management of all patients. Hemiarthroplasty was selected in patients with displaced articular surface fracture or head split patterns, displacement of the anatomic neck greater than 2 cm, impaction of the articular surface, dislocation of the humeral head greater than 24 hours, documented previous rotator cuff tear, or an inability to perform ORIF via an open technique. All other patients underwent an attempt at ORIF with a locked plate. Five patients undergoing ORIF were converted to hemiarthroplasty because of inability to reduce the fracture (3) or iatrogenic head split (2).

Patients were excluded if they expired during the review period, had a pathologic fracture of the proximal humerus, underwent surgical repair via a deltoid split approach, had a documented full thickness rotator cuff tear at the time of initial repair, and sustained a traumatic fracture of the humerus, glenoid, or glenohumeral dislocation during the follow-up period. Fractures were classified according to the Neer and OTA fracture classification systems based on the initial radiographs or computed tomography (CT) scans [which were available in 58 of the 70 (83%) patients]. Fracture parts were defined by using Neer criteria of greater than either 1 cm of displacement or 45 degrees of angulation, and initial radiographs were evaluated by 3 senior authors for number of parts; in cases of disagreement (9/77, 12%), a majority vote prevailed.

All patients had 20-degree external rotation anterior-posterior (AP), scapular Y, and axillary views of the uninvolved shoulder for comparison and assessment of reduction, implant position, and tuberosity displacement or migration. All films were taken at a standardized distance (40 inches) using a true size digital format, and measurements were calculated using a Picture and Archiving Communication System distance and angle measuring software (Kodak, Rochester, NY) by the senior author. Tuberosity displacement was defined as the sum of the greater and lesser tuberosity displacement on the AP and scapular Y view by overlaying the 2 true size images over one another and measuring the greatest extent of displacement. Head–shaft angulation was calculated using the 20-degree external rotation view by a tangent to the articular surface versus a line parallel to the long axis of the humeral shaft as previously described by Hertel et al[7]. The direction of the initial angulation of the humeral head was classified as varus/extension or valgus/impaction based on comparison of the neck–shaft angle with the uninvolved shoulder (Figs.1–3). Metaphyseal segment length was defined as the amount of intact metaphyseal bone in millimeters attached to the anatomic head fragment on the initial AP x-ray or CT scans, if they were available. Patients with suspected tuberosity nonunion or progressive tuberosity migration underwent CT scan to confirm tuberosity nonunion.

A total of 64 patients with valgus impaction 3- or 4-part fractures treated with locked plating were identified. Eighteen patients were excluded: 11 patients had incomplete follow-up, 3 patients expired, 2 patients underwent deltoid split surgical approach, 1 patient sustained a displaced glenoid fracture, and 1 patient refractured the proximal humerus during the follow-up period. Forty-six patients (72%) were included and had a complete clinical and radiographic follow-up for a minimum of 18 months. Mean age for this group was 67.4 (±6.7) years, with 36 women and 9 men and an average follow-up of 37 months. Using the OTA classification, 19 (41%) were type 11-C1, 23 (50%) were type 11-C2, and 4 (9%) were type 11-C3. Four patients (9%) had initial glenohumeral dislocation. Using the Neer criteria, 27 (59%) were 3-part and 19 (41%) were 4-part fractures.

Thirty-one patients with varus (OTA Type B) 3- or 4-part fractures treated with locked plating during the same period

FIGURE 1. The typical radiographic appearance of a valgus impacted fracture.

