The Importance of Medial Support in Locked Plating of Proximal Humerus Fractures

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Objectives: The purpose of this study was to determine what factors influence the maintenance of fracture reduction after locked plating of proximal humerus fractures, and particularly the role of medial column support.

Setting: University medical center.

Intervention: Thirty-five patients who underwent locked plating for a proximal humerus fracture were followed up until healing. For the initial and final radiographs, 2 lines were drawn perpendicular to the shaft of the plate, one at the top of the plate and one at the top of the humeral head, and the distance between them was measured as an indicator of loss of reduction. Medial support was considered to be present if the medial cortex was anatomically reduced, if the proximal fragment was impacted laterally in the distal shaft fragment, or if an oblique locking screw was positioned inferomedially in the proximal humeral head fragment.

Main Outcome Measurements: Multivariate linear regressions were performed to determine the effects that age, sex, fracture type, cement augmentation, and medial support had on loss of reduction.

Results: The presence of medial support had a significant effect on the magnitude of subsequent reduction loss ($P < 0.001$). Age, sex, fracture type, or cement augmentation had no effect on maintenance of reduction. Eighteen patients were determined to have adequate mechanical medial support (+MS group), and the remaining 17 patients did not have medial support (–MS group). In the +MS group, the average loss of humeral head height was 1.2 mm, and 1 case of articular screw penetration occurred that required removal. In the −MS group (without an appropriately placed inferomedial oblique screw and either nonanatomic humeral head malreduction with lateral displacement of the shaft or medial comminution), loss of humeral height averaged 5.8 mm ($P < 0.001$). There were 5 cases in this group in which screw penetration of the articular surface occurred ($P = 0.02$), 2 of which required reoperation for removal. All fractures in both groups healed without delay, and none required revision to arthroplasty.

Conclusions: Achieving mechanical support of the inferomedial region of the proximal humerus seems to be important for maintaining fracture reduction. Locked plates in general do not appear to be a panacea for these fractures and are unable to support the humeral head alone from a lateral tension-band position. However, there are several factors that are in the surgeon's control that may improve the mechanical environment. Achieving an anatomic or slightly impacted stable reduction, as well as meticulously placing a superiorly directed oblique locked screw in the inferomedial region of the proximal fragment, may achieve more stable medial column support and allow for better maintenance of reduction.

Key Words: proximal humerus, fracture, locking plate, locked screw, complications

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INTRODUCTION

The recent introduction of locked plating has offered a novel biomechanical approach to stabilizing fractures. Although many fracture patterns in healthy bone may be reliably stabilized and have high success rates with traditional compression plating, locking plates may have a mechanical advantage over standard implants in osteoporotic bone.[1,2] The vascular anatomy around the proximal humerus precludes plate fixation as a buttress on the medial cortex,[3–6] and for this reason traditional lateral plate fixation of comminuted fractures has proven to be only moderately successful, often because of early loss of fixation.[7–13]

Few clinical reports exist on the results of locking plate fixation of proximal humeral fractures, and short-term functional outcomes and complication rates have been variable.[14–18] When locking plates are placed on the lateral proximal humerus, the mechanical environment is such that the fixed-angle screws are required to act as perpendicular struts to support the humeral head fragment and resist varus displacement. These forces may be exaggerated when there is a lack of medial column support, and the ability of these screws to perform this function is unknown. Guidelines have not been provided about appropriate placement of locking screws such that the mechanical advantage is optimized.

The purpose of this study was to evaluate the radiographic behavior of proximal humerus fractures treated with locking plates in a consecutive series of patients with

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acute fractures. In addition, we sought to determine what patient factors, fracture patterns, reduction variables, and implant placements affect the mechanical stability of fracture fixation. Our hypothesis was that mechanical support of the medial column would be particularly important for establishing a stable construct.

