Functional outcome of locked-plate fixation of displaced three-part and four-part fractures of the proximal humerus

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Background
The treatment of multifragmentary proximal humerus fractures with conventional plate fixation has been associated with implant failure due to lack of bone support. In contrast, limited internal fixation techniques may not allow early rehabilitation because of poor stability. Locked-plate fixation ensures stable fixation of unstable fractures as they rely on the fixed angle between the screws and the plate, thereby facilitating early rehabilitation.

Aim of the study
The aim of this study was to evaluate the results of open reduction and internal fixation of displaced three-part and four-part proximal humerus fractures with locked plate and early mobilization.

Patients and methods
This study included cases of 24 patients (18 female patients and six male patients) who had three-part and four-part proximal humeral fractures treated surgically with open reduction and locked-plate fixation. Their ages ranged from 21 to 63 years (average 45.4 years). The postoperative management included early shoulder mobilization.

Results
Nineteen fractures (79%) healed in good anatomical position, three healed with varus malunion, and two developed avascular necrosis of the humeral head. At the end of the follow-up period, the mean Constant–Murley score was 66.5. The results were excellent or good in 17 patients (71%), fair in five patients (21%), and poor in two patients (8%). The mean DASH score was 28.3. Nine complications (37.5%) were seen during the follow-up period. Complications included avascular necrosis of the humeral head in two patients (8%), varus malunion of the humeral head in three patients (12.5%), and subacromial impingement in four patients (16.7%). Subacromial impingement was mainly caused by the superior plate position. Reoperation was required in five patients (21%).

Conclusion
Proximal humeral locked-plate fixation provides sufficient fracture stabilization in the treatment of unstable proximal humeral fractures; however, the complications are frequent, and careful surgical technique is required to ensure satisfactory results.

Keywords:
fractures, locked-plate fixation, outcome, proximal humerus

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Introduction

Fractures of the proximal humerus account for ~5% of all fractures. Eighty percent of these fractures are minimally displaced and yield good functional results with conservative treatment. However, when the fracture is displaced and unstable, surgical intervention is indicated [1].

Surgical treatment of unstable proximal humeral fractures aims to achieve adequate reduction and stability for a satisfactory functional outcome [2]. Various techniques, such as percutaneous pinning, tension-band techniques, plate fixation, intramedullary nailing, and hemiarthroplasty, have been described to restore biomechanical stability [3].

Osteoporotic bone in elderly patients and marked comminution in young patients involved in high-energy trauma are therapeutic challenges and have variable prognosis [4].

In elderly patients with comminuted fractures, conventional plate osteosynthesis has been associated with hardware problems because of lack of sufficient purchase, and it has been suggested that minimally invasive stabilization techniques may not allow early rehabilitation because of poor stability [5].

The complication rate of surgical treatment of proximal humerus fractures can be 50% or higher. Several complications have been reported, such as cut-out or back-out of the screws and plates, nonunion, avascular necrosis, nail migration, and rotator cuff impairment. Shoulder arthroplasty in proximal humeral fractures also may yield functionally poor results. The optimal treatment of these fractures is still controversial, and

the ideal fixation device for these fractures remains undefined [1,2,6].

The present study was conducted to evaluate the clinical outcome of surgical fixation of proximal humeral fractures, using proximal humerus locked plates, and to analyze the potential treatment-related complications.

Patients and methods

Twenty-four patients (18 female patients and six male patients) were treated between January 2007 and March 2009 in Tanta University Hospitals. Their ages ranged from 21 to 63 years (average 45.4 years).

The inclusion criteria were closed proximal humeral fracture (three-part or four-part according to the Neer classification system) [7], with angulation greater than 45° or displacement greater than 1 cm and failed nonoperative treatment. Patients with pathological fractures or open fractures, those having poor medical condition impeding general anesthesia, patients younger than 18 years of age, fractures-dislocations, patients with a history of metastatic tumors, and those with fractures neglected for more than 2 weeks were excluded from the study.

The fractures were classified according to the Neer classification as displaced three-part or four-part fractures based on radiographs and, when available, computed tomography [7].

