Displacement/Screw Cutout After Open Reduction and Locked Plate Fixation of Humeral Fractures

Kevin C. Owsley and John T. Gorczyca
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By Kevin C. Owsley, MD, and John T. Gorczyca, MD

Investigation performed at the University of Rochester Medical Center, Rochester, New York

Background: Fixation of proximal humeral fractures is challenging. Locking plate technology offers mechanical advantages for treating unstable fractures in weak bone. In this study, we assessed the radiographic and clinical results of a single surgeon's experience treating proximal humeral fractures with a locked proximal humeral plate.

Methods: Fifty-three adult patients with a displaced proximal humeral fracture were treated with a proximal humeral locking plate over a forty-five-month period. A standard postoperative rehabilitation regimen was followed. Radiographs were made at two weeks, six weeks, three months, six months, and one year and were examined for fracture alignment, fracture displacement, hardware position, and healing. Postoperative outcomes were collected with questionnaires.

Results: Fifty-two (98%) of the fifty-three fractures healed by six months. Nineteen patients (36%) had radiographic signs of a complication, including screw cutout with intra-articular displacement in twelve (23%), substantial (>10°) varus displacement in thirteen (25%), and osteonecrosis in two (4%). These radiographic signs of a complication occurred in twelve (57%) of twenty-one patients older than sixty years of age and in seven (22%) of thirty-two patients under sixty years of age ($p = 0.0015$). Screw cutout occurred in nine (43%) of the twenty-one patients older than sixty years. Patients with a complication had worse functional outcomes as measured with the Short Musculoskeletal Function Assessment ($p < 0.05$) and the Quick Disabilities of the Arm, Shoulder and Hand ($p < 0.001$) questionnaires. We were unable to demonstrate a relationship between fracture type and complications. Revision surgery was performed in seven (13%) of the fifty-three patients. There were no cases of infection, nerve injury, or hardware failure.

Conclusions: The use of locking plates in the surgical treatment of proximal humeral fractures is associated with an unexpectedly high rate of screw cutout and revision surgery, especially in patients older than sixty years who have a three or four-part fracture. The indications for open reduction and internal fixation in these patients require continued analysis.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

Although proximal humeral fracture is one of the most common fractures in the elderly population, treatment of this injury remains a challenge and is often an issue of debate. Defining correct treatment guidelines is becoming increasingly important as the prevalence of osteoporotic fractures of the proximal part of the humerus is expected to rise in the next three decades and the functional outcome achieved after treatment may determine a patient's level of independence[1].

Fortunately, most (85%) of these fractures are minimally displaced or are stable and can be treated successfully with nonoperative means and careful early motion[2]. Various operative techniques have been advocated for three-part, four-part, and unstable fractures, including use of tension band sutures, Kirschner wires, locking and nonlocking screw-and-plate constructs, fixed-angle (blade) plates, intramedullary devices, and prosthetic replacement[3]. There are no clear guidelines for treatment, and most of these techniques are associated with complications related to hardware failure, osteonecrosis, nonunion, malunion, hardware migration, rotator cuff impairment, and impingement syndrome[4-14].

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TABLE I Data on Nineteen Patients with Radiographic Evidence of a Complication*

Case	Age *(yr)*	Neer Fracture Type	Varus Collapse	Screw Cutout	Osteonecrosis	Delayed Union	Revised
1	70	2	X				
2	71	2		X			
3	43	2		X			Intra-articular screws exchanged
4	65	2		X			
5	81	2	X	X			
6	35	2	X				
7	68	2	X	X			
8	64	2	X				
9	41	3	X				
10	49	3	X				
11	62	3		X			
12	86	3	X	X			
13	61	3		X			Hardware removed after union
14	59	3		X	X		Converted to hemiarthroplasty
15	62	3	X	X	X	X	Converted to hemiarthroplasty
16	74	3	X				Hardware removed after union
17	58	3	X				
18	59	4	X	X			Hardware removed after union
19	72	4	X	X			Hardware removed after union
Total (% of series of 53 patients)			13 (25%)	12 (23%)	2 (4%)	1 (2%)	7 (13%)

*The group constituted 36% of the total series of fifty-three patients.

Locking plates have recently been developed specifically for the proximal part of the humerus, and they appear to offer improved fixation of these fractures through the use of multiple locking screws oriented in different directions to maximize screw number, position, and resistance to displacement. Long-term functional outcomes of the treatment of these fractures with these plates are not available, to our knowledge. This study is both a radiographic and a clinical review of patients treated with a proximal humeral locking plate.