METHODS

The medical records and radiographs of 35 consecutive patients treated at our institution from March 2003 to February 2006 and who met the inclusion criteria were analyzed after approval from the institutional review board. Inclusion criteria included an acute traumatic fracture of the proximal humerus that was treated with open reduction and internal fixation using a locking plate, adequate preoperative and postoperative radiographs, and age older than 18 years. Patients were considered to have adequate follow-up when fracture healing occurred clinically and radiographically. Preoperative radiographs were evaluated by a fellowship-trained orthopedic traumatologist to determine fracture pattern according to the Neer[19] classification. The extent of medial comminution was specifically noted.

Surgical indications were all 3 part and 4 part fractures, as well as 2 part fractures with approximately 100% displacement or varus malalignment with medial cortical comminution, which were deemed to be unstable by the treating surgeon. Surgery was performed within several days of the traumatic event in all cases by one of 3 surgeons, all fellowship-trained, and was performed through a deltopectoral or an anterolateral acromial approach.[20,21] After surgical reduction, a locking plate was placed (Synthes, Paoli, PA) and the rotator cuff was secured to separate holes in the plate by using nonabsorbable suture. At least 5 locking screws were placed in the proximal fragment in all cases, but in several younger patients, 1 or 2 compression screws were additionally used to assist with indirect reduction techniques. Initial standardized postoperative radiographs were performed with the patient supine, the arm in neutral flexion and rotation, and the beam centered on the glenohumeral joint. These radiographs were analyzed for fracture reduction and implant placement. All patients participated in similar rehabilitation protocols that emphasized early passive and active motion exercises.

The “humeral head height” relative to the plate was measured for each radiograph, both initially and at final follow-up, which allowed for subsequent analysis of loss of reduction. This measurement was done by drawing 2 lines, both perpendicular to the shaft of the plate; one was placed at the top edge of the plate and one was placed at the superior edge of the humeral head (Fig. 1), and the distance between these 2 lines was measured and designated as the head height. The change in this height from immediate postoperative radiographs to final follow-up, at which time all fractures had healed, was calculated. All radiographic measurements were standardized for magnification with the known implant size and were performed by an independent blinded observer.

All cases were then subdivided into one of 2 groups according to the presence or absence of medial mechanical support of the proximal humeral head fragment. The fracture was considered to have adequate medial support (+MS group) if (1) the medial pillar of the proximal humerus was not comminuted and anatomically reduced (Fig. 2); (2) the shaft was medialized and impacted into the head fragment; or (3) an oblique locking screw was placed directly into the inferomedial quadrant of the proximal humeral head fragment to within 5 mm of the subchondral bone (Fig. 3). Conversely, fractures that did not fulfill one of these criteria were designated as having inadequate medial support (–MS group).

