Michael J. Gardner, MD, Dean G. Lorich, MD,
Clément M. L. Werner, MD, and David L. Helfet, MD
on

Second-Generation Concepts for Locked Plating of Proximal Humerus Fractures

Abstract

Displaced fractures of the proximal humerus remain particularly difficult to treat. Because of the poor quality of cancellous bone, it seemed that locking plates would be ideally suited for fixation in this region. However, as clinical reports begin to become available, it appears that these plates are not a panacea for these fractures and may be associated with a high complication rate. Coupled with the generally poor long-term outcomes of hemiarthroplasty, new fixation methods must be sought. Several technical factors, techniques, and alternative approaches have recently been described as possibly improving fixation stability in these fractures. Specifically, the anterolateral acromial approach, which avoids vascularity exposure, allows direct access to the lateral plating zone, and minimizes soft-tissue dissection, may be useful. Mechanical support of the medial column when anatomic cortical contact is not possible is also critical to maximizing stability. This may be achieved either with purposeful inferomedial humeral head screws or endosteal fibula allograft augmentation.

Dr. Gardner is Fellow, Orthopaedic Trauma, Harborview Medical Center, Seattle, Washington. He was a Resident, Orthopaedic Trauma Service, Hospital for Special Surgery/ New York Presbyterian Hospital, New York, New York, at the time the article was written.
Dr. Lorich is Attending, Orthopaedic Trauma Service, Hospital for Special Surgery/ New York Presbyterian Hospital, New York, New York.
Dr. Werner is Attending, Department of Orthopaedic Surgery, University of Zurich, Balgrist, Zurich, Switzerland.
Dr. Helfet is Director, Orthopaedic Trauma Service, Hospital for Special Surgery and New York Presbyterian Hospital, New York, New York, and Professor, Orthopaedic Surgery, Weill Cornell University Medical College, New York, New York.

Requests for reprints: Michael J. Gardner, MD, Harborview Medical Center, 325 9th Ave, Seattle, WA 98105 (tel, 206-731-3267; fax, 206-731-3227; e-mail, michaelgardnermd@gmail.com).

Am J Orthop. 2007;36(9):460-465.

Historical Perspective

Fractures of the proximal humerus most often present with a stable, minimally displaced fracture pattern. In these cases, sling immobilization and early rehabilitation lead to predictable healing and functional outcomes. However, when one or several fragments are displaced in an unstable configuration, surgical intervention should be considered.

> "Obtaining stable fixation within the humeral head has historically been difficult..."

Several techniques have been used for surgical fixation, including suture tension banding, percutaneous pinning, intramedullary nailing, and plating. Obtaining stable fixation within the humeral head has historically been difficult because of several factors. First, many musculotendinous units insert on the proximal humeral head and shaft, which impart significant deforming forces across the fractures. This can vary depending on associated fractures of the greater or lesser tuberosity. The pectoralis major tends to displace the humeral shaft medially. Second, many fractures occur after low-energy traumatic mechanisms in elderly patients with significant osteopenia (Figure 1). With increasing age, overall bone mass decreases, and trabecular connectivity and thickness decrease[1-3]—a

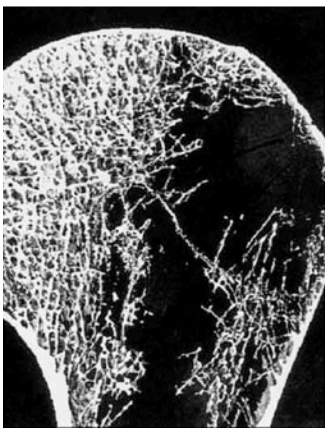

Figure 1. Microcomputed tomography (MicroCT) scanning of the humeral head shows the typical degree of osteopenia in elderly patients, particularly in the lateral region. Reprinted from *J Shoulder Elbow Surg*, vol. 13, Meyer DC, Fucentese SF, Koller B, Gerber C, Association of osteopenia of the humeral head with full-thickness rotator cuff tears, pages 333-337, copyright 2004, with permission from Elsevier.