Materials and Methods

From April 2002 to December 2005, fifty-eight consecutive patients with a displaced proximal humeral fracture treated with a proximal humeral locking plate were identified from the orthopaedic trauma database of a single university-based regional trauma center. Patients older than eighteen years of age who had radiographic evidence of fracture-healing or had been followed for one year were included in the study. Four patients were excluded on the basis of age, and one patient was lost to follow-up prior to fracture-healing. The remaining fifty-three individuals (forty-one women and twelve men) with a mean age of fifty-two years (range, eighteen to eighty-nine years) made up the study population. According to the Neer classification, there were twenty-three two-part fractures, twenty-eight three-part fractures, and two four-part fractures.

Medical records were reviewed for patient demographic data, medical history, mechanism of injury, concomitant injuries, dates of injury and surgery, and perioperative complications. All patients had anteroposterior scapular, transscapular lateral, and axillary lateral radiographs made preoperatively and at each follow-up visit. Radiographs were analyzed to determine fracture type, postoperative and final fracture alignment and hardware position, and healing time[15]. Preoperative computed tomography scans were performed for twelve patients because the presence of coronal (head-splitting) fracture lines could not be excluded on the standard radiographs. Seven additional patients had computed tomography scans of the chest as part of their initial trauma evaluation, and these scans provided visualization of the proximal part of the humerus that was helpful for the fracture classification.

The fractures were classified according to the Neer system[11]. The criteria of Hertel et al. were measured on preoperative anteroposterior radiographs of the shoulder[16]. Healing was determined by a combination of painless palpation of the shoulder and radiographic evidence of bridging bone on anteroposterior and lateral radiographs. The duration of follow-up

Fig. 1-A

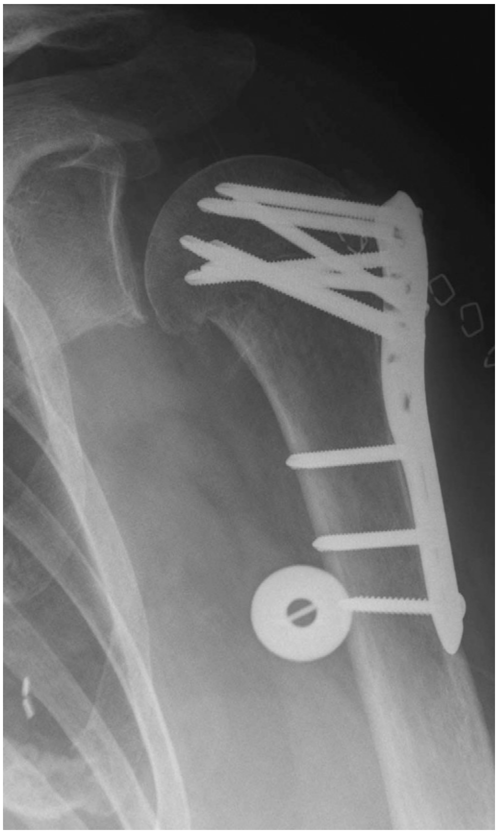

Fig. 1-B

Fig. 1-A Anteroposterior shoulder radiograph of a seventy-two-year-old woman who fell in her bathtub and sustained a four-part valgus-impacted proximal humeral fracture. **Fig. 1-B** Satisfactory reduction and screw position were obtained and were maintained at ten days.

averaged thirty-one months (range, seventeen to sixty months). One observer, who did not participate in any of the operations or clinical examinations, made all radiographic measurements.

Open reduction and internal fixation was considered for fractures displaced >1 cm or angulated >45° on anteroposterior or transscapular lateral radiographs. If the patient and the surgeon believed that overhead use of the involved hand and arm was of functional importance and they were willing to accept the surgical risks, then surgery was performed. No patient was treated with closed reduction of a displaced fracture during this period. In all cases, we used a locking plate system designed specifically for the proximal part of the humerus; we used forty-eight Proximal Humeral Internal Locking Systems (Synthes, West Chester, Pennsylvania), four Periarticular Proximal Humeral Locking Plates (Zimmer, Warsaw, Indiana), and one Numelock II Polyaxial Locking System (Stryker, Freiberg, Germany). During the study period, head-splitting fractures were treated with hemiarthroplasty and isolated fractures of the greater tuberosity were treated with sutures and screws but no plate. For the first two years of the study, long proximal humeral locking plates were not available, and fractures with extension into the humeral diaphysis were treated with a long 90° cannulated blade-plate.