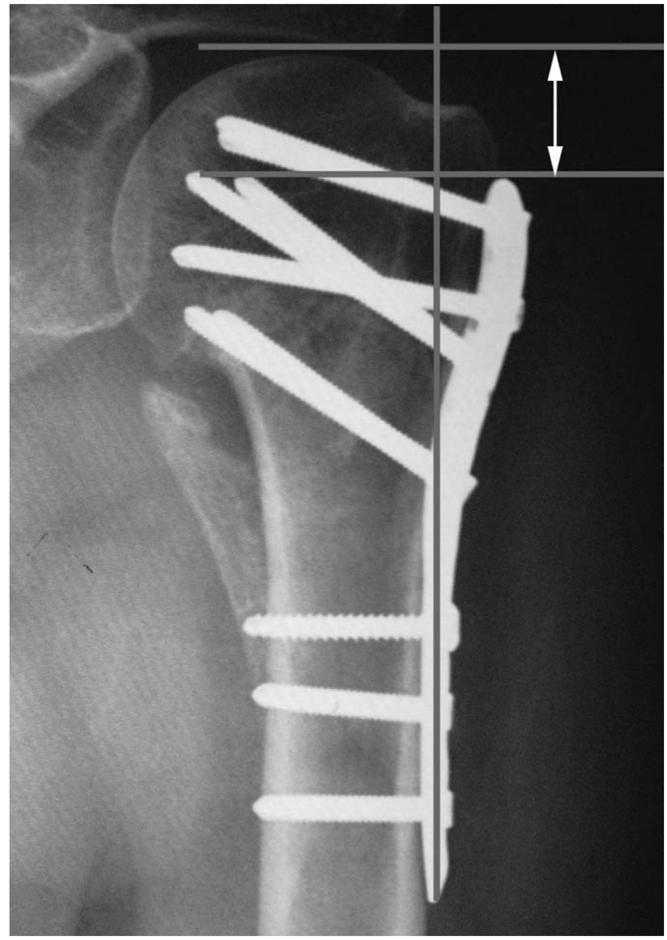

FIGURE 1. Humeral head height was calculated as the distance between the top of the plate and the top of the humeral head, both measured perpendicular to the axis of the plate.

To quantify the amount of implant migration after fracture healing occurred (or the amount of additional humeral head migration that occurred), a secondary analysis was performed between 3 months and at least 6 months. The change in humeral head height between 3 and 6 months was determined for these patients.

Statistical Analyses

Variables in each group were compared directly to each other using Fisher exact tests (for dichotomous variables) or Student *t* tests (for continuous variables) with 2 sided *P* values. To determine which variables were significant predictors of change in humeral head height, multivariate linear regressions

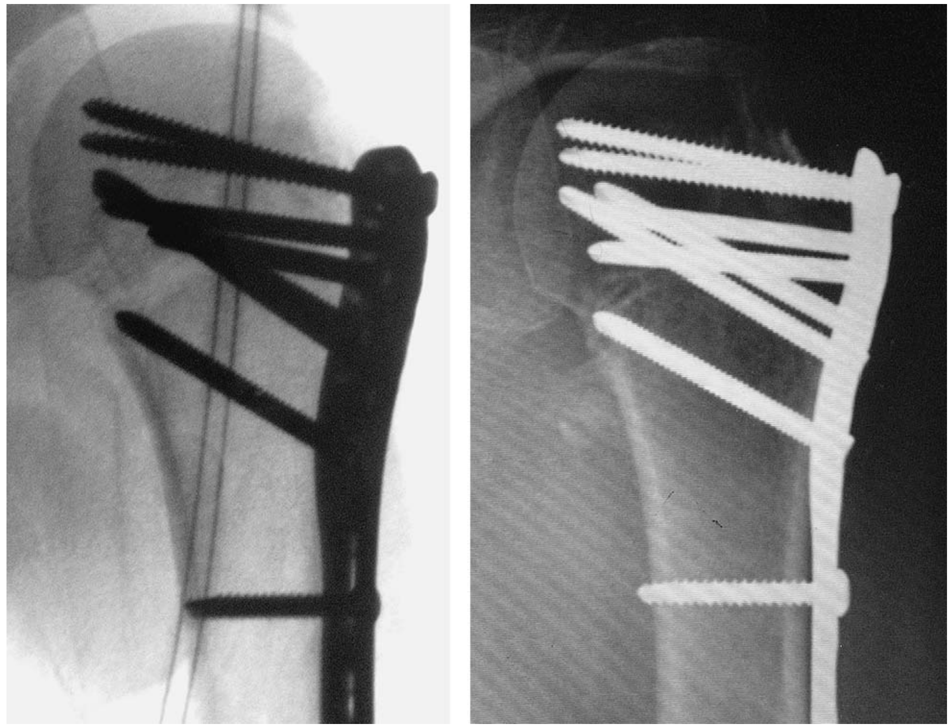

FIGURE 2. In this case, the plate was placed several millimeters too distal, which prevented screw anchorage in the inferomedial segment in the proximal humeral head fragment. Despite this, the medial cortex was anatomically reduced, with good cortical contact, and after 3.5 months, the fracture had healed, with the reduction maintained.

were performed. The magnitude of reduction loss was set as the dependent continuous variable, and the 5 independent variables were age, sex, fracture type, cement augmentation, and the presence or absence of medial support. For the analysis of the reduction change from 3 months to 6 months, a 2 tailed Student *t* test was performed, with a significance threshold of

