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Complications encountered in proximal humerus fractures treated with locking plate fixation

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Objectives: We evaluated the complications encountered following locking plate fixation of proximal humerus fractures.

Methods: The study included 103 patients (70 females, 33 males; mean age 62 years; range 21 to 90 years) who were treated with open reduction and locking plate fixation for proximal humerus fractures between September 2005 and April 2009. Fixation was performed using the PHILOS locking plate in 93 patients, and S3 humerus plate in 10 patients. Postoperatively, a shoulder-arm sling was applied for six weeks and a standard rehabilitation program was used in all the patients. Intraoperative, acute postoperative, and late postoperative complications were assessed on radiographs. Varus inclination was defined as less than 120 degrees of the inclination angle on immediate postoperative radiographs, and varus displacement as postoperative increases in the varus angle. The mean follow-up period was 19 months (range 2 weeks to 43 months).

Results: Complications were seen in 10 patients (9.7%; mean age 67 years). The PHILOS plate was used in nine patients and S3 plate was used in one patient. Five patients (4.9%) had varus inclination with a mean inclination angle of 112.6° (range 105° to 118°), four patients (3.9%) developed varus displacement with a mean inclination angle of 102.5° (range 95° to 110°), and intra-articular screw penetration was seen in five patients (4.9%). The remaining complications were fixation failure (n=1, 1%), implant fracture (n=1), and deep infection (n=1). Screw penetration exceeded 3 mm in three patients, requiring revision surgery. The mean ages of patients with varus inclination, varus displacement, and screw penetration were 76.6, 74.4, and 71 years, respectively. Three patients with varus inclination (60%) developed varus displacement. Screw penetration was observed in three patients (60%) with varus inclination, and in all patients with varus displacement. The mean Constant-Murley shoulder score was 67.8 (range 50 to 90) in patients who developed a complication.

Conclusion: Our findings show that locking plate and screw systems represent a significant treatment option in the treatment of comminuted and displaced humerus fractures, with low complication rates. Accurate indication, protection of the head's inclination angle through appropriate surgical approach and proper technique, and fine calculation of screw length are essential for successful functional results.

Key words: Bone plates; fracture fixation, internal/methods; fractures, comminuted/surgery/complications; humeral fractures/surgery/complications; shoulder fractures/surgery; treatment outcome.

Proximal humerus fractures are usually caused by low-energy trauma in osteoporotic elderly individuals or by high-energy trauma in younger patients.[1] These fractures are often nondisplaced and nondisplaced two-part fractures can be treated conservatively, whereas displaced fractures with two or more fragments require surgical treatment for good functional results.[2]

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The aim of all implants used in the treatment of fractures is to keep the fracture in proper reduction until fracture healing occurs and to provide adequate stability for early motion. Although locking plate systems are excellent fixation methods for these fractures, complications have been reported.[3-10] Owsley et al.[5] reported complications in 19 patients (36%) in a series of 53 patients (13 angulation, 12 screw penetration). Egol et al.[7] reported complications in 12 patients (23.5%) among 51 patients, of which eight were screw penetration. Hepp et al.[10] reported complications in 26 patients (31.3%) in a series of 83 patients, including varus angulation in three patients and screw penetration in 12 patients. Screw penetration results in poor functional outcomes and is the most frequent complication that requires revision surgery. Varus angulation has been implicated as the cause of screw penetration.[5]

Irrespective of the fixation method, there are numerous pitfalls that cause poor functional outcomes and necessitate revision surgery in the treatment of proximal humerus fractures.[3] Based on our experience, we noticed that the incidence of complications following locking plate fixation of proximal humerus fractures was lower than the rates reported in similar studies. The aim of this study was to evaluate complications associated with locking plate fixation of proximal humerus fractures and to review relevant points to avoid complications and approaches to achieve good functional outcomes.

Patients and methods

Between September 2005 and April 2009, 103 patients (70 females, 33 males; mean age 62 years; range 21 to 90 years) underwent surgical treatment for proximal humerus fractures. Open reduction was performed in all the patients, followed by fixation using the PHILOS locking plate (Proximal Humeral Internal Locking System, Synthes, Stratec Medical, Mezzovico, Switzerland) in 93 patients, and S3 humerus plate (S3 Proximal Humerus Plating System, DePuy, Kirkel-Limbach, Germany) in 10 patients.