Surgical Procedure

The goal of surgery was to obtain anatomic fracture alignment and stability to allow soft-tissue and osseous healing. In particular, efforts were made to restore humeral offset and tuberosity position[17]. Surgery was performed with the patient under general anesthesia, and all patients received prophylactic intravenous antibiotics just prior to the procedure and for forty-eight hours postoperatively. Patients were positioned supine on a radiolucent operating table. Prior to preparation and draping, fluoroscopic positioning and viewing were performed to ensure that adequate imaging of the shoulder, including axillary lateral views, could be done intraoperatively.

A standard deltopectoral incision was used. The fracture fragments were reduced and were provisionally stabilized with Kirschner wires, and the reduction was checked with fluoroscopy. Tuberosity fractures were secured by passing at least one, and usually two, number-5 Ethibond suture(s) (Ethicon, Somerville, New Jersey) through the tendon-bone junction. The proximal humeral locking plate was secured to the proximal fragments and head first, with care taken to disperse the locking screws throughout the humeral head. Early in the series, the first screw placed into the humeral head was a nonlocking screw in order to pull the plate flush against the

Fig. 1-C

Anteroposterior (Fig. 1-C) and axillary lateral (Fig. 1-D) radiographs made at five months demonstrate cutout with intra-articular location of at least three screws. The hardware was subsequently removed.

proximal humeral cortex. Later, it became clear that digital pressure could hold the plate flush against the lateral cortex, and only locking screws were placed into the humeral head.

Screws were placed into the humeral head after the initial passage of guidewires to determine length, with the intent that the screw tips remain 5 to 10 mm from the subchondral bone. This involved rotating the proximal part of the humerus under anteroposterior and axillary lateral fluoroscopy to identify the view that showed the closest position of each guidewire and/or screw to the subchondral bone. Drilling was performed only through the lateral cortex in the bone proximal to the fracture in order to preserve bone stock. Screws were exchanged when necessary to obtain the intended position of the screw tip relative to the subchondral bone. The locking screws were placed in a divergent position in accordance with the design of the locking plate.

Next, the plate was reduced to the shaft and secured to it with screws. Additional screws were then positioned in the humeral head with the intent to place at least six screws into the head if possible. In some cases in which the humeral head fragment seemed small, an attempt was made to place more than six screws into the humeral head. The tuberosity sutures were then tied to the plate and to each other.

Postoperatively, anteroposterior scapular, transscapular lateral "Y," and axillary lateral radiographs were made prior to hospital discharge and at serial intervals until healing was achieved. Often, anteroposterior scapular radiographs with the shoulder in external rotation were made after we noted excessive overlap of the anterolateral plate on the proximal part of the humerus when the shoulder was not externally rotated.

In all cases, the shoulder was immobilized in a sling postoperatively and the patient was instructed about independent gentle active and active-assisted motion exercises within five days after the surgery. This activity was progressed to passive stretching and gravity-resistance motion exercises at six weeks, and unrestricted exercises with formal physical therapy were usually started at twelve weeks. Patients were instructed to wear the shoulder immobilizer at all times, except when performing these exercises and when bathing, until twelve weeks postoperatively. Follow-up was carried out in a standardized manner at two weeks, six weeks, three months, six months, and twelve months postoperatively.

Postoperative outcome measures were collected with use of patient-reported questionnaires. Patients were mailed the Short Musculoskeletal Function Assessment questionnaire (SMFA) and the Quick Disabilities of the Arm, Shoulder and Hand Outcome Measure (QuickDASH) one year or more after the surgery. The SMFA is a forty-six-item shortened version of the full Musculoskeletal Function Assessment questionnaire. Its use results in two scores: the function index and the bothersome index. The sum of the responses is transformed to a score ranging from 0 to 100 points, with higher scores indicating worse function. The SMFA has been validated as a generic health-status measure for patients with musculoskeletal disorders[18]. The QuickDASH is an eleven-item questionnaire that addresses symptoms and physical function of patients with disorders of the upper limb. The questionnaire also contains optional work and sports/performing arts modules. The total score ranges from 0 to 100 points, with 100 points indicating the most disability. The QuickDASH has been validated for either proximal or distal disorders of the upper extremity[19].