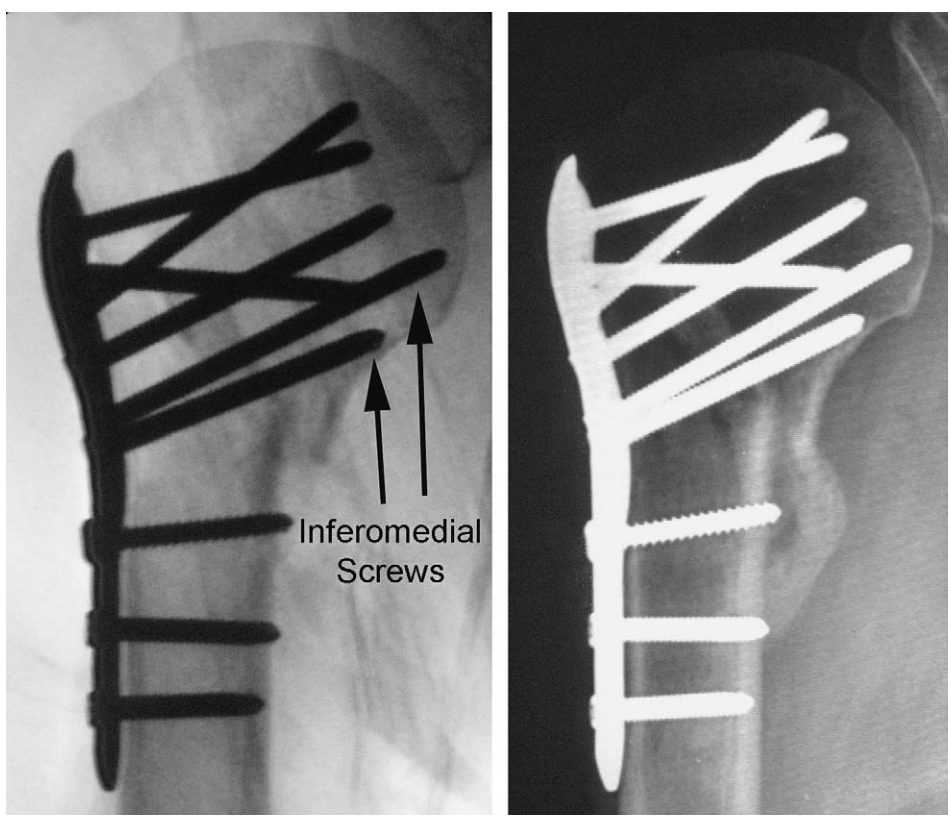

FIGURE 3. In this case, the medial cortex was malreduced, with medial translation of the proximal fragment. Locking screws placed in the inferomedial region (arrows) achieved a stable medial column, and 7 months postoperatively the humeral head height and alignment were well maintained, and the fracture healed.

$P < 0.05$. All tests were conducted with commercial statistical software (SPSS version 11.0; SPSS Inc, Chicago, IL).

RESULTS

Average patient age was 62 years (range, 23 to 89 years; median, 62 years). Sixteen patients were older than 65 years, and all had low-energy traumatic events. Four additional patients also sustained low-energy mechanisms of injury. Overall, there were 6 two-part, 15 three-part, and 14 four-part fractures according to the Neer classification, and 24 patients were women. Average follow-up was 7 months (range, 6 to 77 weeks; median, 25 weeks). Regression analysis revealed that the presence or absence of medial support was a significant predictor of loss of fracture reduction ($P < 0.001$). Patient age ($P = 0.77$), sex ($P = 0.25$), fracture pattern ($P = 0.64$), and cement augmentation ($P = 0.68$) were not significantly associated with humeral head height loss.