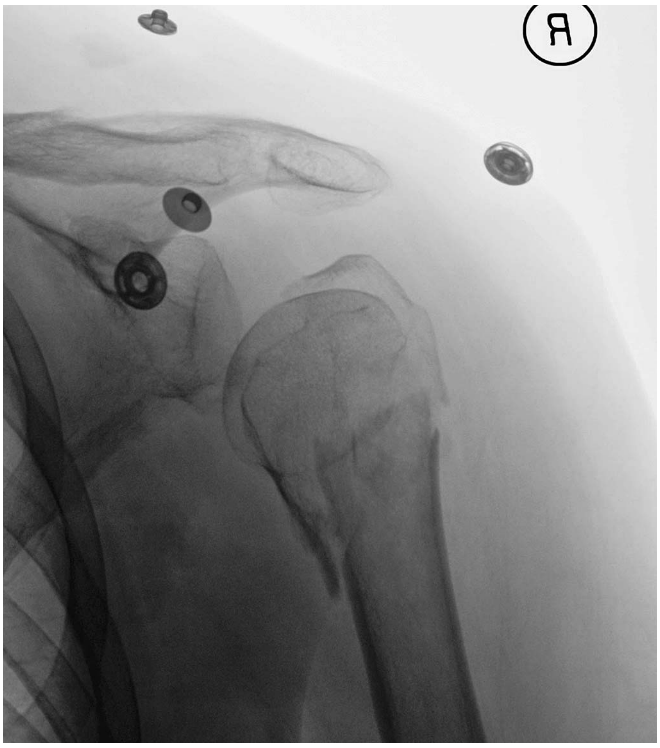

FIGURE 2. The typical radiographic appearance of a varus fracture.

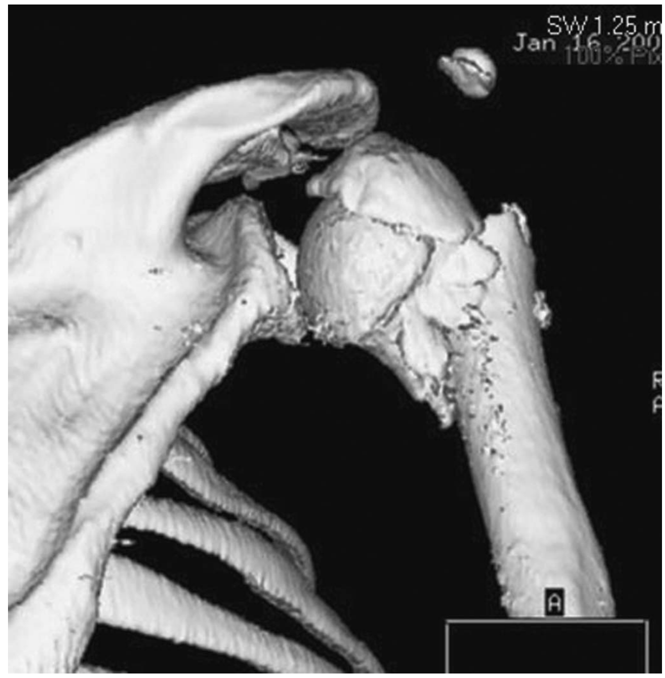

FIGURE 3. A 3-dimensional CT scan of the same varus extension fracture confirming 3 parts.

were identified. Seven were excluded: 4 had incomplete follow-up, 1 patient expired, 1 had a full thickness rotator cuff tear documented at the time of the index procedure, and 1 patient sustained a refracture of the proximal humerus requiring revision. Twenty-four patients (77%) had complete clinical and radiographic follow-up for a minimum of 18 months. Mean age for this group was 65.6 ($\pm$11.0) years, with 17 women and 7 men and an average follow-up of 34 months. Using the OTA classification, 8 (33%) were type 11-B1, 9 (27%) were type 11-B2, and 7 (29%) were type 11-B3. Dislocation was present in 7 patients (29%). Using the Neer criteria, 14 (58%) patients had 3-part fractures and 10 (42%) had 4-part fractures.

Surgical repair used 1 of 3 locked proximal humeral plate systems: Synthes (West Chester, PA), Stryker (Mahwah, NJ), and Zimmer (Warsaw, IN). Implant selection was not randomized and was subject to surgeon preference. Patients in both groups underwent surgical treatment at an average of 5.2 days postinjury. Surgical repair was performed in the supine position on a radiolucent table via a standard deltopectoral surgical approach with image intensification brought from the ipsilateral side. Surgical dissection was undertaken in the fracture line between the tuberosities, and articular surface reductions were carried out using a tamp on the lateral articular margin or an elevator under the medial calcar segment. Tuberosity fragments were manipulated using K-wires, sutures through the intact rotator cuff attachment, or tenaculum clamps. Fractures were reduced and provisionally fixed with K-wires before application of the locked plate. Internal fixation was applied under image intensification in the AP and lateral and axillary views to verify reduction, plate position, and screw lengths. Screw position was evaluated with live fluoroscopy, and screws were placed within 5 mm of the subchondral bone at the time of repair. Tuberosity repair was augmented using nonabsorbable sutures through the rotator cuff tendons in the cephalad suture holes in the plate. Radiographs (20-degree external rotation anteroposterior and axillary views) were taken intraoperatively or immediately postoperatively to assess reduction and implant position. Five patients (5/70, 7%) were taken back to the operating room within 48 hours for humeral head screw perforation >3 mm (Fig. 4). For patients presenting with late onset screw perforation, CT scans were performed to assess the magnitude and location of the implant perforation.