Table. Pros and Cons of the Deltopectoral Approach and the Anterolateral Acromial Approach

	Deltopectoral Approach	Anterolateral Acromial Approach
Pros	• Familiar to orthopedic surgeons • Extensile distally • Easy conversion to hemiarthroplasty	• Minimizes soft-tissue dissection • Direct approach to lateral plating zone, no deltoid retraction • Humeral head blood supply not in surgical field • Allows reduction from within fracture lines, no periosteal manipulation
Cons	• Requires substantial retraction and often release of deltoid • Humeral head blood supply in dissection field • Difficulty reducing greater tuberosity fragment • Difficulty obtaining lateral to medial vector for locking drill guides for distal locking screws	• Unfamiliar to trauma surgeons • Axillary nerve at risk • Difficult, but possible, to convert to hemiarthroplasty

phenomenon that is pronounced in the humeral head.[1] The generalized poor bone quality in the humeral head in these patients has direct implications for anchoring screws for fracture stabilization, and age is the most important predictive variable for successful fixation.[4,5]

Traditional compression plating has not led to reliable fixation in osteoporotic displaced proximal humeral fractures.[6-10] Results are unsatisfactory in up to 80% of patients with multifragmentary fractures.[7] Sturzenegger and colleagues[9] found a 3-fold risk of avascular necrosis (AVN) after open buttress plating of proximal humerus fractures. Other authors have corroborated the high AVN rate and fixation failure with traditional open reduction and internal fixation (ORIF) and have recommended percutaneous pinning or other minimally invasive techniques for 3-part fractures and nonoperative, minimally invasive, or prosthetic treatment for 4-part fractures.[11-15]

Unfortunately, for these difficult fractures, hemiarthroplasty has not produced reliably good outcomes either. Zyto and colleagues[16] found that mean flexion and abduction were 70°, and 33% of patients had moderate to severe pain and disability. Goldman and colleagues[17] reported that mean flexion was 107°, that one fourth of patients had at least moderate pain, and that 73% had substantial functional deficits. In patients younger than 50 years, incidence of glenoid erosion is high, and, in a large series of atraumatic shoulder pathology cases, almost 50% of patients had unsatisfactory results.[18] Results from these studies and others imply that hemiarthroplasty may not be an ideal long-term solution for patients with high functional demands. We believe that elderly patients with 4-part fractures with a head-splitting component, poor bone quality, or traumatic vascular damage are ideal candidates for primary hemiarthroplasty. Otherwise, recently improved understanding of the necessary components of successful locked plating, development of soft-tissue-sparing approaches, and poor results with hemiarthroplasty make humeral head replacement not advisable in the majority of patients.

First-Generation Locked Plating

The advent of locked plating has shown the potential to achieve more stable fixation in osteoporotic bone because of the fixed angle established at the plate–screw interface.[19,20] Despite frequent use of these devices in recent years, guidelines for critical reduction parameters and implant position to create a biomechanically sound construct have not been fully elucidated. As a result, preliminary outcomes studies using locked plates have resulted in a significant number of mechanical failures.

Bjorkenheim and colleagues[21] reported a 26% incidence of varus deformity. Fankhauser and colleagues[22] found an 11% incidence of fixation failure, with frequent screw penetration of the articular surface. A preliminary report of a multicenter study of 132 patients found a 9% rate of fixation loss and a 20% revision rate, and 23% of cases were considered failures at 1 year.[23] Frangen and colleagues[24] demonstrated a 22% failure rate of the locked plate construct in 166 patients. Similarly, Owsley and Gorczyca[25] reported that 20% of the 75 patients in their series failed in varus, and 17% had hardware cutout of the humeral head.

Despite these early suboptimal results with locking implants, several factors and modifications have been identified as possibly improving on initial fixation stability. Specifically, more direct surgical approaches may minimize muscle retraction and vascular damage. In addition, attention to reduction of the medial cortex, directed implant placement, and endosteal augmentation of the medial column and humeral head may help maintain the reduction until fracture healing occurs.

Surgical Approaches

The traditional workhorse approach to the proximal humerus is through the deltopectoral interval. However, several disadvantages are associated with this approach when used for ORIF of proximal humerus fractures (Table). Most important, this interval is anterior to the shoulder joint. Placing screws through a locked plate

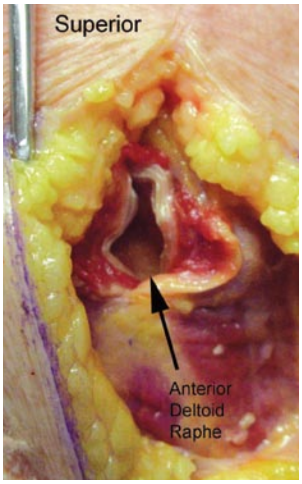

Figure 2. In the anterolateral acromial approach, the raphe between the anterior and middle heads of the deltoid is developed. Reprinted from *J Orthop Trauma*, vol. 20, Gardner MJ, Voos JE, Wanich T, Helfet DL, Lorich DG, Vascular implications of minimally invasive plating of proximal humerus fractures, pages 602-607, copyright 2006, with permission from Lippincott Williams & Wilkins.