Fractures were caused by low-energy trauma (fall from standing height) in seven patients and by road traffic accident in 17 patients. The right side was affected in 14 patients and the left side in ten patients.

Preoperative evaluation

A standard radiographic trauma series (anteroposterior, lateral, and axillary or velpeau views) was obtained to assess fracture displacement. Computed tomography scan was used only in 11 patients for better visualization of the fracture fragments and plan the method of fixation. Indications for surgery were three-part (16 patients) or four-part (eight patients) closed proximal humeral fractures (according to the Neer's classification system) with angulation greater than 45° or displacement greater than 1 cm.

Surgical procedure

Under general anesthesia and the patient in the beach-chair position, using a standard deltopectoral approach, the cephalic vein was routinely taken medially to prevent inadvertent injury during retractor placement. Soft-tissue attachments to the fracture fragments were carefully preserved to prevent devascularization of the bone. The biceps tendon was used as a landmark between the greater and lesser tuberosities.

The osseous attachments of the rotator cuff were often displaced and had to be identified and reduced with sharp hook retractors or pointed reduction clamp. Temporary fixation was carried out using Kirschner wires, and reduction was checked using an image intensifier. The plate was positioned 5–10 mm lateral to the bicipital groove and 10–15 mm distal to the tip of the greater tuberosity and fixed to the humeral head with at least four proximal locking screws before the distal locking, or cortical screws were inserted into the humeral diaphysis. The lesser tuberosity was fixed with nonabsorbable heavy sutures placed in the subscapularis tendon and then through one or two holes in the plate.

Postoperative care

The upper limb was immobilized in an arm sling. On the third postoperative day, passive motion and pendulum exercises were initiated to prevent stiffness. Active assisted motion was limited to 40 degrees up to 6 weeks. Resistive strengthening exercises were begun after fracture union had been ensured. All patients received a similar physical therapy program.

Evaluation of results

The patients were assessed clinically and radiographically at the time of last follow-up, which ranged from 12 to 35 months (average 23 months).

At the latest follow-up, standard anteroposterior and lateral plain radiographs were obtained (Figs. 1 and 2). Radiographic evaluation was performed to assess union, avascular necrosis, implant loosening, and complications related to the hardware. Complications during the follow-up period and functional outcome were recorded.

The functional outcome was assessed using the Constant–Murley score [8]. Range of motion was measured with a goniometer. The Constant–Murley score was graded as poor (0–55 points), moderate (56–70), good (71–85), or excellent (86–100) [11]. Moreover, the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire was used as a measure of disability [9].

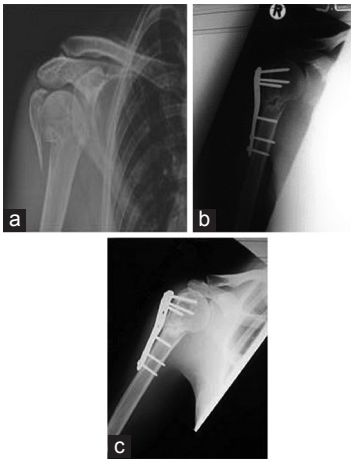
Results

The demographic data of the study patients are detailed in Table 1.

Figure 1

(a) Preoperative radiograph of a three-part fracture in a 43-year-old male patient. (b,c) Postoperative radiographs A–P and lateral views, showing good reduction and fixation with a locked plate and screws. (d) Follow-up radiograph at 18 months postoperatively with excellent result.

Figure 2



(a) Preoperative radiograph of a four-part fracture in a 54-year-old male patient. (b) Postoperative radiograph after open reduction and fixation with a locked plate and screws. (c) Follow-up radiograph after 14 months with good results.