Eighteen patients were considered to have medial support and were designated in the +MS group. The average age of this group was 55 years (range, 23 to 83), and there were 4 two-part, 8 three-part, and 6 four-part fractures. Nine patients had an anatomic reduction of the medial cortex without comminution, and 6 had 1 or 2 inferomedial screws placed; 3 patients had both. In 3 patients, Norian bone substitute was placed in the cancellous bone after reduction. The average height loss of the humeral head was 1.2 mm (SD, 1.4 mm), and the maximum was 4.1 mm. One patient, a 61-year-old woman with a 3 part comminuted surgical neck and greater tuberosity fracture, had an inferomedial screw placed but had screw penetration through the humeral head and required revision surgery for screw removal at 3 months postoperatively. All patients' fractures healed without any delayed union.

The 17 remaining patients were in the –MS group. Average age in this group was 69 years (range, 45 to 89 years), which was significantly greater than in the +MS group ($P = 0.004$). The breakdown of fracture types in this group were 2 two-part, 7 three-part, and 8 four-part, which was not significantly different between the groups ($P = 0.68$). Twelve patients had a malreduction with lateral displacement of the shaft fragment, without apposition of the medial cortex, and 5 had significant medial comminution; no patient had a screw placed in the inferomedial region. Six patients had Norian cement placed, which was similar to the +MS group ($P = 0.12$). Humeral head height loss in this group averaged 5.8 mm (SD, 3.9 mm), which was significantly greater than in the +MS group ($P < 0.001$). The maximum loss of humeral head height was 13.6 mm, and 9 patients had greater than 5 mm of height loss ($P < 0.001$). Of these 17 patients without medial support, 5 had screw penetration of the articular surface ($P = 0.02$; Fig. 4), 2 of whom had loosening of other screws ($P < 0.001$) and 2 of whom underwent revision for screw removal ($P = 0.56$). One additional patient had screw pullout from the distal plate and required revision to a longer plate, and 1 patient underwent irrigation and debridement for persistent wound drainage (Table 1). Despite the fracture migration and implant cutout in this group, all fractures achieved solid bony union in a timely fashion.

To assess the amount of additional humeral head height loss that occurred after 3 months, a subanalysis was

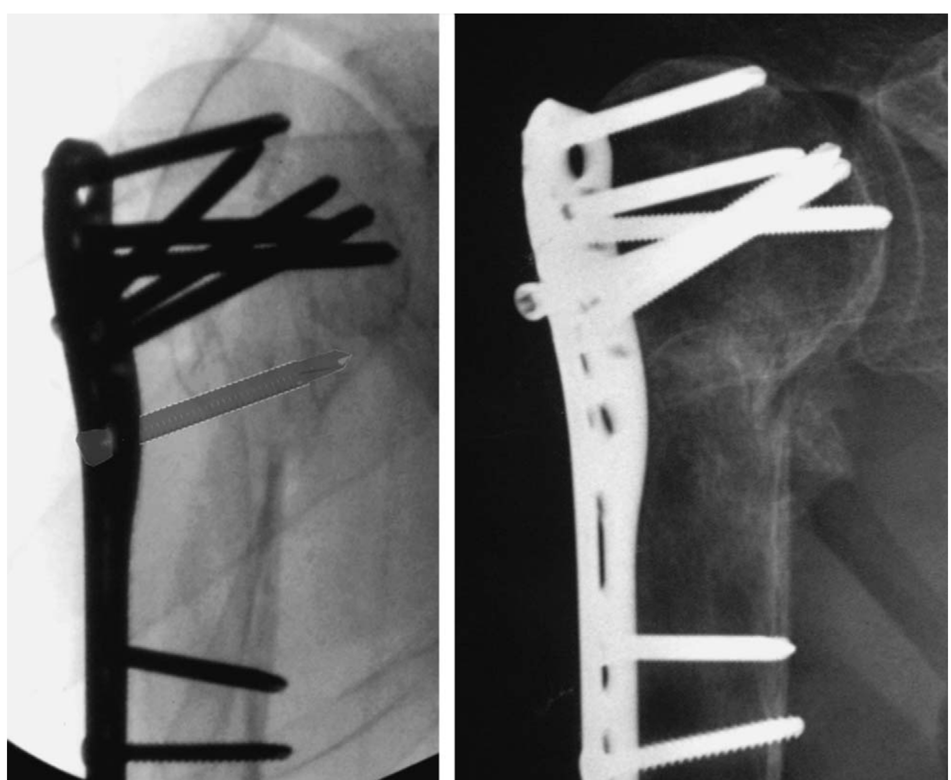

FIGURE 4. A malreduction of the medial cortex was associated with comminution in this case. The opportunity for placing an inferomedial screw was not taken (gray screw). After 2 months, the humeral head had failed in varus, and several screws had backed out of the plate and penetrated the articular surface.