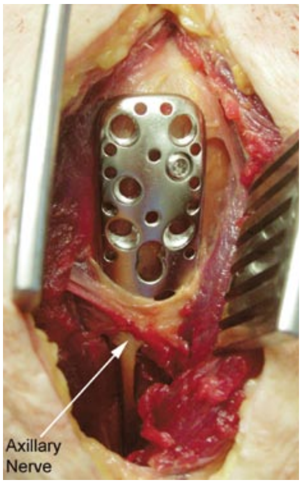

Figure 3. With the axillary nerve protected, the plate can be slid deep to the nerve. Reprinted from *J Orthop Trauma*, vol. 20, Gardner MJ, Voos JE, Wanich T, Helfet DL, Lorich DG, Vascular implications of minimally invasive plating of proximal humerus fractures, pages 602-607, copyright 2006, with permission from Lippincott Williams & Wilkins.

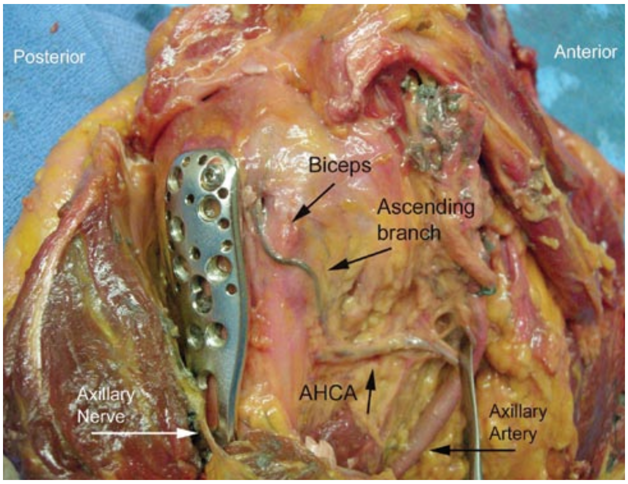

Figure 4. The anterior humeral circumflex provides the vascular supply to a large portion of the humeral head and is directly in the plane of dissection during a deltopectoral approach. Reprinted from *J Orthop Trauma*, vol. 20, Gardner MJ, Voos JE, Wanich T, Helfet DL, Lorich DG, Vascular implications of minimally invasive plating of proximal humerus fractures, pages 602-607, copyright 2006, with permission from Lippincott Williams & Wilkins.

does not allow variation in screw angle insertion, and threaded guides are screwed to the plate to establish the correct angle for drilling and screw placement. An anterior approach requires substantial retraction of the deltoid muscle mass and internal rotation of the humerus for lateral access. Techniques such as partial release of the deltoid insertion may be used to overcome this,[26,27] but the deltoid insertion is only 40% of the circumference of the humerus,[28] and even minimal release of the deltoid insertion can lead to functional deficits.[29]

Anterolateral Approaches

The anterolateral acromial approach is a direct surgical approach to the plating region of the lateral proximal humerus.[30,31] The skin is incised from the anterolateral corner of the acromion distally, and the anterior deltoid raphe, between the anterior and middle deltoid heads, is developed (Figure 2). The axillary nerve is found approximately 6 cm from the acromion and 3.5 cm from the prominence of the greater tuberosity if it is intact.[30] With the nerve protected, reduction of the fracture can proceed, working through the fracture lines to protect the tenuous blood supply. The locked plate can be slid distally under the nerve under direct visualization after reduction is achieved (Figure 3). No iatrogenic axillary nerve injuries have occurred in more than 70 cases performed using this approach, and in several cases the nerve was found to be incarcerated in the fracture and freed before fracture reduction.

Laflamme and colleagues,[32] who used a proximal deltoid-split approach for locked plating of 30 proximal humerus fractures, noted that the axillary nerve was easily palpated and protected in all cases. Similarly, Lill and colleagues,[33] who used a deltoid-splitting approach emphasizing vigilant protection of the axillary nerve, performed fracture reduction and locked plating without complication. Finally, Robinson and Page[34] advocated a strap incision, also with protection of the axillary nerve. They used a laterally based approach to facilitate reduction and encountered no related nerve injuries. These approaches have been based on well-described anatomical data and may minimize soft-tissue dissection and facilitate appropriate implant placement during fracture treatment.

