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Abstract

Introduction:
Locked plating for complex proximal humerus fractures through a deltopectoral incision can be difficult due to the fracture morphology and need for fixed angle screws. Although good results have been reported with the deltopectoral approach; technical difficulties, excessive soft tissue stripping and fears of avascular necrosis have lead to the use of minimal access techniques.
Method:
Fifteen patients with three or four part fractures were treated by locked plating through a mini-invasive lateral trans-deltoid approach. All patients were relatively young with good bone quality and had sustained a high-

velocity injury. Initial closed reduction was attempted in all patients, but majority of the patients (9/15) required open reduction to achieve a satisfactory reduction.
Results:
Union was achieved in all patients. All fractures united with an acceptable alignment. There were no incidences of axillary nerve palsy. There were no incidences of hardware failure or loss of reduction. There were no incidences of avascular necrosis at 1-year follow-up. The mean normalized constant score at last follow-up was 85.24.
Conclusion:
Locked plating through lateral trans-deltoid incision may offer a better alternative to the deltopectoral approach in these complex fractures where locked plating is contemplated. It respects the fracture biology, allows ease in placement of the locking plate and angle stable screws and offers a stable construct with less surgical morbidity.

Keywords (separated by '-')	Locking plates - MIPO - Proximal humerus fractures - Deltoid splitting
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Arch Orthop Trauma Surg
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TRAUMA SURGERY

Biological osteosynthesis of complex proximal humerus fractures: surgical technique and results from a prospective single center trial

Ashok S. Gavaskar · S. Muthukumar · Naveen Chowdary

Received: 6 April 2009

Abstract
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Keywords Locking plates · MIPO · Proximal humerus fractures · Deltoid splitting

Introduction

Proximal humerus fractures are on the rise because of the increasing life span and resultant elderly population [16]. More often, these fractures are a result of low velocity injuries and are complicated by osteoporosis and poor general condition. On the contrary, proximal humerus fractures in younger population usually involve a high-velocity injury and the fractures are usually complex with greater comminution and soft tissue injury. Even though an anatomical reduction is not mandatory in a shoulder for normal function [18], these fractures need to be fixed in a stable manner, especially in younger patients to allow early mobilization, faster recovery and minimize loss of function. Surgical options for three and four part fractures of the proximal humerus include plating, percutaneous fixation techniques, trans-osseous wiring and hemiarthroplasty [10, 12, 19, 26]. Encouraging results with locking plates have made it the implant of choice [11] and has reduced the need for arthroplasty even in difficult four part fractures and in patients with poor bone quality. Several biomechanical studies have validated the efficacy of locking plates in these fractures [1, 3].

Locked plating through the conventional deltopectoral approach involves a great deal of soft tissue stripping, exposes the fracture fragments, cause devitalisation and may increase the risk of avascular necrosis [9]. Percutaneous techniques using screws or multiple K wires can shorten the

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surgical time and can avoid surgical morbidity associated with open techniques [21], but the fixation may not be strong enough to allow early rehabilitation. Our technique of mini-invasive transdeltoid plating combines the methods and benefits of both closed and open fixation techniques.

We present a prospective study of 15 patients who underwent the procedure for a three or four part fracture of proximal humerus at our institution.

Materials and methods

Fifteen patients with a displaced three or four part fracture of the proximal humerus were treated at our institution from January 2007 to November 2007 using mini-invasive locked plating through two small lateral trans-deltoid incisions. Fractures were classified as per Neer's criteria. Neer's original criteria (angulation >45° or displacement >1 cm) were used to define displacements. The mean age was 43 (33–58) years. Patients with a two part surgical neck fracture, pathological fracture and open fractures were excluded. All patients were operated by a single surgeon (ASG). Thirteen patients reported early and were operated within 2 days of injury. Two patients presented to us with the loss of reduction following percutaneous fixation with K wires at a different center. Both patients were re-operated at an interval of 2 weeks after the injury.