Postoperatively, a shoulder-arm sling was applied for six weeks and a standard fracture rehabilitation program was used in all the patients. Intraoperative, acute postoperative, and late postoperative complications were assessed on radiographs (true anteroposterior, anteroposterior internal rotation and external rotation views, and axillary views). Follow-up examinations were made at 15-day intervals for the first 1.5 months, and at six-month intervals thereafter. Patients with an inclination angle (head-diaphysis angle) of less than 120 degrees on immediate postoperative radiographs were accepted as having varus inclination.[11] Varus displacement was defined as a postoperative increase in the varus angle. The mean follow-up period was 19 months (range 2 weeks to 43 months).

Results

Complications were seen in 10 patients (9.7%), of whom seven were females and three were males (mean age 67 years; range 41 to 89 years). According to the AO classification, there were two A3, three B1, two B2, two C2, and one C3 type fractures. The PHILOS plate was used in nine patients and S3 plate fixation was performed in one patient.

Five patients (4.9%) had varus inclination on immediate postoperative radiographs with a mean inclination angle of 112.6° (range 105° to 118°). Four patients (3.9%) developed varus displacement during follow-up, with a mean inclination angle of 102.5° (range 95° to 110°). Intra-articular screw penetration was seen in five patients (4.9%). The remaining complications were fixation failure (n=1, 1%), implant fracture (n=1), and deep infection (n=1). Screw penetration exceeded 3 mm in three patients, requiring revision surgery and replacement of the screws with shorter ones (Fig. 1).

Among 10 patients who developed complications, three patients had high-energy trauma and they also had a femoral fracture. The mean ages of patients with varus inclination, varus displacement, and intra-articular screw penetration were 76.6 (71-89), 74.4 (62-89), and 71 years (59-89), respectively. Of patients with varus inclination, the deformity progressed in three patients resulting in varus displacement (Fig. 2).

Screw penetration was observed in three patients (60%, 3/5) with varus inclination, and in all patients with varus displacement. Varus displacement occurred in 3-4 part fractures, and screw penetration was observed in 2-4 part fractures. While two patients with varus inclination showed no further decrease in the inclination angle, one patient with a normal inclination angle developed varus displacement (Fig. 1). At final examinations, the mean inclination angle decreased to 107° (range 95° to 115°) in patients with varus incli-