Patients underwent closure over a small suction drain and were immobilized in a sling for the first 10 days postoperatively. Physical therapy was started with gentle Codman and active-assisted range of motion within the first 2 weeks postoperatively. Gentle resistive exercises with unrestricted passive motion were begun at 6 weeks postoperatively. Patients were followed clinically and radiographically at 2 and 6 weeks postoperatively and at 3-month intervals thereafter. Shoulder outcomes were assessed using the Constant–Murley scoring system based on the shoulder examination at the last clinical follow-up.[8,9] Average range of motion testing using a goniometer was used for the range of motion portion of the scoring system. Power testing was performed using a digital dynamometer with the elbow extended and the shoulder abducted at 60 degrees.

Statistical analysis was reviewed by a biostatistician. Group demographics were compared using a Fisher exact test

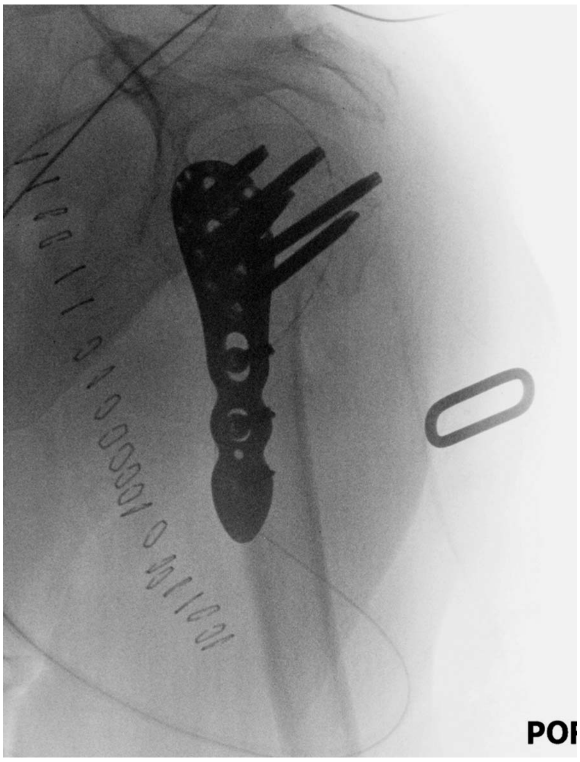

FIGURE 4. Immediate postoperative film showing posterior–superior screw perforation of the humeral head.

FIGURE 5. The method used for measuring humeral head to shaft angulation.

or Student *t*-test, whereas group outcome data were analyzed using a Mann–Whitney test (Wilcoxon rank sum test). Correlation was analyzed with a Spearman correlation coefficient. Level of significance was set to $P \leq 0.05$.

RESULTS

The demographics of the 2 groups were comparable, and there was no difference between the 2 groups with regard to age, sex, Neer fracture type, length of follow-up, or dislocation (Table 1). The varus group had an overall mean Constant score (CS) of 63.3 (±7.2); 3-part fractures averaged 65.1 (±5.1) versus 60.8 (±8.9) points in 4-part fractures at the last follow-up ($P = 0.11$). CSs in patients with less than 5-degree initial varus malreduction were 68.0 (±2.8), whereas patients with less than 10 degrees of initial varus malreduction had an overall CS of 65.4 (±3.5, $P = 0.22$). The valgus impaction group had a mean CS of 71.2 (±9.7); 3-part fractures averaged 72.4 (±9.5) points and 68.5 (±9.9) points in 4-part fractures at the last follow-up ($P = 0.09$). CSs in patients with less than 5-degree initial varus malreduction were 74.1 (±6.9), whereas patients with less than 10 degrees of initial varus malreduction had an overall CS of 72.9 (±9.6, $P = 0.24$). Outcome data for the 2 groups are summarized in Table 2.