Vascular Considerations

Vascularity is also a critical consideration in the treatment and outcomes of proximal humerus fractures. The vascular supply around the proximal humerus has been the subject of much research.[35-40] Gerber and colleagues,[37] who conducted a perfusion study of the humeral head, demonstrated that the arcuate artery, a branch of the anterior humeral circumflex system, was critical for perfusion of the majority of the humeral head. These authors emphasized that this branch must be preserved during surgical approaches, and they noted that many techniques of internal fixation are likely to injure this vascular supply (Figure 4). Other investigators have reported that the posteromedial vascular plexus may also play an important role in reperfusion of the humeral head after a displaced fracture.[35,36,39,41] Hertel and colleagues[41] correlated length of medial metaphy-

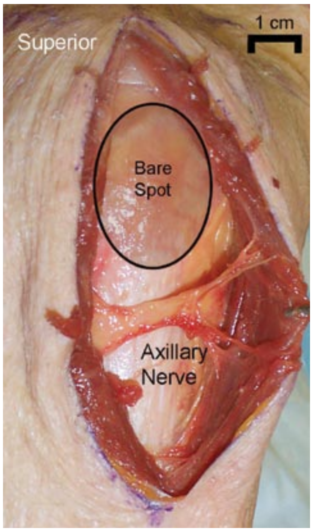

Figure 5. The anterolateral approach provides direct access to the lateral "bare spot," which minimizes vascular disruption. Reprinted from *J Orthop Trauma*, vol. 20, Gardner MJ, Voos JE, Wanich T, Helfet DL, Lorich DG, Vascular implications of minimally invasive plating of proximal humerus fractures, pages 602-607, copyright 2006, with permission from from Lippincott Williams & Wilkins.

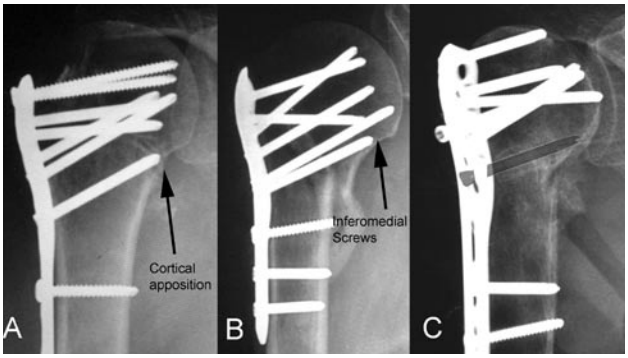

Figure 6. Either anatomical reduction of the medial cortex (A) or placement of inferomedial screws (B) leads to stable fixation. When neither is present, there is a significantly higher rate of hardware failure and reduction loss (C). Reprinted from *J Orthop Trauma*, vol. 21, Gardner MJ, Weil Y, Barker JU, Kelly BT, Helfet DL, Lorich DG, The importance of medial support in locked plating of proximal humerus fractures, pages 185-191, copyright 2007, with permission from Lippincott Williams & Wilkins.

seal extension and medial displacement with risk for AVN, which suggests that the posteromedial vessels play a major role in perfusion. Although the critical vascularity to the humeral head may vary according to fracture pattern and displacement, surgical interventions should minimize dissection medial to the bicipital groove to preserve the potentially tenuous anterior blood supply. The anterolateral acromial approach allows direct access to the lateral "bare spot" on the proximal humerus, which is between the arcuate artery and a vessel that dives intraosseously at the posterior border of the greater tuberosity (Figure 5).[31] These lateral approaches, which avoid exposure and dissection in the region of the anterior vascular system, may cause less iatrogenic vascular injury and minimize incidence of AVN. In high-risk cases, with medial comminution and displacement and with traumatic soft-tissue stripping, augmenting fracture healing with demineralized bone matrix or bone morphogenetic protein (BMP) locally, or parathyroid hormone systemically, may prove to be useful.[42-44]

Medial Column Stabilization

Placement of a locking plate on the lateral cortex of the proximal humerus establishes a mechanical construct that functions as a tension band. As the rotator cuff fires and attempts to deform the humeral head in varus, these forces may be converted to medial compression forces, essentially offloading the implant and creating a load-sharing construct between the implant and the bone. Mechanical stability of the construct, however, relies on an intact and apposed medial cortex that is functionally able to transmit load. For this reason, Gerber and colleagues[5] and Hertel[45] emphasized the importance of achieving an anatomical reduction of the medial cortex in achieving a successful outcome with plate fixation. Other studies have shown, in fractures treated with locking plates without mechanical support of the medial cortex, a high incidence of loss of fixation with varus malalignment and hardware cutout.[46]