The mode of violence was due to high-velocity road traffic accident in 12 patients, fall from a height in one patient and accidental fall at home in two patients. All fractures were closed. Multiple bony injuries were present in six patients. AP and axial views of the shoulder were taken in all patients as part of the initial evaluation. A CT scan was also taken in all patients for three-dimensional analyses of the fracture geometry and to plan surgical fixation. Functional integrity of the axillary was examined in all patients before surgery. The preoperative data is summarized in Table 1.

Surgical technique (Fig. 1)

Patients were placed in beach chair position on a radiolucent table with the image intensifier from the opposite side. In three part fractures involving the greater tuberosity, the humeral head is usually internally rotated by the pull of the subscapularis and the tuberosity fragment is pulled upwards and posteriorly. We attempted closed reduction by aligning the shaft fragment with the head fragment in adduction, axial traction and internal rotation. The reduction was maintained by one or two K wires passed from the superior aspect of the humeral head into the medial aspect of the shaft fragment.

The incision starts 1 cm distal to the lateral border of acromion and ends at the level of the axillary nerve. A slightly longer incision was made by extending proximally in case of gross upward displacement of the tuberosity and in cases with severe comminution of the tuberosity fragment to facilitate suture placement. The deltoid fibers were split bluntly and the axillary nerve was identified, freed and protected using an infant feeding tube. Impacted three part fractures and four part fractures where a satisfactory closed reduction of the shaft fragment and head fragment cannot be achieved were reduced under vision.

In impacted fractures, a small periosteal elevator was used to manipulate and disimpact the head fragment to reconstruct

Table 1

No.	Age/sex	Fracture pattern	Mode of violence	Reduction method	Quality of reduction	Comments
1	37/M	3 part	RTA	Closed	Anatomical	
2	46/M	3 part	RTA	Closed	Anatomical	
3	43/F	4 part (valgus impacted)	RTA	Open	Anatomical	
4	51/M	4 part (valgus impacted)	Fall from height	Open	Non-anatomical	Valgus malreduction
5	33/M	3 part (valgus impacted)	RTA	Open	Anatomical	
6	39/M	4 part (valgus impacted)	RTA	Open	Anatomical	
7	55/M	3 part	Fall at home	Closed	Anatomical	
8	58/M	4 part	Fall at home	Open	Non-anatomical	Varus malreduction
9	47/F	3 part	RTA	Closed	Anatomical	
10	51/M	4 part	RTA	Open	Anatomical	
11	35/M	3 part	RTA	Open	Anatomical	Repeat surgery[a]
12	39/M	3 part	RTA	Closed	Anatomical	
13	40/M	3 part (valgus impacted)	RTA	Open	Anatomical	
14	33/F	3 part	RTA	Closed	Anatomical	
15	39/M	4 part	RTA	Open	Non-anatomical	Varus malreduction repeat surgery[a]

[a] Second delayed surgery following failed surgery at another center

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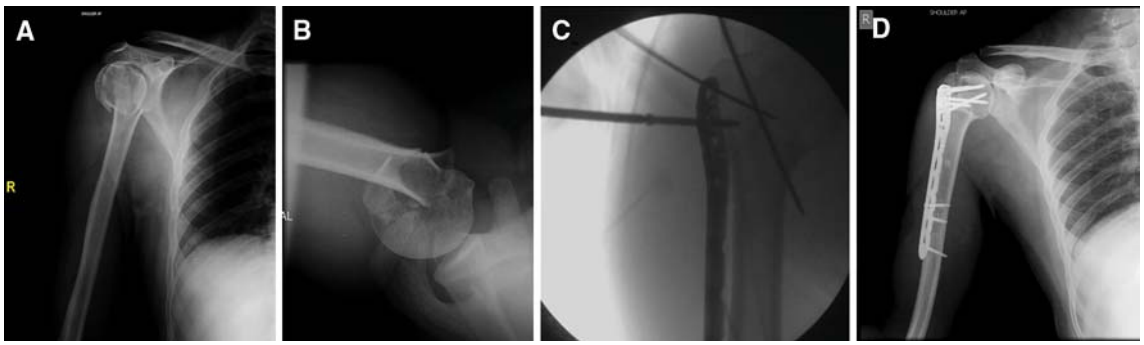