Statistical Analysis

T tests were used to examine the relationship between age and radiographic outcome as well as the relationship between radiographic outcome and functional outcome scores. The Fisher exact test was used to examine the effect of fracture type on the radiographic outcome. The relationship between the criteria of Hertel et al.[16] and the radiographic outcome was measured with t tests. Chi-square analysis was used to examine the effect of an age of more than sixty years on radiographic outcome and also

Fig. 1-D

to examine if there was a difference in radiographic outcomes between two-part fractures and three or four-part fractures. A p value of <0.05 was considered significant.

Results

Fifty-two (98%) of the fifty-three fractures healed within six months after the surgery. Nineteen patients (36%) had radiographic evidence of a complication, including twelve cases of intra-articular cut-through by hardware, thirteen cases of relevant varus displacement (>10°) (some with concomitant hardware cut-through), and two cases of osteonecrosis (one of which was associated with nonunion) (Table I). The average age of the patients with radiographic evidence of a complication was sixty-two years, compared with forty-eight years for patients without an evident complication (p = 0.006). Radiographic evidence of a complication was present in twelve (57%) of the twenty-one patients over sixty years of age and seven (22%) of the thirty-two patients who were sixty years of age or younger (p = 0.0015). We were unable to demonstrate a significant relationship between fracture type and radiographic evidence of a complication.

Hardware cut-through was measured by comparing the distances from the screw tip to the articular surface on serial anteroposterior radiographs of the shoulder (Figs. 1-A through 1-D). In twelve patients, screws had moved >3 mm through the bone, and all of these screws protruded through the subchondral bone (i.e., there was "cutout") as seen on plain radiographs of the shoulder.

In patients older than sixty years of age, the prevalence of cutout was nine (43%) of twenty-one. This prevalence was not related to fracture type, as four of the eight two-part fractures had cutout and five of the thirteen three or four-part fractures had cutout in this age-group. However, in this age-group, three of the five patients with a three or four-part fracture and cutout had revision surgery whereas none of the four patients with a two-part fracture and cutout had revision surgery.

The mean humeral head-shaft angle was 129° (range, 112° to 158°) immediately postoperatively. At the time of final follow-up, the mean head-shaft angle was 123° (range, 103° to 150°). Thirteen (25%) of the fifty-three patients had a change of >10° in the humeral head-shaft angle as measured on an external rotation anteroposterior radiograph. These thirteen patients had an average age of sixty-two years (range, thirty-five to eighty-six years) (Table I). The rate of relevant varus displacement varied depending on the fracture type: five (22%) of the twenty-three two-part fractures had varus collapse, six (21%) of the twenty-eight three-part fractures had varus collapse, and both four-part fractures had varus collapse.

Seven patients chose to have revision surgery. Three patients underwent removal of the plate and screws after the fracture had healed because of intra-articular screw cutout (Figs. 1-A through 1-D). One patient with substantial varus displacement had impingement symptoms one year after the fracture had healed, and that patient had removal of a prominent plate, which resulted in pain relief. A patient who did not comply with instructions and returned to performing strenuous labor three weeks postoperatively had two screws cut out; the screws were exchanged for shorter screws that did not protrude into the joint, and the fracture healed well without screw cutout. A proximal humeral hemiarthroplasty was performed in two patients; it was done because of osteonecrosis with intra-articular screws in one and because of advanced

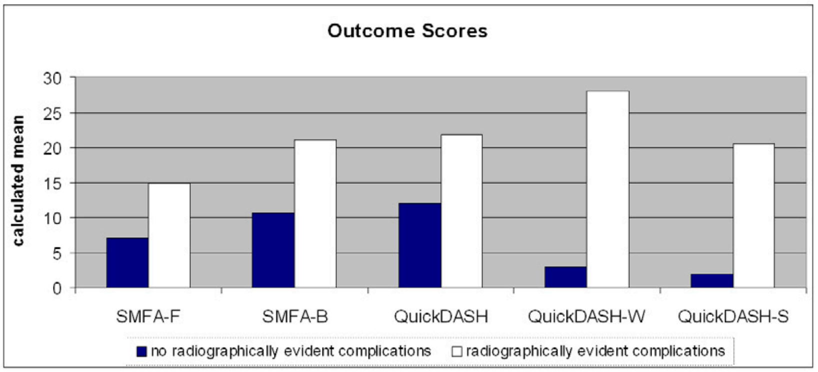

Fig. 2

Graph displaying the outcomes of patients without radiographic evidence of a complication and those with radiographic evidence of a complication. The SMFA function (SMFA-F) and bothersome (SMFA-B) indices as well as the QuickDASH and its work (QuickDASH-W) and sports/performing arts (QuickDASH-S) modules are scored such that higher scores indicate worse outcomes. All scores were found to differ significantly between the two groups ($p < 0.05$), with the exception of the QuickDASH-S ($p = 0.05$).