Unfortunately, in many of the fractures that occur after high-energy mechanisms or in osteoporotic bone, significant comminution of the medial column is present. When the medial cortex is either malreduced or comminuted, it is unable to share load with the implant, and high stresses occur at the locking screws in the humeral head. In this situation, a lateral locked plate may be unable to neutralize the deforming forces of the proximal fragment, in either young or older patients.[46] In these situations, there are several technical options for creating a mechanically favorable construct. First, the shaft may be medialized, effectively impacting the proximal humeral head fragment laterally in the shaft. Although this creates deformity in several planes, an element of stability is likely to be conferred. All attempts should be made to anatomically reduce the medial cortex, or to medialize the shaft if necessary.

When initial medial displacement of the humeral head fragment is present and associated with comminution, reduction can be difficult. Regardless of the reduction achieved, it appears that placement of locking screws in the inferomedial quadrant of the humeral head, to within 5 mm of the subchondral bone, imparts a substantial mechanical advantage. In a series of patients with proximal humerus fractures who had medial comminution and malreduction of the medial cortex, screws placed inferomedially minimized subsequent reduction loss and implant cutout (Figure 6).[46] The basis for screw placement in this region is supported by histomorphometric studies, which have reported particularly poor bone quality in the superior regions of the humeral head.[47]

It is important to consider that the vascular anatomy around the medial surgical neck of the humerus,[35,36,39,41] particularly the posteromedial vascular tree, is also important for humeral head perfusion. Direct exposure or implant placement medially is contraindicated, so only indirect reduction techniques of the medial column are possible. The anterolateral approach may be particularly

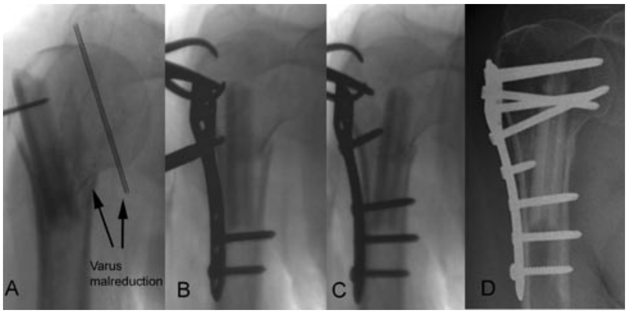

Figure 7. A segment of fibular allograft is inserted through the lateral fracture lines **(A)** to the appropriate depth. The locking plate is placed laterally over the reduced tuberosities **(B)**, and a push screw is used to translate the fibula medially, indirectly reducing the medial cortex **(C)**. The fibula is locked in place, allowing it to maintain the medial reduction and provide additional mechanical support. Additional locking screws are placed inferomedially, creating a stable construct. In this case, uneventful healing occurred with a maintained reduction at 10 weeks **(D)**.

suited for this purpose, as the lateral exposure goes directly to the intertuberosity fracture line, allowing the surgeon to work within the fracture lines to indirectly reduce the medial column.

Besides reduction of the medial cortex, several factors are critical to maximizing outcome. Anatomical reduction of the tuberosities, followed by secure fixation with heavy nonabsorbable sutures through the rotator cuff, cannot be overemphasized. Newer implants have holes on the borders of the plate head specifically for assisting in anchoring the tuberosities. Finally, height of the humeral head fragment should be restored relative to the tuberosities and humeral shaft. This maintains a lever arm for the rotator cuff mechanism to work efficiently, minimizes risk for subacromial impingement, and reverses any residual varus deformity of the humeral head reduction.

Endosteal Implants

Because the cancellous bone in the humeral head may be extremely brittle and not amenable to stable screw anchorage, techniques using endosteal implants have been developed on the basis of techniques popularized by Mast and colleagues.[49] Implants placed endosteally have the advantage of being able to assist both in indirect reduction of the medial column and in providing mechanical support for the medial column and humeral head fragment. These functions may be used in combination or individually, depending on the needs of the fracture. Small fragment plates may be used in this role, but we have found that a short segment of fibula allograft is extremely effective for this purpose.