Table 1 Demographic data of the study patients

Number	Age (years)	Sex	Side	Associated medical condition	Time to surgery (days)	Secondary procedures	Complications
1	45	F	Right	DM and HT	7	–	Humerus head AVN
2	34	F	Right	–	5	–	–
3	21	M	Left	–	6	–	–
4	63	M	Right	DM	7	–	–
5	55	F	Left	–	3	–	Varus malunion
6	24	F	Right	–	1	–	–
7	33	F	Right	–	4	–	–
8	62	M	Left	HT	5	–	–
9	41	F	Left	–	4	–	–
10	28	F	Right	–	1	–	–
11	51	M	Right	–	5	–	–
12	48	F	Left	HT	1	Implant removal	Impingement
13	43	F	Left	–	4	–	–
14	51	F	Right	–	1	Implant removal	Impingement
15	58	F	Right	–	3	–	–
16	54	F	Left	HT	4	–	–
17	49	M	Right	–	5	–	–
18	44	F	Left	–	4	Implant removal	Humerus head AVN
19	52	F	Right	–	1	–	–
20	58	F	Left	–	3	–	Varus malunion
21	48	F	Right	HT	4	Implant removal	Impingement
22	55	F	Left	DM and HT	7	–	–
23	41	M	Right	–	4	Implant removal	Impingement
24	32	F	Right	–	1	–	Varus malunion
Total/ average	45.4	18 F6 M	14 R10 L	7	3.7	5	9

AVN, avascular necrosis; DM, diabetes mellitus; F, female; HT, hypertension; L, left; M, male; R, right.

The cases of 24 patients were reviewed. Their ages ranged from 21 to 63 years (average 45.4 years). There were 18 female and six male patients. The right shoulder was affected in 14 patients (58%) and the left shoulder in 10 (42%). Seven patients (29%) had associated medical conditions. The time elapsed before surgery ranged from 1 to 7 days (average 3.7 days). Three-part fracture was diagnosed in 17 patients (71%) and four-part fracture in seven (29%).

Nineteen fractures (79%) healed in good anatomical position, three fractures healed with varus malunion, and two patients developed avascular necrosis of the humeral head. The time to radiological bone healing ranged from 15 to 20 weeks (average 18 weeks).

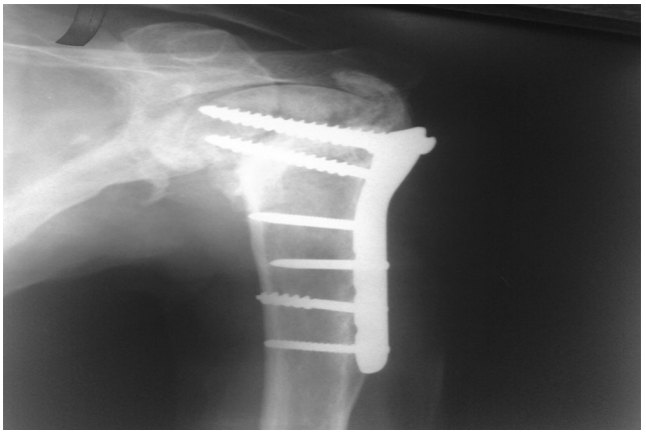
Varus malunion occurred in three patients (12.5%), mainly the patients who were operated upon in the beginning of the study and those who had four-part fractures. Secondary procedures for implant removal was required in five patients (21%) (due to impingement of a superiorly placed plate in four patients and due to avascular necrosis of the humeral head in one). Complications occurred in nine patients (37.5%) and included avascular necrosis of the humeral head in two patients (8%) (Fig. 3), varus malunion of the humeral head in three patients (12.5%), and subacromial impingement in four patients (17%); subacromial impingement was mainly caused by the superior plate position.

At the end of the follow-up period, the mean Constant–Murley score was 66.5. The results were excellent or good in 17 patients (71%), fair in five patients (21%), and poor in two patients (8%). The mean DASH score was 28.3.

Discussion

Displaced proximal humeral fractures represent a therapeutic challenge particularly when associated with osteoporosis and comminution. Operative fixation of proximal humeral fractures is indicated in ~20% of patients; the majority of which are displaced two-part, three-part, and four-part fractures according to Neer's classification. Key principles for obtaining a satisfactory result include stable fixation to allow early mobilization and minimal soft-tissue disruption to prevent further vascular compromise [1,2,10,11].