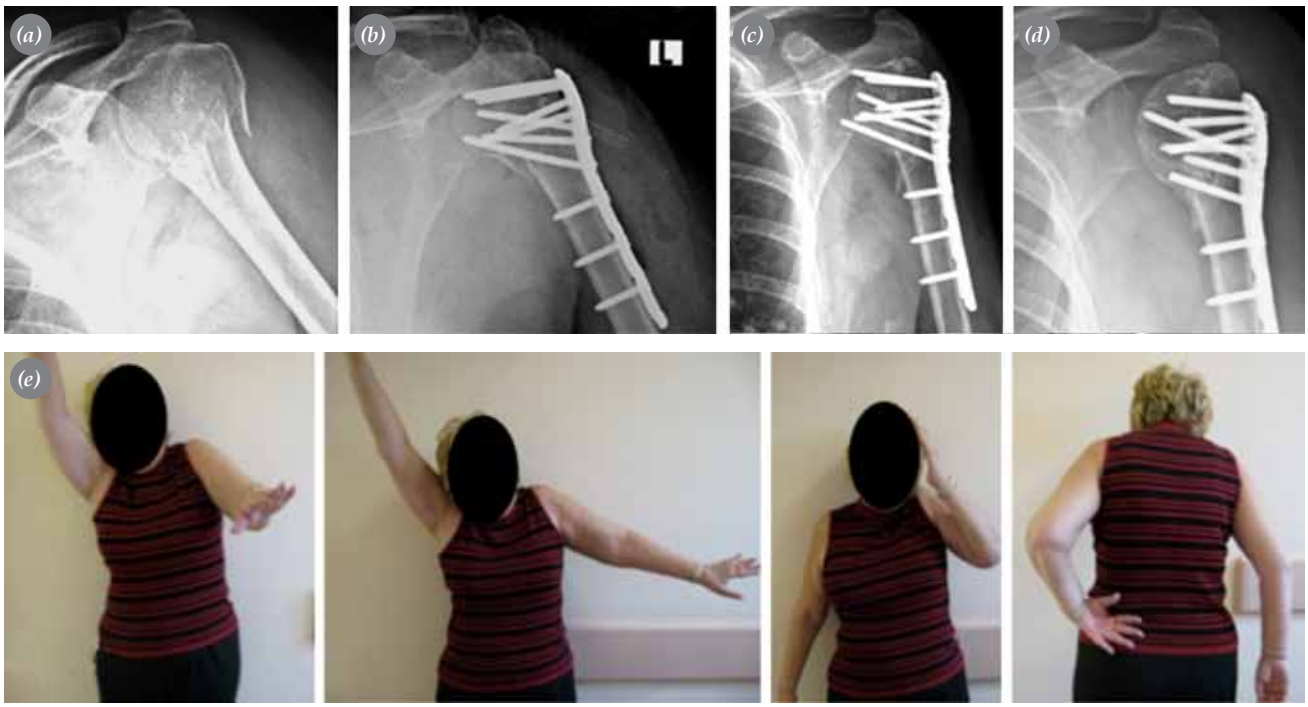

Fig. 1. **(a)** Preoperative radiograph of a 62-year-old woman who sustained an 11B2 fracture. **(b)** The inclination angle following fixation with the PHILOS plate was measured as 125°. **(c)** During the follow-up, she had varus displacement with the inclination angle decreasing to 95°, as well as screw penetration. **(d)** The screws penetrating into the joint were replaced with shorter ones. **(e)** Early postoperative restricted range of motion of the patient. At final follow-up, the Constant-Murley score was 70.

nation, representing about 5% reduction in the varus angle. Of four patients with varus displacement and concomitant screw penetration, medial support was provided with a locking screw in the inferomedial aspect of the head in three patients.[12] One of these patients developed avascular necrosis. In one patient, superior positioning of the plate resulted in intra-articular penetration of the topmost screw (Fig. 3).

Infection developed in the patient with a C3 fracture. It completely resolved following debridement and antibiotic therapy. The patient's implant was removed after completion of union (Fig. 4).

The mean Constant-Murley score in patients who developed a complication was 67.8 (range 50 to 90).

Discussion

Locking periarticular plate fixation offers more advantages compared to many implants and have been shown to be superior to nonlocking plates.[13-15] These plates enclose the fracture well, have a low profile, allow insertion of multidirectional proximal screws, use locking plate technology for angular stability, and have a greater reliability in osteoporotic bones.[16] Although locking plates represent

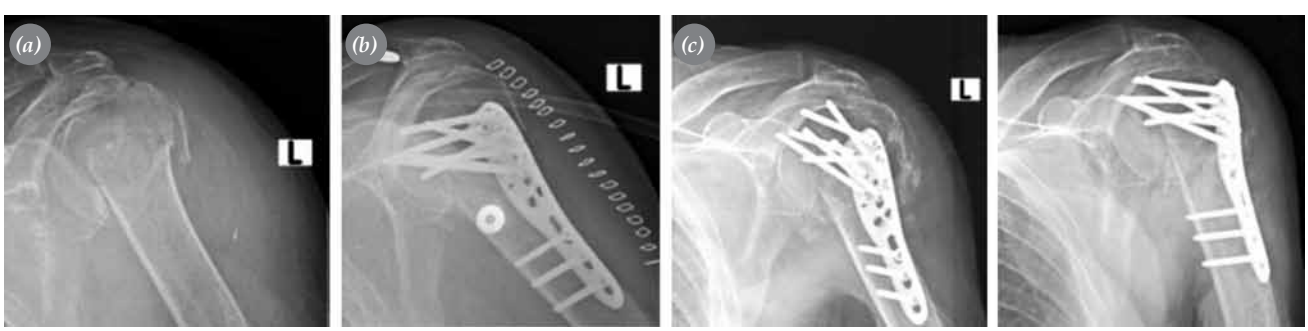

Fig. 2. **(a)** Preoperative radiograph of an 89-year-old male patient who sustained an 11B1 fracture. **(b)** The inclination angle following fixation with the PHILOS plate was measured as 118°, showing varus inclination. **(c)** During the follow-up, the inclination angle decreased to 105° resulting in varus displacement, and screw penetration was noted.