The complication rates were significantly different between the 2 groups (Table 3). The overall complication rate for the varus group was 19/24 (79%) versus 9/46 (19%) in the valgus group ($P < 0.01$). Complications in the varus group included 2 wound infections with 1 patient requiring surgical debridement, screw perforation of the humeral head in 5 (21%), initial varus malreduction of >5 degrees in 17 (71%), and loss of fixation in 3 (13%). Complications in the valgus group included 3 wound infections, screw perforation of the humeral head in 3 (7%), initial varus malreduction >5 degrees in 8 (17%), and loss of fixation in 3 patients (7%). The 6 patients with loss of fixation had initial varus malreduction in excess of 20 degrees and the mean CS for this group at latest follow-up was only 47 (43–49) despite conversion to secondary hemiarthroplasty. Implant failures occurred within 10 weeks of initial repair, and hemiarthroplasty was performed within 17 weeks of the index procedure. There were no cases of locked plate fracture.

Secondary surgical procedures more than 6 months after the index procedure were performed in 29 patients. Implant removal for mechanical subacromial impingement was performed in 15 patients (63%) in the varus group versus 7 patients (15%) in the valgus group ($P = 0.02$) at an average of 9.6 (±6.4) months postoperatively. Three patients developed CT scan-confirmed nonunion of the greater tuberosity (2 varus and 1 valgus) requiring revision with autogenous bone grafting. Four patients (2 varus and 2 valgus) developed late screw perforation of the humeral head at an average of 7.2 (±5.4) months postoperatively requiring screw removal.

Avascular necrosis (AVN) rates were comparable between groups and developed in 5 patients (21%) in the

FIGURE 6. The method used for measuring metaphyseal segment length.

varus group versus 7 patients (15%) in the valgus group (P = 0.34). Of the 12 patients with AVN, 9 patients developed this complication within the first 9 months of follow-up, 2 patients between 10 and 18 months, and 1 patient developed AVN at 22 months postoperatively. Six patients (50%) had a dislocation at the time of presentation. However, all 12 patients developing AVN had a metaphyseal segment length of less than 2 mm, whereas the 58 patients with a metaphyseal segment length of 2 mm or more did not develop AVN, and this was independent of the presence or absence of initial dislocation ($P < 0.001$). CSs in the AVN group were significantly less (CS 62.1 ± 4.5)

TABLE 1. Patient Characteristics of Both Groups

	Varus OTA Type B	Valgus OTA Type C	*P*
N	24	46	
Age in yrs (mean ± SD)	65.6 (±11.0)	67.4 (±6.7)	0.46 (*t* test)
Follow-up	34.2 (±13.0) m	36.7 (±12.8) m	0.45 (*t* test)
Male/Female	7/17	9/36	0.28*
3-part fractures	14 (58%)	27 (59%)	0.83
4-part fractures	10 (42%)	19 (41%)	
Dislocation	7 (29%)	4 (9%)	0.09*

Values are expressed as mean ± SD.
*Fisher exact test.

TABLE 2. Outcomes Data for the Two Groups

	Varus	Valgus	*P* (MW)
Total score	63.3 (±7.2)	71.2 (±9.7)	<0.01
Pain	11.7 (±2.9)	13.2 (±3.0)	0.06
Power	14.6 (±1.1)	16.6 (±4.3)	<0.01
Range of motion	22.9 (±3.2)	25.0 (±4.3)	0.04
ADL	14.0 (±2.0)	16.0 (±1.8)	<0.01
3-part fractures	65.1 (±5.1)	59.7 (±6.4)	<0.01
4-part fractures	60.8 (±8.9)	59.8 (±6.2)	0.19
Good reduction (<5 degrees malreduction)	68.0 (±2.8)	74.1 (±6.9)	0.08
Satisfactory reduction (<10 degrees varus malreduction)	65.4 (±3.5)	73.0 (±7.4)	<0.01
Non-AVN	63.6 (±8.0)	72.9 (±9.6)	<0.01

Values are expressed as mean ± SD.
MW, Mann–Whitney test (Wilcoxon rank sum test); ADL, Activities of daily living.

than the valgus group ($P < 0.01$) but were comparable to the varus group (P = 0.19).