osteonecrosis with a degenerated joint, nonunion, and intra-articular screws in the other. Six patients with intra-articular screws opted not to have revision surgery and were able to maintain a comfortable lifestyle with screws that protruded predominantly anteriorly and inferiorly into the glenohumeral joint.

There were no radiographic signs of breakage of any screws or plates. None of the locking screws appeared to unlock or loosen from the plate. There were no intraoperative complications, no perioperative neurovascular injuries, and no deep infections.

The criteria of Hertel et al.[16] for predicting ischemia of the humeral head after a fracture were measured. The average length of metaphyseal extension was 7 mm. Twenty-three (43%) of the fifty-three patients had an intact medial hinge. Eleven (21%) of the fifty-three patients had an anatomic head fracture. In the group of thirty-four patients who did not have a radiographically evident complication, the metaphyseal extension averaged 8.3 mm, an intact medial hinge was present in eighteen (53%), and an anatomic neck fracture was present in four (12%). In the group of nineteen patients with a radiographically evident complication, the metaphyseal extension averaged 5.0 mm, an intact medial hinge was present in five (26%), and an anatomic head fracture was present in seven (37%). Although all three of these criteria for predicting ischemia were present more commonly in patients in whom a complication was noted radiographically, the difference was significant only for metaphyseal extension ($p < 0.021$). Of nine patients who had all three high-risk factors, five had screw cutout and four had revision surgery.

Twenty-seven (79%) of the thirty-four patients without radiographic evidence of a complication and thirteen (68%) of the nineteen patients with a complication responded to the questionnaires. One patient without radiographic signs of a complication died from a mediastinal tumor seven months postoperatively. The fracture had healed prior to her death, but she did not complete the functional outcome surveys. The remaining twelve patients did not respond to mailings and/or telephone messages. Six of the patients who did not respond had radiographic evidence of a complication.

Each outcomes measure that we used showed the functional outcome to be better in the group without radiographic evidence of a complication than in the group with radiographic evidence of a complication (Fig. 2). The mean SMFA score was 47 points (range, 34 to 94 points) for all patients, 44 points for the patients without radiographic evidence of a complication, and 54 points for those with radiographic evidence of a complication ($p < 0.05$). The mean SMFA function index was 10 points for all patients, 7 points for those without radiographic evidence of a complication, and 15 points for those with radiographic evidence of a complication ($p = 0.05$). The mean SMFA bothersome index was 14 points for all patients, 11 points for those without radiographic evidence of a complication, and 21 points for those with radiographic evidence of a complication ($p < 0.04$). The mean QuickDASH score was 15 points for all patients, 12 points for patients without radiographic evidence of a complication, and 22 points for patients with radiographic evidence of a complication ($p < 0.0001$). The mean score for the optional work module of the QuickDASH was 11 points for all patients, 3 points for patients without radiographic evidence of a complication, and 28 points for those with radiographic evidence of a complication ($p < 0.017$). The mean score for the optional sports/performing arts module of the QuickDASH was 7 points for all patients, 2 points for those without radiographic evidence of a complication, and 21 points for those with radiographic evidence of a complication ($p = 0.05$).

Discussion

Proximal humeral fractures are challenging injuries to treat. Despite the relatively high prevalence of these injuries in the general population, there are no clear-cut indications for each of the various surgical options. There are several techniques for performing open reduction and internal fixation, and no implant is ideal for all fractures. The goals of surgery, however, remain the same with all implants: obtaining and maintaining satisfactory reduction in order to allow early motion, achieve healing, and restore function[11].

Fixation with a locked periarticular plate has the advantages of a well-contoured, low-profile plate, several proximal multidirectional screws, and locking screw technology to achieve angular stability. There is a general belief that these plates provide more secure fixation of proximal humeral fractures, especially in weak bone[20-23].