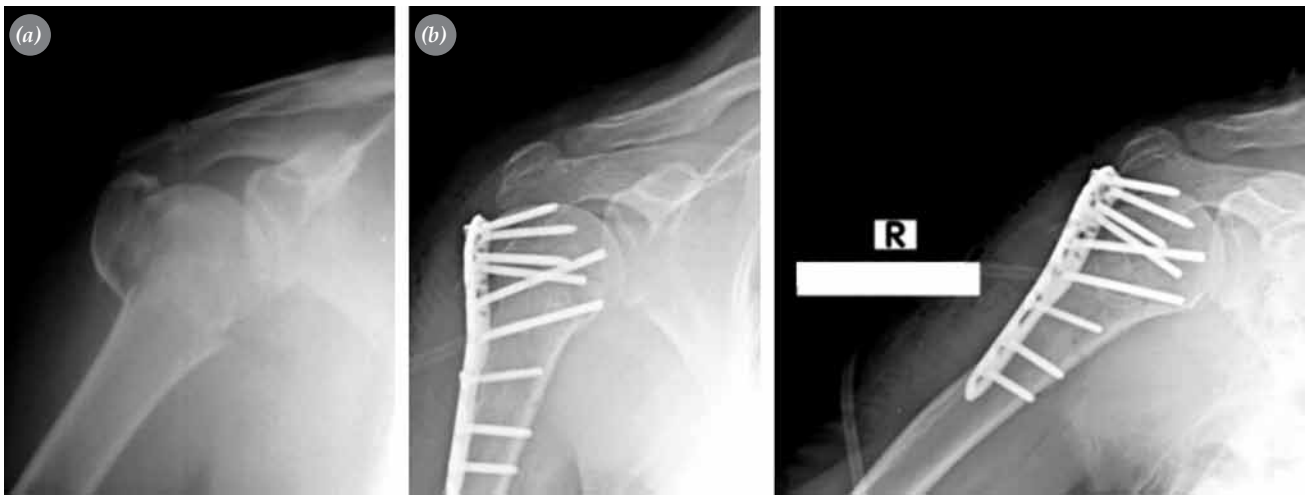

Fig. 3. **(a)** Preoperative radiograph of a 59-year-old female patient who sustained an 11B2 fracture. **(b)** Postoperative radiographs showing superior positioning of the PHILOS plate leading to intra-articular penetration of the topmost screw. At final follow-up, the Constant-Murley score was 90.

a very good fixation method for proximal humerus fractures, they are associated with several complications (Table 1).[3-7,10] One weakness of our study was that it was a prospective study including patients in diverse age groups. It was not designed as a randomized study for comparison with other treatment methods used. However, other case series published till now are either retrospective or prospective multicenter studies. The major difference of our case series is that all operations were performed by two experienced surgeons. Other studies have been carried out in education hospitals where operations are performed by numerous surgeons. Such differences may influence indications and patient selection, both of which have significant effects on outcomes.

Table 1
Complications reported following treatment of proximal humerus fractures with locking plates

	Agudelo et al.[6]	Owsley et al.[5]	Egol et al.[7]	Koukakis et al.[9]	Hepp et al.[10]	This study
Follow-up period (mean)	55 months	44 months	16 months	16.2 months	12 months	19 months
Number of patients	153	53	51	20	83	103
Cases with complications (No.; %)	29; 19%	19; 36%	12; 23.5%	3; 15%	26; 31.3%	10; 9.7%
Screw penetration		12; 23%	8; 16%		12; 14.4%	5; 4.9%
Varus inclination		13; 25%			3; 3.6%	5; 4.9%
Avascular necrosis	7; 4.5%	2; 4%	2; 4%	1; 5%	4; 4.8%	1; 1.0%
Delayed union	2; 1.3%					
Nonunion	1; 0.7%		1; 2%		3; 3.6%	
Subacromial impingement	3; 2%				2; 2.4%	
Adhesive capsulitis	3; 2%			1; 5%		
Infection	7; 4.5%		1; 2%	1; 5%	1; 1.2%	1; 1.0%
Wound problems	1; 0.7%					
Heterotopic ossification			1; 2%			
Implant failure			2; 4%	1; 5%	1; 1.2%	1; 1.0%
Rotator cuff tear	5; 3.2%					
Fixation failure						1; 1.0%