The neurovascular anatomy around the medial proximal humerus precludes direct approaches to this region. As already mentioned, medial reduction is critical, and indirect methods are often needed to achieve reduction. When the humeral head fragment remains medial and in varus malalignment after indirect reduction techniques, a fibular allograft segment approximately 6 cm long can be used for reduction and reconstruction of the medial cortex. The fibula is inserted into the humeral shaft through the lateral fracture lines and positioned such that several centimeters lie above the surgical neck. The tuberosities are reduced, and the plate is placed laterally. One or several push screws are used to translate the fibula medially, allowing precise positioning of the shaft fragment relative to the proximal fragment. The fibula, which is then locked into place with several screws, subsequently augments cortical support of the medial column (Figure 7).

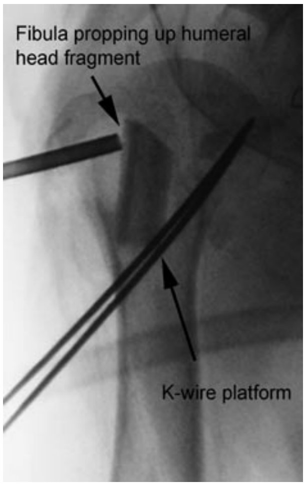

Figure 8. In the case of valgus impaction of the humeral head, a shorter fibular allograft can be leveraged off Kirschner wires to assist in reduction and to function as a mechanical prop to the head fragment.

An endosteal fibula allograft may alternatively be used as an oblique strut to "prop up" the humeral head fragment—analogous to fibular strut grafting used for mechanical support in osteonecrosis of the hip, originally described by Phemister.[49] This application is most useful in valgus impacted fractures. Kirschner wires should be placed from the shaft fragment into the inferior humeral head as a stable platform on which to leverage the fibular allograft under the head (Figure 8). The proximal fibula may be cut at an oblique angle parallel to the fracture surface of the humeral head fragment. The fibula can then be incorporated into the locking construct to contribute mechanical support. Other authors have reported the necessity of using allograft materials to provide support and subsequent good results in these fractures.[34]

Allograft fibula strut graft is ideal for use in proximal humerus fractures because of its dimensions and initial strength. We have used fibula allografts in 7 proximal humerus fractures and have had no reduction loss or implant failure. In our clinical experience, the cortical edges of the fibula become blunted, and the allograft appears to incorporate into the host bone by 6 to 12 weeks. Drawbacks to using a fibula—similar to those of any allograft tissue—include risk for infection and relatively limited availability. Given the high rate of hardware complications with standard techniques of proximal humerus locked plating,[23-25,46] we believe that mechanical augmentation of the medial column with a fibula may offset the cost of a high reoperation rate. Alternatively, however, endosteal plates may be used to confer additional medial column support.

Summary

Displaced proximal humerus fractures present difficult challenges in establishing stable fixation. Unique to these fractures are the tenuous blood supply, the proximity of critical neurovascular structures to the surgical intervals, and the poor quality of bone available for fixation. Locked plates have provided an important initial step in improving initial fracture fixation stability. When used incorrectly, however, these devices do not appear to be a panacea in treating these fractures. Newer concepts in treating proximal humerus fractures with these devices may improve on early fixation failures. More direct surgical approaches that minimize soft-tissue stripping and vascular damage may improve fracture healing potential. Recognition of the importance of the integrity of the medial column, as well as screw placement in the inferomedial humeral head, appears to be a major factor in the resulting mechanical stability. Finally, endosteal implants, particularly fibular allografts, may be useful as reduction tools and can be locked into place to provide additional support in difficult fractures with medial comminution. Further refinement of these and other techniques, with correlation to maintenance of reduction and functional outcomes, will be critical to develop reliable methods of fracture stabilization.