Initial tuberosity displacement in the varus group averaged 9.0 ± 5.0 mm compared with 4.0 ± 4.6 mm in the valgus group ($P < 0.001$). Progressive tuberosity drift averaged 7.2 ± 4.6 mm in the varus group versus 2.3 ± 3.6 mm for the valgus group ($P < 0.001$). Two radiographic factors, tuberosity displacement and humeral head angulation, were independently assessed for their influence on final outcomes. The correlation between humeral head angulation on final CS was highly significant ($r^2 = 0.74$, $P < 0.001$), whereas the correlation between initial tuberosity displacement did not reach statistical significance ($r^2 = 0.62$, $P = 0.16$).

DISCUSSION

Optimal treatment of 3- and 4-part fractures of the proximal humerus in patients with poor bone quality is controversial.[3,6] The use of locked implants, which maintain angular stability in the face of axial load, has demonstrated significant benefit over standard plating in biomechanical studies; however, the clinical benefit has not been as widely accepted.[10,11] The advantage of these devices in more complex fracture patterns has not been clearly defined, and complications including loss of fixation or humeral head screw

TABLE 3. Complications

Complication	Varus (n = 24)	Valgus (n = 46)	*P*
AVN, n (%)	5 (21)	7 (15)	0.33
Head perforation, n (%)	5 (21)	3 (7)	0.08
Varus subsidence (degrees)	7.2 (±4.7)	2.4 (±3.6)	0.02
Initial varus malreduction >5 degrees, n (%)	17 (71)	8 (17)	0.02
Loss of fixation, n (%)	3 (13)	3 (7)	0.14
Total complications, n (%)	19 (79)	9 (19)	<0.01

perforation have led to difficult problems.[6] Interpretation of outcomes studies in the literature has been compounded by significant interobserver variation in classifying these fractures using either the OTA or the Neer systems.[12] Determining which fractures are at higher risk of complications in soft bone is unclear, and some studies still advocate endoprosthetic replacement for most fracture patterns.[13] The purpose of our series was to report the outcomes of 3- and 4-part fractures in older patients treated with locked plating and identify which fracture patterns seemed to be at higher risk for complications including loss of fixation and AVN.

One of the inherent weaknesses of this series stemmed from difficulty in classifying the fracture patterns using the OTA and Neer systems. For example, the Neer system did not take initial humeral head angulation into consideration. Using the OTA classification, displaced varus/extension fracture patterns were considered "extraarticular" even though tuberosity involvement was confirmed radiographically. In addition, many of the varus fractures had more than 1-cm displacement of the head fragment and could have been grouped as C2 fractures based on the head displacement but were classified as B1 or B2 fractures because of the varus angulation and metaphyseal impaction. These issues confounded our ability to simplify our clinical decision making or devise an algorithm for these fractures based on these classification systems alone.

Other weaknesses of the study included the retrospective study design and lack of data on the variability and reproducibility of the methods we used to calculate the neck–shaft angle, tuberosity displacement, and overall quality of reduction using plain film technique. We did not control strictly for arm rotation during the radiograph process and were unable to calculate the extent of potential error introduced by this factor and body habitus. Moreover, the use of 3 different implants in the repair process may have added additional confounding variables to the data, which were not addressed.

Surgical treatment of varus fracture patterns was problematic in many regards. They were more difficult to obtain an initial good reduction, and we had a significant learning curve during the first 12 months of the series. Initial varus malreductions were more common in this group (71%), and the presence of initial varus malreduction of more than 5 degrees was associated with progressive subsidence of the humeral head in all cases. The reason for this finding may be that the plate functions as a tension band by "pulling" the humeral head out of varus. In poor bone quality, varus fractures place the implant at a distinct mechanical disadvantage in which mechanical failure is determined by the pullout resistance of the screws rather than the compressive strength of the bone. Subsequent implant removal for subacromial impingement was more common in the varus group because of the progressive humeral head subsidence, which we observed in a majority of cases, effectively lateralized the upper portion of the plate. Overall, the varus group had worse outcomes because of an inability to obtain or maintain humeral head reduction. In these instances, additional methods to maintain reduction, such as strut or bulk allograft or additional screws along the calcar, should be considered. Treating surgeons should be cognizant of the high complication rates, especially in cases with greater than 60 degrees of initial varus angulation.