Fig. 4. Preoperative **(a)** radiograph and **(b)** computed tomography scans of a 41-year-old male patient showing an 11C3 proximal humerus fracture and a bony Bankart lesion. **(c)** The proximal humerus fracture was fixed with the PHILOS plate and two cannulated screws, and the Bankart lesion was repaired using a suture anchor. **(d)** The patient's implant was removed after union and, at final follow-up, his Constant-Murley score was 64.

Following surgical treatment of proximal humerus fractures, numerous complications may develop, resulting in poor functional outcomes and requiring revision surgery. These complications may be associated with incorrect evaluation of the fractures, inappropriate indications, inadequate operation room conditions and surgical experience, advanced osteoporosis, inappropriate postoperative follow-up and rehabilitation.[3]

Adequacy of radiologic studies is very important in the determination of surgical approach and operative planning. We recommend real shoulder anteroposterior and scapular Y views and computed tomography in the evaluation of patients. Good imaging enables diagnosis of associated glenoid fractures and dislocations, and thus is helpful in choosing appropriate surgical method. For example, in the case illustrated in Figure 4, deltopectoral incision should be used instead of the deltoid split incision in order to repair the Bankart lesion as well. In our first cases, we noticed that even the use of fluoroscopy in an incorrect angle resulted in complications (Fig. 3). The X-ray beam should be perpendicular to the shoulder when the patient is in the beach chair position, which otherwise will result in incorrect positioning of the plate and penetration of the superior screws into the joint cavity. Severe osteoporosis may cause fixation failure irrespective of the surgical method. Screw penetration into the joint cavity was due to collapse in the early postoperative period in an 89-year-old patient who had both proximal humerus and hip fractures and was under follow-up for colon cancer (Fig. 2). If surgery is considered in these patients, we recommend the use of cement or calcium phosphate cement to support bone stock.[17,18]

Important aspects of the surgical technique include placement of the plate in strict adherence to the technique, determination of appropriate length and placement of screws with fluoroscopy, insertion of screws to the head in adequate number and position, providing medial cortex support for the prevention of varus displacement[19] and, to fix tubercle fragments, fixation of the sutures passing through the junction of the tubercle and rotator cuff to the plate.[20,21] During fixation of the head, attention should be paid to keep the inclination angle in normal range. If the humeral head is fixed with the inclination angle in varus, this will result in further decreases in the inclination an-

gle with increases in varus displacement during the follow-up leading to screw penetration. Screw penetration is a complication associated with the worst functional result and represents the most frequent cause of revision. The most important way to avoid this complication is to achieve and maintain reduction with an acceptable inclination angle.

In our series, we used two types of locking plates, the PHILOS and S3 humerus plates. The most superior part of the PHILOS plate must be 8 mm (0.5-1 cm) below the superior part of the greater tubercle.[3,20] The S3 plate, however, is placed in a lower position than that of the PHILOS plate, therefore it is less likely to result in impingement syndrome.

In our study, we used the deltoid split approach in 83 patients (80.6%) and deltopectoral incision in 20 patients (19.4%). The deltoid split approach allows a wide control (270°) of the proximal humerus. The most important advantage of the deltoid split incision is its indirect contribution to the reduction of fracture fragments, because it enables fixation without disturbing the vascularization of these fragments. Especially in cases where the tubercular fragments are displaced, plate and screw systems are not reliable in maintaining reduction. These fragments should be fixed to the plate with thick, nonabsorbable sutures passing through the tendon of the rotator cuff.[20,21] Loss of innervation of the deltoid or surgical separation from the acromion will result in failure. Vascular structures should not be compromised. Particular care should be given to the ascending branch of the anterior circumflex artery (arcuate artery) that passes lateral to the bicipital groove. The axillary nerve must be protected. In four-part fractures of the proximal humerus, split incision of the supraspinatus is more advantageous for both osteosynthesis and hemiarthroplasty. Opening the rotator interval may aid in the reduction of the humeral head; however, it does not allow a stable fixation since it will not provide adequate exposure.[3,10,22] The head and tubercle are frequently displaced posteriorly, and opening the rotator interval may turn a four-part fracture to a five-part fracture. If the head is valgus impacted, after its elevation, the cavity in the metaphyseal bone should be filled with bone graft. The graft should be placed deeper to the tubercles, and especially under the head to achieve reduction and support the locking plate.[3,18,20,21] The approach used for fracture fixation should also allow a prosthesis procedure when necessary.