Fig. 1 **a**, **b** Preoperative radiographs of a three part fracture, **c** intraoperative fluoroscopy image showing closed reduction and provisional fixation with K wires, **d** final reduction and fixation

the medial calcar. The reduction was maintained with K wires during plate placement. If the greater tuberosity involves a good chunk of bone, it was reduced with external rotation and provisionally fixed with K wires. Non-absorbable sutures through the cuff at the tendon bone junction were used to reduce the tuberosities in case of comminuted fractures.

A pre-contoured proximal humerus locking plate (PHILOS, Synthes, India or proximal humerus locking plates, Zimmer, India) was inserted along the submuscular tunnel safe guarding the axillary nerve from getting trapped under the plate. The plate was placed proximally below the apex of the greater tuberosity maintaining its reduction. Non-absorbable sutures if used were secured to the small plate holes. The plate was anchored proximally with multiple angle stable screws into the head fragment. Screw placements were checked fluoroscopically with the shoulder in neutral, internal and external rotations to identify intraarticular penetration. The distal part of the plate was secured to the bone using a 2–3 cm incision. Care was taken to insert at least one locking screw into the distal fragment.

Postoperative protocol

Pendulum exercises were started on the first postoperative day and were continued till suture removal. Active-assisted exercises of the shoulder were started at that time and were continued up to 6 weeks. External rotation beyond neutral was not allowed till 4 weeks. Active range of motion exercises were instituted by 6 weeks at home under supervision by a physiotherapist and rotator cuff strengthening exercises were started with progressive fracture union. Supervised home physiotherapy was followed up to 4 months.

Follow-up and outcome assessment

Follow-up and immediate postoperative X rays were read by a senior orthopedic surgeon blinded to the outcome of the study. Fracture reduction was classified as anatomical and non-anatomical. Non-anatomical reductions were further classified as valgus and varus malalignments. Patients were followed up at regular intervals. AP and axial X rays of the shoulder were taken at follow-up visits to assess union, loss of reduction and screw pull outs. All patients completed a Constant and Murley shoulder outcome questionnaire [2] at 1-year follow-up. The constant score was adjusted for age and gender and a normalized score was calculated as suggested by Katolik et al. [13] (Table 2). The functional analysis was done by an independent blinded fellow in orthopedic trauma. All data were obtained and analyzed prospectively.

Table 2 Normalized constant scores of the study population

Patient no.	Raw score	Normal score	Normalized score
1	89	95	93.6
2	87	96	90.6
3	81	92	94.1
4	81	94	86.1
5	87	95	91.5
6	85	95	89.4
7	81	94	86.1
8	77	94	81.9
9	81	92	88
10	77	94	81.9
11	59	95	62.1
12	89	95	93.6
13	87	96	90.6
14	83	93	89.2
15	57	95	60
Mean	80.06		85.24