Valgus impacted fractures were easier to obtain and maintain a good reduction, and the overall complication rate and subsequent late problems were significantly less regardless of Neer fracture type. Varus malreduction was less common, and there was a significantly lower rate of malreduction, loss of fixation, and need for subsequent surgical procedures. Again, the differences may be due to manner in which the plate acts, which is as a mechanical strut under compressive forces in valgus patterns. In this setting, implant failure is determined by the compressive strength of the bone rather than resistance to screw pullout.

Our overall AVN rate of 12/70 (17%) was comparable to previous studies of 3- and 4-part fractures and may have been underestimated.[14] We performed CT or magnetic resonance imaging scans only in patients with radiographic evidence of humeral head collapse. The rate of AVN without radiographically visible articular collapse may be higher, but the presence of implants throughout the head precluded routine magnetic resonance imaging screening. We felt that 18 months' follow-up was sufficient for the development of this sequella, and only 1 patient (8%) developed AVN after the 18-month time frame. Despite the development of AVN, this group of patients did reasonably well clinically and were comparable to historical outcomes reported for hemiarthroplasty. None of the patients with AVN in our series requested conversion to hemiarthroplasty for continued pain. Given these relatively favorable outcomes, this complication may be better tolerated in the elderly population than previously thought.[14]

Aside from AVN, 3 other distinct complications were observed in both the varus and the valgus fracture pattern groups: tuberosity migration, varus humeral head displacement and subsidence, and humeral head screw perforation. Moreover, we observed humeral head screw perforation as 2 distinct groups: immediate postoperatively and late. The postoperative group was a product of missed head perforations, and this was largely corrected by using fluoroscopy from the ipsilateral side with live rotational views of the head for assessment of head perforation. The acute perforations were all in the posterior–superior quadrant, which is an area of the head that is difficult to visualize fluoroscopically. The late group developed screw perforation from progressive varus subsidence, and these were in the superior portion of the humeral head. Despite the presence of perforation, none of the patients had a significantly worse outcome as a whole than the other patients without screw perforation, and none of these patients developed significant erosive changes in the glenoid.

Humeral head varus malreductions had the greatest effect and correlation to final outcome. The patients with an initial varus malreduction of more than 5 degrees developed progressive subsidence of the humeral head and worse outcomes. The cutoff for progressive subsidence was about 5 degrees of initial humeral head varus malreduction. Conversely, although tuberosity displacement did demonstrate some progression over time, this was seen in conjunction with humeral head subsidence and was not significantly correlated with final outcome as an independent variable. Separating out the effects of humeral head subsidence and tuberosity migration was difficult and the 2 were linked to some extent. However, we found mechanical subacromial impingement to be more often associated with prominent hardware on the lateral aspect of the proximal humerus, and this complication was secondary to varus subsidence.

CONCLUSIONS

Based on our findings, we propose a simple method for stratifying risk of postoperative complications in older patients based on 2 radiographic criteria: direction of the initial humeral head displacement and length of the intact metaphyseal segment remaining attached to the intact articular fragment. Patients with valgus impacted fracture patterns and metaphyseal segment length of greater than 2 mm should undergo attempt at repair independent of Neer or OTA fracture types. Any patient with a metaphyseal segment length of less than 2 mm is at high risk of developing AVN. Patients with varus displacement and longer metaphyseal segments represent the greatest clinical dilemma. In these patients, if an initial varus malreduction of less than 5 degrees compared with the contralateral side can be obtained, ORIF is clearly favorable to hemiarthroplasty, but with 5–10 degrees of varus malreduction, there is no clear clinical benefit to ORIF based on our results. Patients with large amounts of initial varus angulation (>60 degrees) on initial AP radiographs or extensive comminution at the medial head neck junction were at highest risk for varus malreduction >10 degrees and should be approached cautiously. Any patient with varus malreduction of more than 20 degrees postoperatively failed in our series, and we consider this an indication for early conversion to hemiarthroplasty.

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