The head should be in neither varus nor valgus when the plate is placed. The superior aspect of the articular surface of the head is 8±3.2 mm superior than the superior aspect of the greater tubercle.[2] If the plate is placed too high, it will result in subacromial impingement and penetration of the superior screws into the joint; if it is placed too low, it will result in insertion of inadequate number of screws to the head. The plate should not hamper the insertion of the rotator cuff.[3,22] The medial column should be reduced anatomically and fixed with an inferomedial screw.[12,16] Care should be taken not to injure the axillary nerve while using the drill and screws. The most important disadvantage of locking plates is that it is not possible to know for sure whether the screw has caught the bone due to the locking of the screw to the plate. The locking of the screw to the plate may lead to a misinterpretation that the fragments are held by the implant, which may in turn result in screw penetration.[5] Screw penetration is the complication that accounts for the most frequent cause of revisions and has the worst effect on functional outcomes. Varus inclination of the head may also cause screw penetration. During reduction of the fracture, the inclination and rotation of the head require particular attention.

Screws that penetrate may injure the humerus and glenoid cartilage when they exceed cartilage thickness, and subsequently cause significant functional loss that may require revision surgery. In our cases, screws that showed a penetration greater than 3 mm required revision. The incidence of screw penetration is greater in comminuted fractures.[5] There is a significant correlation between loss of fixation and varus reduction, and thus avoidance of varus is necessary to decrease the risk for fixation loss.[6] The number of screws applied in the head and the distance of the screw from the joint surface are also associated with reduction loss. As the central, inferoposterior, and superoposterior regions of the head have the highest mineral density, they also exert the greatest force for screw pull-out. Screws inserted in divergent directions provide greater stability.[6] Medial support obtained by anatomical reduction in the medial cortex or by an inferomedial locking screw in the proximal head fragment is important in the maintenance of reduction.[7,12] Determination of screw height should not rely on tactile sense, its penetration and localization in the joint must be assessed by fluoroscopy. Sufficient length of the plate will prevent implant failure due to stress fracture.[19] All screw

holes must be filled in order to minimize the bending moments of locking plates.[22]

In our series, avascular necrosis was observed in only one patient, and it was partial. No signs of avascular necrosis were noted in the remaining patients throughout the follow-up period.

Postoperative faults also have an adverse impact on clinical results. For example, immobilization of the shoulder for a long period will result in frozen shoulder; keeping the arm in a brace in medial rotation may cause displacement of the greater tubercle; and overaggressive rehabilitation may cause implant failure and fracture displacement.[3] Postoperative physical therapy and rehabilitation is mandatory after surgical treatment of proximal humerus fractures. Active motion and rotation movements must be avoided until achievement of radiographic union.

Successful surgical treatment of proximal humerus fractures is only possible with accurate evaluation of fracture type and bone stock of the patient. In our series, locking plate systems in the treatment of proximal humerus fractures were associated with lower complication rates compared with those reported in the literature, which may be attributed to good imaging and biological fixation methods, patient-customized surgical technique, advanced surgical experience and favorable operating room settings, and early initiation of rehabilitation based on the need of the patient. The fact that all the patients were operated on by two experienced surgeons is another factor in obtaining a lower complication rate. In conclusion, locking plate and screw systems represent a significant treatment option in the treatment of comminuted and displaced humerus fractures, with low complication rates.