Authors' Disclosure Statement

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

References

1. Ding M, Hvid I. Quantification of age-related changes in the structure model type and trabecular thickness of human tibial cancellous bone. *Bone.* 2000;26:291-295.
2. Hepp P, Lill H, Bail H, et al. Where should implants be anchored in the humeral head? *Clin Orthop.* 2003;415:139-147.
3. Kawashima T, Uhthoff HK. Pattern of bone loss of the proximal femur: a radiologic, densitometric, and histomorphometric study. *J Orthop Res.* 1991;9:634-640.
4. Gaebler C, McQueen MM, Court-Brown CM. Minimally displaced proximal humeral fractures: epidemiology and outcome in 507 cases. *Acta Orthop Scand.* 2003;74:580-585.
5. Gerber C, Werner CM, Vienne P. Internal fixation of complex fractures of the proximal humerus. *J Bone Joint Surg Br.* 2004;86:848-855.
6. Bathis H, Tingart M, Bouillon B, Tiling T. Surgical treatment of proximal humeral fractures. Is the T-plate still adequate osteosynthesis procedure? *Zentralbl Chir.* 2001;126:211-216.
7. Speck M, Lang FJ, Regazzoni P. Proximal humeral multiple fragment fractures—failures after T-plate osteosynthesis [in German]. *Swiss Surg.* 1996;2:51-56.
8. Kristiansen B, Christensen SW. Plate fixation of proximal humeral fractures. *Acta Orthop Scand.* 1986;57:320-323.
9. Sturzenegger M, Fornaro E, Jakob RP. Results of surgical treatment of multifragmented fractures of the humeral head. *Arch Orthop Trauma Surg.* 1982;100:249-259.
10. Szyszkowitz R, Schippinger G. Fractures of the proximal humerus [in German]. *Unfallchirurg.* 1999;102:422-428.
11. Jaberg H, Jakob RP. Compound fractures of the proximal humerus [in German]. *Orthopade.* 1987;16:320-335.
12. Jakob RP, Ganz R. Proximal humerus fractures [in German]. *Helv Chir Acta.* 1982;48:595-610.
13. Münst P, Kuner EH. Osteosynthesis in dislocated fractures of the humerus head [in German]. *Orthopade.* 1992;21:121-130.
14. Zyto K. Non-operative treatment of comminuted fractures of the proximal humerus in elderly patients. *Injury.* 1998;29:349-352.
15. Zyto K, Ahrengart L, Sperber A, Tornkvist H. Treatment of displaced proximal humeral fractures in elderly patients. *J Bone Joint Surg Br.* 1997;79:412-417.
16. Zyto K, Wallace WA, Frostick SP, Preston BJ. Outcome after hemiarthroplasty for three- and four-part fractures of the proximal humerus. *J Shoulder Elbow Surg.* 1998;7:85-89.
17. Goldman RT, Koval KJ, Cuomo F, Gallagher MA, Zuckerman JD. Functional outcome after humeral head replacement for acute three- and four-part proximal humeral fractures. *J Shoulder Elbow Surg.* 1995;4:81-86.
18. Sperling JW, Cofield RH, Rowland CM. Neer hemiarthroplasty and Neer total shoulder arthroplasty in patients fifty years old or less. Long-term results. *J Bone Joint Surg Am.* 1998;80:464-473.
19. Gardner MJ, Griffith MH, Demetrakopoulos D, et al. Hybrid locked plating of osteoporotic fractures of the humerus. *J Bone Joint Surg Am.* 2006;88:1962-1967.
20. Edwards SL, Wilson NA, Zhang LQ, Flores S, Merk BR. Two-part surgical neck fractures of the proximal part of the humerus. A biomechanical evaluation of two fixation techniques. *J Bone Joint Surg Am.* 2006;88:2258-2264.
21. Bjorkenheim JM, Pajarinen J, Savolainen V. Internal fixation of proximal humeral fractures with a locking compression plate: a retrospective evaluation of 72 patients followed for a minimum of 1 year. *Acta Orthop Scand.* 2004;75:741-745.
22. Fankhauser F, Boldin C, Schippinger G, Haunschmid C, Szyszkowitz R. A new locking plate for unstable fractures of the proximal humerus. *Clin Orthop.* 2005;430:176-181.
23. Babst RH, Sommer C, Bahrs C, et al. Open reduction and internal fixation of proximal humerus fractures with an angle stable form plate: an international multicenter analysis of outcome and complications. *Trans Orthop Trauma Assoc.* 2006. Paper 65.
24. Frangen TN, Dudda M, Arens S, Martin D, Muhr G, Kalicke T. Proximal humeral fractures with angle-stable plate osteosynthesis: is everything better now? *Trans Orthop Trauma Assoc.* 2006. Paper 58.
25. Owsley KC, Gorczyca JT. Fracture displacement and hardware migration after open reduction and internal fixation of proximal humerus fractures. *Trans Orthop Trauma Assoc*. 2006. Paper 67.