Raw score: obtained using the constant score questionnaire

Normal score: normal constant score adjusted for age and gender

Normalized score: raw score/normal score × 100

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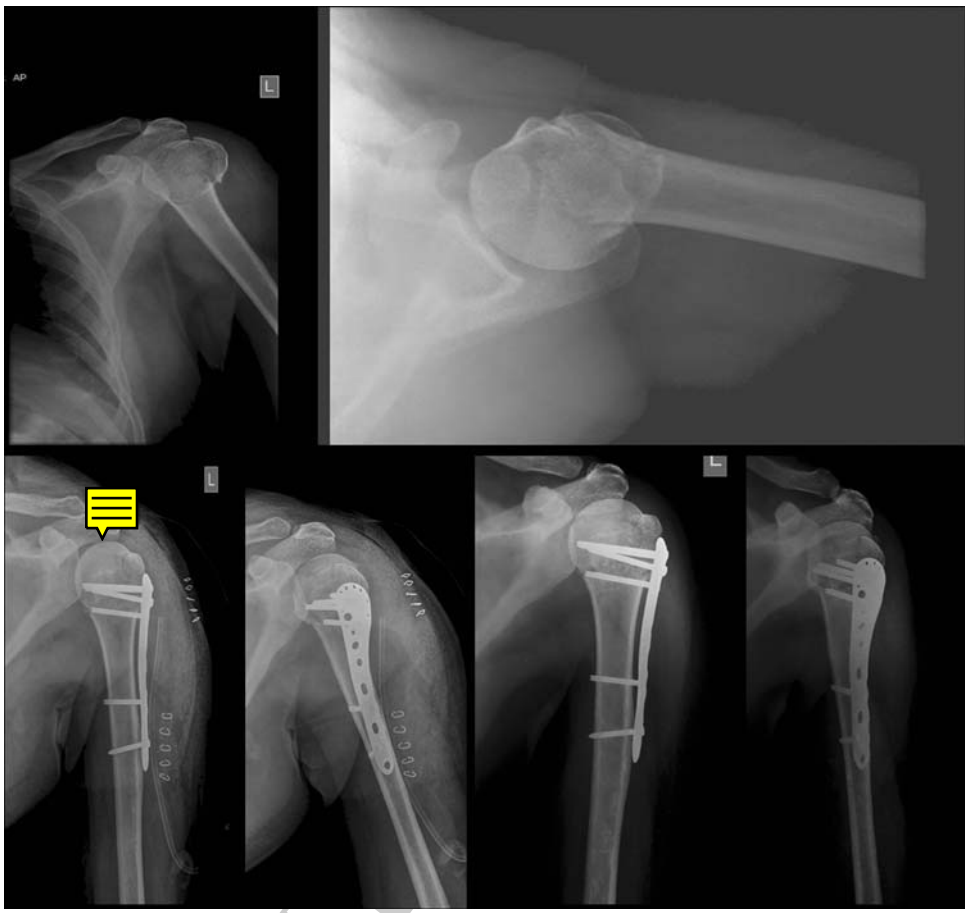

Fig. 2 Pre- and postoperative radiographs of a 37-year-old male patient showing the size of the incision and the final result

Results (Fig. 2)

All fractures united at a mean of 9 weeks (range 7–10 weeks). The absence of tenderness on palpation and presence of bridging bone on radiographs were taken as definitive evidence of union. The average surgical time was 56 min (45–60 min). The average blood loss was 120 ml (80–150 ml). The average fluoroscopy exposure was 60 s (40–100 s). The average length of the proximal incision was 5.5 cm (4.5–6.5 cm). There were no incidences of axillary nerve palsy.

Fracture reduction was deemed anatomical in 12 patients in the immediate postoperative X rays. Reduction was non-anatomical in three patients. One patient had a valgus malalignment of 10°, but the medial calcar continuity was restored. Two patients with a true four part fracture had a varus malalignment of 15° due to the presence of comminution at the medial calcar area. Greater tuberosity was reduced to a level below the humeral head articular surface in all patients. There was no loss of reduction or implant failure at last follow-up. There was no intraarticular screw penetration or impingement.

There were no incidences of avascular necrosis as analyzed by X rays at last follow-up. The average abduction of the shoulder at last follow-up was 134° (90–165). The average forward flexion was 135° (85–160). The mean constant score at last follow-up was 80.06. The normalized constant score adjusted for age and gender was 85.24 at last follow-up (Table 2).