TABLE 1. Patient Data for the +MS (Medial Support) and −MS (No Medial Support Group)

		Group		
		+MS	−MS	*P* Value
N		18	17	
Sex	Females	14	10	0.15
	Males	4	7	
Average age (yr)		55	69	0.004
Fracture distribution (Neer)	2 Part	4	2	
	3 Part	8	7	0.68
	4 Part	6	8	
CaP cement augmentation		3	6	0.12
Change in humeral head height (mm)	Mean	1.2	5.8	
	SD	1.4	3.9	<0.001
	Max	4.1	13.6	
>5 mm Loss of reduction	N	0	9	<0.001
	%	0	53	
Screw penetration		1	5	0.02
Screw loosening		0	2	<0.001
Revision surgery		1	3	0.56

conducted. Nine patients had greater than 6 months of follow-up (average, 11 months; range, 6–18 months). The change in humeral head height between the 3 month follow-up and the final follow-up averaged 0.3 mm (maximum, 1.7 mm), which was not significant ($P = 0.40$).

DISCUSSION

Unstable proximal humerus fractures frequently present difficulty in obtaining stable fixation because of comminution and poor bone quality.[11,12,22] Our results suggest that locked screws placed into the humeral head from lateral to medial are unable to independently stabilize the medial column of the proximal humerus. We propose that adequate medial support may be obtained through cortical contact or, in the case of medial comminution, by placing locking screws specifically into the inferomedial aspect of the humeral head fragment.

The mechanical performance of proximal humeral locking plates has been variable, according to previous authors. A preliminary report of a multicenter study of 147 patients found a 14% incidence of mechanical complications, and this was closely related to varus malreduction.[23] Bjorkenheim et al.[18] reviewed 72 patients with proximal humeral fractures treated with a locking plate, and although they reported only 2 "implant technical failures," 19 of the fractures (26%) healed with varus malalignment. Fankhauser et al.[17] also reported that in 3 of 27 patients (11%), early varus displacement occurred, and 7 screws lost plate purchase and 5 penetrated the humeral head. Because these devices were developed only recently, little has been published about the technical details of reduction and implant placement using locking screw constructs in these fractures, but it seems that these factors may play an important role in maintaining fracture stability.

Fixed-angle devices such as blade plates have also been used for humeral head fixation. A recent series by Meier et al.[13] reported on using a custom 3.5 mm 110 degree blade plate for proximal humeral fractures, and these authors found a 22% incidence of blade penetration into the humeral head. Similar to our results, this complication occurred equally as frequently in elderly and young patients. Additionally, the failure examples in this study clearly demonstrated lack of inferomedial screws or medial support. In contrast, Hintermann et al.[24] reported no blade penetrations in a series of 42 patients with a 90 degree blade plate. Their success may have been partly related to the fact that a 90 degree device obtains purchase in the inferomedial region, similar to appropriately placed fixed-angle screws.

The locking plate may be adjusted slightly proximally or distally, and is often placed where it best fits the anatomy of the lateral cortex and greater tuberosity, without particular attention to the location of the screws in the proximal fragment. Placing the plate too proximal or distal may lead to impingement of the plate on the acromion in abduction or may prevent the use of locked screws of sufficient length, respectively.[17] But ultimately, according to our results, if the position of the plate is not chosen by ensuring that the inferomedial screws will be placed in the proper location, the screws may be easily misplaced and early mechanical failure may be more likely. It seems that constructs that have screws only superiorly in the humeral head without fixation anchored inferomedially, especially when medial comminution or malreduction is present, may be ineffective in maintaining the reduction.