26. Hawkins RJ, Kiefer GN. Internal fixation techniques for proximal humeral fractures. *Clin Orthop.* 1987;223:77-85.
27. Martini M. The sub-deltoid approach to the metaphyseal region of the humerus. *J Bone Joint Surg Am*. 1976;58:377-379.
28. Morgan SJ, Furry K, Parekh AA, Agudelo JF, Smith WR. The deltoid muscle: an anatomic description of the deltoid insertion to the proximal humerus. *J Orthop Trauma*. 2006;20:19-21.
29. Klepps S, Auerbach J, Calhon O, Lin J, Cleeman E, Flatow E. A cadaveric study on the anatomy of the deltoid insertion and its relationship to the deltopectoral approach to the proximal humerus. *J Shoulder Elbow Surg.* 2004;13:322-327.
30. Gardner MJ, Griffith MH, Dines JS, Briggs SM, Weiland AJ, Lorich DG. The extended anterolateral acromial approach allows minimally invasive access to the proximal humerus. *Clin Orthop.* 2005;434:123-129.
31. Gardner MJ, Voos JE, Wanich T, Helfet DL, Lorich DG. Vascular implications of minimally invasive plating of proximal humerus fractures. *J Orthop Trauma.* 2006;20:602-607.
32. LaFlamme GY, Berry G, Benoit B. Percutaneous plating of fractures of the proximal humerus: a prospective multi-center clinical trial. Poster presented at: Annual Meeting of the Orthopaedic Trauma Association; 2005; Ottawa, Canada. Poster 28
33. Lill H, Hepp P, Rose T, Konig K, Josten C. The angle stable locking-proximal-humerus-plate (LPHP) for proximal humeral fractures using a small anterior-lateral-deltoid-splitting-approach—technique and first results [in German]. *Zentralbl Chir.* 2004;129:43-48.
34. Robinson CM, Page RS. Severely impacted valgus proximal humeral fractures. Results of operative treatment. *J Bone Joint Surg Am*. 2003;85:1647-1655.
35. Brooks CH, Revell WJ, Heatley FW. Vascularity of the humeral head after proximal humeral fractures. An anatomical cadaver study. *J Bone Joint Surg Br.* 1993;75:132-136.
36. Duparc F, Muller JM, Freger P. Arterial blood supply of the proximal humeral epiphysis. *Surg Radiol Anat.* 2001;23:185-190.
37. Gerber C, Schneeberger AG, Vinh TS. The arterial vascularization of the humeral head. An anatomical study. *J Bone Joint Surg Am.* 1990;72:1486-1494.
38. Laing PG. The arterial supply of the proximal humerus. *J Bone Joint Surg Am.* 1956;38:1105-1116.
39. Meyer C, Alt V, Hassanin H, et al. The arteries of the humeral head and their relevance in fracture treatment. *Surg Radiol Anat.* 2005;27:232-237.
40. Panagopoulos AM, Dimakopoulos P, Tyllianakis M, et al. Valgus impacted proximal humeral fractures and their blood supply after transosseous suturing. *Int Orthop*. 2004;28:333-337.
41. Hertel R, Hempfing A, Stiehler M, Leunig M. Predictors of humeral head ischemia after intracapsular fracture of the proximal humerus. *J Shoulder Elbow Surg.* 2004;13:427-433.
42. Govender S, Csimma C, Genant HK, et al. Recombinant human bone morphogenetic protein-2 for treatment of open tibial fractures: a prospective, controlled, randomized study of four hundred and fifty patients. *J Bone Joint Surg Am.* 2002;84:2123-2134.
43. Alkhiary YM, Gerstenfeld LC, Krall E, et al. Enhancement of experimental fracture-healing by systemic administration of recombinant human parathyroid hormone (PTH 1-34). *J Bone Joint Surg Am.* 2005;87:731-741.
44. Chakkalakal DA, Strates BS, Mashoof AA, et al. Repair of segmental bone defects in the rat: an experimental model of human fracture healing. *Bone.* 1999;25:321-332.
45. Hertel R. Fractures of the proximal humerus in osteoporotic bone. *Osteoporos Int.* 2005;16(suppl 2):S65-S72.
46. Gardner MJ, Weil Y, Barker JU, Kelly BT, Helfet DL, Lorich DG. The importance of medial support in locked plating of proximal humerus fractures. *J Orthop Trauma.* 2007;21:185-191.
47. Liew AS, Johnson JA, Patterson SD, King GJ, Chess DG. Effect of screw placement on fixation in the humeral head. *J Shoulder Elbow Surg.* 2000;9:423-426.
48. Mast JW, Jakob R, Ganz, R. *Planning and Reduction Technique in Fracture Surgery.* Berlin, Germany: Springer-Verlag; 1989.
49. Phemister DB. Treatment of the necrotic head of the femur in adults. *J Bone Joint Surg.* 1949;31:55-66.

This paper will be judged for the Resident Writer's Award.