Discussion

The introduction of locking plates has brought a new dimension in the treatment of these complex fractures [5]. The presence of multiple angle stable screws in different directions, the availability of jigs and sleeves to ease screw insertion and a thin plate profile enable a stable fixation through minimal access techniques. The conventional deltopectoral approach offers good access to the shoulder joint and is still the approach of choice for fracture fixation among trauma surgeons [20]. Good surgical technique, meticulous handling of fracture fragments and careful preservation of the vascular supply has been shown to produce good long-term results with the deltopectoral approach even in these complex fractures [4]. However, fears of vascular compromise and the possibility of increased incidence of avascular necrosis have been raised by some authors [23, 27].

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The anterior deltopectoral incision can jeopardize the vascular supply during manipulation of the fracture fragments, since the chief vascular supply to the humeral head is located in the bicipital groove [8, 9]. Gerber et al. [10] reported avascular necrosis of the humeral head in 11 of the 31 patients (35.4%) who underwent open reduction through the deltopectoral incision in a similar study population. Although avascular necrosis of the humeral head has been shown to be less problematic in this non-weight bearing joint, it can compromise long-term outcome especially in young patients. The mini-lateral incision used in the current study allows fracture reduction with minimal manipulation, less soft tissue stripping anteriorly and may reduce the incidence of avascular necrosis.

Fracture reduction and fixation with locking plates through the deltopectoral incision can also be technically difficult [15]. It is the reduction of the tuberosity fragment that poses the greatest difficulty with the deltopectoral approach [24]. It requires greater soft tissue dissection and muscle retraction. The anterior deltoid origin and pectoralis major insertion may need erasure [14, 17]. Reduction and stable fixation of the tuberosity fragment may become furthermore difficult in case of severe comminution.

The proximal humerus locking plates are designed to be placed on the greater tuberosity. The posterolateral location of the tuberosity make plate placement and screw insertion a tedious process through the deltopectoral incision. Alternate incisions have been described to overcome this problem. The shoulder strap incision [22] and the extended lateral incision [7] involve substantial deltoid splitting and muscle retraction. Gallo et al. [6] used two incisions to facilitate the procedure. They achieved reduction in the anterior fracture fragments through the deltopectoral incision and used a small lateral incision similar to the one in the current series to facilitate tuberosity reduction and insertion of the proximal fixed angle screws. We had used only the second incision described by Gallo for the major part of the procedure. Additional incision was used only to secure the plate distally.

Although an anatomical study by Smith et al. [25] has shown that it is safe to slide the plate percutaneously without fear of nerve entrapment, chances of injury to the axillary nerve is the chief limitation to the use of this approach. A similar deltoid splitting technique of percutaneous plate fixation in supine position was described by Laflamme et al. [15]. The study included only two part surgical neck and three part valgus impacted fractures that were amenable to closed reduction. They advocated identifying the axillary nerve by palpation before sliding the plate and advised additional use of deltopectoral incision, if it was not possible to palpate the axillary nerve.

The length of the incision in our series depended on the location of the axillary nerve. The average length of the incision was a bit longer in our series compared to study by Laflamme et al. [14]. The slightly longer incision and beach chair position used in the current study helps in identifying and protecting the axillary nerve under vision. It also provides adequate visualization of fracture fragments to enable the surgeon to perform open reduction when required with minimal anterior soft tissue stripping.

The study is a single center and single surgeon series and all data were collected prospectively. Although the study population was young, functional outcome was adjusted for age and gender. The study has its own limitations. The study size was small, fracture patterns were non-homogenous and the follow-up was short. The high constant score absence of implant failure and loss of reduction may be attributed to the young study cohort and small sample size. Long-term results and consistent reproducibility of the technique in larger study population are required to draw definitive conclusions.

In conclusion,

1. the technique of mini-invasive trans-deltoid plating is biomechanically sound; it respects the fracture biology and provides a stable mechanical construct to facilitate early rehabilitation;
2. the transdeltoid incision offers good visualization in case of need for open reduction of these difficult fractures;
3. identification of the axillary nerve is important and should be protected under vision. It facilitates the procedure and allays fear of nerve entrapment;
4. the use of locking plates in these complex fractures coupled with supervised physiotherapy provides a stable fixation and allows early functional recovery.

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