References

1. Flatow EL. Fractures of the proximal humerus. In: Bucholz RW, Heckman JD, editors. Rockwood and Green's fractures in adults. Vol. 1, 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2001. p. 997-1041.
2. Green A. Proximal humerus fractures. In: Norris TR, editor. Orthopaedic knowledge update: shoulder and elbow 2. 2nd ed. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2002. p. 209-17.
3. Boileau P, Pennington SD. Common pitfalls in the management of proximal humeral fractures: how to avoid them. In: Boileau P, Walch G, Mole D, Favard L, Levigne C, Sirveaux F, et al, editors. Shoulder concepts 2008. Proximal humeral fractures and fracture sequelae. Montpellier: Sauramps Medical; 2008. p. 303-23.
4. Kılıç B, Uysal M, Çınar BM, Özkoç G, Demirörs H, Akpınar S. Early results of treatment of proximal humerus fractures with the PHILOS locking plate. [Article in Turkish] Acta Orthop Traumatol Turc 2008;42:149-53.
5. Owsley KC, Gorczyca JT. Fracture displacement and screw cutout after open reduction and locked plate fixation of proximal humeral fractures [corrected]. J Bone Joint Surg [Am] 2008;90:233-40.
6. Agudelo J, Schürmann M, Stahel P, Helwig P, Morgan SJ, Zechel W, et al. Analysis of efficacy and failure in proximal humerus fractures treated with locking plates. J Orthop Trauma 2007;21:676-81.
7. Egol KA, Ong CC, Walsh M, Jazrawi LM, Tejwani NC, Zuckerman JD. Early complications in proximal humerus fractures (OTA Types 11) treated with locked plates. J Orthop Trauma 2008;22:159-64.
8. Ring D. Current concepts in plate and screw fixation of osteoporotic proximal humerus fractures. Injury 2007;38 Suppl 3:S59-68.
9. Koukakis A, Apostolou CD, Taneja T, Korres DS, Amini A. Fixation of proximal humerus fractures using the PHILOS plate: early experience. Clin Orthop Relat Res 2006; (442):115-20.
10. Hepp P, Theopold J, Voigt C, Engel T, Josten C, Lill H. The surgical approach for locking plate osteosynthesis of displaced proximal humeral fractures influences the functional outcome. J Shoulder Elbow Surg 2008;17:21-8.
11. Boileau P, Walch G. The three-dimensional geometry of the proximal humerus. Implications for surgical technique and prosthetic design. J Bone Joint Surg [Br] 1997;79:857-65.
12. 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;21:185-91.
13. Siffri PC, Peindl RD, Coley ER, Norton J, Connor PM, Kellam JF. Biomechanical analysis of blade plate versus locking plate fixation for a proximal humerus fracture: comparison using cadaveric and synthetic humeri. J Orthop Trauma 2006;20:547-54.
14. Seide K, Triebe J, Faschingbauer M, Schulz AP, Püschel K, Mehrtens G, et al. Locked vs. unlocked plate osteosynthesis of the proximal humerus - a biomechanical study. Clin Biomech 2007;22:176-82.
15. Walsh S, Reindl R, Harvey E, Berry G, Beckman L, Steffen T. Biomechanical comparison of a unique locking plate versus a standard plate for internal fixation of proximal humerus fractures in a cadaveric model. Clin Biomech 2006; 21:1027-31.
16. Siwach R, Singh R, Rohilla RK, Kadian VS, Sangwan SS, Dhanda M. Internal fixation of proximal humeral fractures with locking proximal humeral plate (LPHP) in elderly patients with osteoporosis. J Orthop Traumatol 2008;9:149-53.

17. Robinson CM, Page RS. Severely impacted valgus proximal humeral fractures. Results of operative treatment. J Bone Joint Surg [Am] 2003;85:1647-55.
18. Atalar AC, Demirhan M, Uysal M, Seyahi A. Treatment of Neer type 4 impacted valgus fractures of the proximal humerus with open reduction, elevation, and grafting. [Article in Turkish] Acta Orthop Traumatol Turc 2007;41:113-9.
19. Gardner MJ, Voos JE, Wanich T, Helfet DL, Lorich DG. Vascular implications of minimally invasive plating of proximal humerus fractures. J Orthop Trauma 2006;20:602-7.
20. 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;9:423-6.
21. Moonot P, Ashwood N, Hamlet M. Early results for treatment of three- and four-part fractures of the proximal humerus using the PHILOS plate system. J Bone Joint Surg [Br] 2007;89:1206-9.
22. Drosdowech DS, Faber KJ, Athwal GS. Open reduction and internal fixation of proximal humerus fractures. Orthop Clin North Am 2008;39:429-39.