We reported on a large series of proximal humeral fractures that were fixed with these implants by a single surgeon, and we reported an alarming rate of screw cutout through the subchondral bone of the humeral head and into the glenohumeral joint. This problem was especially common in patients older than sixty years of age. There are several possible explanations for this unexpected complication. The locking mechanism on many of the modern plate systems can impair the surgeon's ability to assess the quality of screw purchase in bone and can often lead to a false sense of security regarding the implant's purchase in the osseous fragments[20]. In this series, not every screw hole was filled with a screw, although all patients with cutout had at least six screws positioned in the humeral head unless the plate did not have that many screw holes (one patient).

In some cases in which preoperative computed tomography scans had been performed, it was noted that an anatomic neck fracture left only a thin portion (<1.5 cm) of the humeral head intact. This may be a relative contraindication to open reduction and internal fixation with a proximal humeral locking plate, as the quantity and quality of the bone are insufficient for fixation even with the use of multiple locking screws in the humeral head, leading to an unacceptable cutout rate.

Other authors have reported cutout when treating proximal humeral fractures. Meier et al. reviewed the cases of thirty-six patients in whom a proximal humeral fracture had been treated with an angled blade-plate[24]. Eight patients had protrusion of the blade into the glenohumeral articulation. Fankhauser et al. reported treating twenty-nine proximal humeral fractures with a locking proximal humeral plate[5]. They reported breakage of one plate, four episodes of redisplacement of the fracture, two cases of partial osteonecrosis, one deep infection, no nonunions, and two reoperations. They commented that one or more screws cut through the head in three patients in whom the fracture displaced. Cutout of screws in the femoral head has been described after open reduction and internal fixation of intertrochanteric femoral fractures and has led to the design of telescoping implants and an emphasis on precise implant positioning to minimize this risk[25,26]. It appears that an unstable proximal humeral fracture, like an unstable intertrochanteric femoral fracture, "wants to settle" into a nonanatomic position of stability, even when rigid implants are placed. Although fixed-angle implants such as the 90° blade-plate and the proximal humeral locking plate appear to have some mechanical advantage, the strength of the bone in the humeral head seems to be the weak link in the fixation construct[24]. Thus, it appears that fixation failure will occur, albeit by a different means, even with these newer implants.

Hertel et al. studied intraoperative bleeding and laser Doppler flowmetry in the humeral head in a series of patients with a proximal humeral fracture[16]. This study was biased in favor of making a diagnosis of ischemia. Hertel et al. reported that the most relevant predictors of ischemia were the length of the dorsomedial metaphyseal extension, the integrity of the medial soft-tissue hinge, and the fracture type. Of the patients who had all three high-risk factors (a short [<8-mm] metaphyseal extension, a disrupted medial hinge, and an anatomic neck fracture), 97% had ischemia noted intraoperatively. These criteria for predicting osteonecrosis are considered important by many investigators. In our study, thirty-four patients without radiographic evidence of a complication had a metaphyseal extension averaging 8.3 mm; an intact medial hinge was present in eighteen (53%) and an anatomic neck fracture was present in four (12%). In comparison, the nineteen patients with radiographic evidence of a complication had a mean metaphyseal extension of 5.0 mm; an intact medial hinge was present in five (26%) and an anatomic head fracture was seen in seven (37%). Thus, there was a trend toward a higher rate of these ischemia-predicting criteria in the patients with radiographic evidence of a complication. However, of our nine patients who met all three high-risk criteria for ischemia, five had cutout and four had revision surgery. Thus, the criteria described by Hertel et al. did not have a high predictive value with regard to screw cutout and thus may not be useful in identifying contraindications to the use of the locking plate.

We caution surgeons about the complication of cutout and its frequency. We recommend careful consideration regarding the decision whether to perform open reduction and internal fixation or arthroplasty for a three-part or four-part fracture in a patient with osteopenia, particularly when the bone available for fixation in the humeral head is thin. We believe that both the quality and the quantity of the humeral head bone are critical to obtain stable fixation. Although all but one of the patients who had cutout of the screws had at least six screws placed in the humeral head, some plates allow placement of nine screws into the humeral head. It is unclear whether filling every possible screw hole in the plate will decrease the rate of cutout. It is reasonable to assume that it would result in stronger fixation, but the effect of the multiple screws on fracture-healing and on the perfusion of the humeral head is not known. ■

Kevin C. Owsley, MD
John T. Gorczyca, MD
University of Rochester Medical Center, 601 Elmwood Avenue, Box 665, Rochester, NY 14642. E-mail address for J.T. Gorczyca: john_gorczyca@urmc.rochester.edu

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