Figure 3



X-ray A–P view of four-part fractures fixed with a locked plate and screws complicated with avascular necrosis of the humeral head.

Different techniques have been described for fixation of comminuted and displaced proximal humeral fractures. All these techniques have been associated with a varying rate of complications including cut-out or back-out of the screws, malunion, nonunion, avascular necrosis of the humerus head, and fractures distal to the plate. The functional outcome depends not only on the quality of bone stock but also on the stability provided by the implant [12–14].

The locking proximal humerus plate was designed to maintain a stable fracture reduction even in osteoporotic bone with minimal soft-tissue dissection. The advantages of the locking proximal humerus plate include gentle fracture reduction with the use of indirect maneuvers, a high resistance to avulsion even in patients with poor bone stock because of the combination of fixed-angle screw-plate locking and three-dimensional placement of screws in the humeral head, and the possibility of early exercise and a short period of immobilization because of the high initial stability achieved [15].

Using a locked plate, all forces are transmitted from the bone through the locking screw-head to the blade, and vice versa. Hence, the principle of fixed-angle plates lies in increasing the torsional stiffness and stability of the construct, thereby improving the outcome, through a combination of multidirectional locking screws for the head and minimal soft-tissue damage, as the plate lies ~2 mm above the cortical surface preserving additional blood supply to the periosteum. Precise knowledge of and experience with the surgical technique is required to maximize clinical outcomes, including appropriate preoperative and postoperative management [16]. Unfortunately, fixation with locked plate alone cannot guarantee stable fixation. Gardner *et al*. [17] concluded that achieving mechanical support of the inferomedial region of the proximal humerus seems to be important for maintaining fracture reduction. Locked plates are unable to support the humeral head alone from a lateral tension-band position; they recommended achieving an anatomic or slightly impacted stable reduction, as well as meticulous placement of a superiorly directed oblique locked screw in the inferomedial region of the proximal fragment, which may achieve more stable medial column support and allow for better maintenance of reduction.

The cumulative complication rate, in our series, was 37.5%. The main complications were varus malunion and subacromial impingement associated with a high positioning of the plate, suggesting that the plate

Table 2 Comparing our results with other studies on the basis of to constant score

References	Mean age (years)	Three-part fracture score (*n*)	Four-part fracture score (*n*)
Lee *et al.* [6]	64.4	77 (26)	63 (13)
Bjorkenheim *et al.* [10]	67	78 (22)	60 (12)
Fazal *et al.* [11]	56	73 (12)	58 (2)
Konrad *et al.* [12]	48	76 (43)	69 (16)
This study	45.4	73 (16)	60 (8)

n, number of patients.

should be placed more distally to prevent subacromial impingement during abduction. In all cases, complaints resolved after plate extraction. Moreover, a learning curve does exist in using locked-plate fixation for periarticular fractures, and the results should improve with careful attention to the details of the technique.

On the basis of their observations, Geiger *et al.* [18] concluded that inadequate positioning of the implant resulted in reduced functional outcome. Hence, to improve the functional outcome, they considered plate positioning to be of utmost importance when using locked-plate fixation.

Two patients with four-part fractures developed avascular necrosis of the humeral head. In an attempt to avoid avascular necrosis of the humeral head, minimal dissection was preferred to preserve the ascending branch of the anterior humeral circumflex artery. Even if this vessel is disrupted, protection of soft-tissue attachments, especially those containing the posteromedial vessels, may preserve some flow to the humeral head as recommended by previous studies [19].

Excellent or good results (according to the Constant–Murley score) were seen in 17 patients (71%), fair results in five patients (21%), and poor clinical outcome in two patients (8%). These results are comparable to the reported results for the locked-plate fixation method (Table 2).

Conclusion

On the basis of the results of this study, we believe that the locking plate and screw system is a useful tool for fixation of comminuted and displaced proximal humerus fractures, despite the frequent complications, which should lessen with gaining experience with the technique. Good patient selection, protection of the head's inclination angle, fine calculation of screw length, and meticulous rotator cuff repair are essential if complications are to be avoided and to ensure a satisfactory functional outcome.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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