Analysis of the histomorphometry and microstructural architecture of the humeral head bone stock demonstrated that trabecular thickness and density are the greatest in the medial region.[25] Liew et al[26] also found screw purchase to be significantly greater when screws were placed into the medial subchondral bone and cautioned about relying on fixation in the superior humeral head. The typical failure mode of varus collapse caused by rotator-cuff forces suggests that some medial support is necessary to maintain reduction. A recent clinical study by Gerber et al[27] reported good results in younger patients after precise reduction, and these and other authors have stressed the necessity of anatomic reduction, particularly medially, for achieving stable fixation.[28]

The phenomenon of locked screws cutting through the cancellous humeral head bone, particularly in osteoporotic patients, has been attributed to the stiffness of the construct,[17] which has been confirmed in a biomechanical study.[29] As the rotator cuff fires, a varus moment is applied, and high stresses occur at the tips of the locked screws. It seems from our results that there may be several ways to counteract these forces. Anatomic reduction of the medial cortex is preferable and provides a stable medial support column to create a load-sharing situation and minimize forces at the screw-bone interface. However, medial comminution may prevent cortical contact, and in these cases the proximal humeral head fragment may be impacted slightly laterally in the distal fragment. Finally, regardless of the medial reduction achieved, we advocate placing 1 or several inferomedial screws, which seems to be particularly important with medial comminution or medial malreduction.

With the numbers available, there was no benefit of placing calcium phosphate into the fracture to improve stability. Indications for cement augmentation were not applied according to a specific protocol, nor were they based on estimation of the bone quality, but rather were at the surgeon's discretion. The lack of effect may have been due to its use in more severe fractures. Regardless, cement augmentation could not prevent humeral head height loss without medial column support. Age, sex, and fracture type also were not independently related to reduction loss, which implies that patients typically associated with difficult fixation may be successfully treated with adequate inferomedial stabilization. Although it may be intuitive that the age differential between the groups may have had an effect, this was not the case. Independent of the group designation, a linear regression analysis compared the effect of age on the amount of displacement in all patients, and no correlation was observed. The different age distribution between groups may have been because osteoporotic fractures have more extensive medial comminution and it was more difficult to achieve medial support with cortical contact. In these cases, the use of appropriately placed inferomedial screws may be even more important.

We are aware of several inherent limitations in this study. Aside from the few mechanical failures that required reoperation, the clinical sequelae of the occurrence and amount of settling and varus loss of reduction, even if the fracture progresses to union, are unknown and were not addressed in this study. However, settling of the humeral head represents a loss of reduction, even if slight, and is generally an undesirable situation. Stable fracture fixation is the surgical goal and leads to improved outcomes in these fractures.[7,24] The patient cohort evaluated in this study was a heterogeneous group, which included patients of various ages and with different fracture patterns. Although we found no effect of age and fracture type on maintenance of reduction, the relative importance of inferomedial support in specific age groups or fractures can not be determined from these data. Adequate length of follow-up in trauma patients has been debated, particularly in radiographic studies after healing has occurred. In this study, only a minimal amount of additional humeral head settling occurred after 3 months, implying that slight hardware migration did not preclude fracture healing. Thus, although fracture healing as an endpoint appears to be appropriate for the purposes of the mechanical behavior of an implant, it does not factor in late sequelae such as osteonecrosis. Finally, we used a novel method for measuring the loss of reduction, which is useful because it is unaffected by humeral rotation on radiographs and it is sensitive to the typical mode of implant failure. However, this technique does not account for implant position on the axillary view, which must not be ignored on initial and subsequent radiographs.

In conclusion, we found that mechanical support of the medial region is important for maintenance of reduction when proximal humerus fractures are treated with locking plates. When this construct characteristic was considered, neither age, sex, nor fracture pattern was associated with loss of reduction. Failure to recreate a medial buttress may lead to early loss of reduction, and it seems that locking screws are unable to support the medial column without anatomic reduction or carefully placed inferomedial screws.

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