

Outcome of anatomic locking plate in extraarticular distal humeral shaft fractures

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ABSTRACT

Background: Extraarticular fractures of distal humerus are challenging injuries to treat because of complex anatomy and fracture patterns. Functional bracing may not provide adequate stability in these injuries and operative treatment with intramedullary nails or conventional plates also has the limitation of inadequate fixation in the short distal fragment. The 3.5 mm precontoured single column locking plate (extraarticular distal humerus plate [EADHP]) has been introduced to overcome this problem. We evaluated the clinical and functional outcomes of treating these fractures with the EADHP.

Materials and Methods: 26 patients with extraarticular fractures of distal humerus presenting within 3 weeks of injury between January 2012 and June 2015, were included in this prospective study. Open IIIB and IIIC fractures, nonunions, or those with a history of previous infection in the arm were excluded. Operative fixation was done using the EADHP in all the cases. The time for union, range of motion at shoulder and elbow and secondary procedures were recorded in followup. The shoulder and elbow function was assessed using the University of California Los Angeles (UCLA) shoulder scale and Mayo Elbow Performance Score (MEPS) respectively.

Results: There were 21 males and 5 females with mean age of 37.3 years (range 18–72 years). Twenty two (84.6%) cases had complex fracture patterns (AO/OTA Type 12-B and C). The mean time to fracture union was 22.4 weeks (range 16–28 weeks). The mean followup time was 11.6 months, (range 4–24 months). Four patients (15.4%) had failure of cortical screws in the proximal fracture fragment, of which two required revision fixation with bone grafting. Another nonunion was seen following a surgical site infection, which healed after wound lavage and bone grafting. The MEPS (average: 96.1; range 80–100) was excellent in 81% cases ($n = 21$) and good in 19% cases ($n = 5$). UCLA score (average: 33.5; range 25–35) was good/excellent in 88.5% cases ($n = 23$) and fair in 11.5% cases ($n = 3$).

Conclusion: EADHP is a reliable option in treating extraarticular distal humeral fractures as it provides stable fixation with an early return to function.

Key words: Anatomic plate, distal humerus, extraarticular, humeral fracture, posterolateral plate

MeSH terms: Trauma, bone plates, humeral fractures, fracture fixation

INTRODUCTION

Extraarticular fractures of distal humerus occur at an anatomical watershed between the humerus shaft and the intercondylar region. These injuries are often displaced and have complex fracture pattern with associated

comminution. Functional bracing, though advocated, may not provide adequate stability and acceptable alignment due to the distal extent of these fractures.^{1,2} Therefore, operative stabilization of these fractures is rational and is favored by many authors.^{3–6} Restoration of alignment and stable fixation is critical to allow early rehabilitation and a good functional outcome. Management of these injuries takes a cue from the treatment options of both humeral shaft, as well as intercondylar fractures. Intramedullary nailing, as well as plating, with 4.5 mm compression or locking techniques has the limitation of inadequate fixation

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in the short distal fragment. Plate impingement at olecranon fossa with the subsequent limitation of elbow extension is also an issue. Other plating techniques such as dual plating, lambda plate, and metaphyseal plate fixation have been proposed to overcome this problem but have not proved to be reliable and effective.⁷⁻¹⁰

The extraarticular distal humerus plate has been specifically designed to address these complex fractures.¹¹ It is anatomically precontoured to be placed along the central humeral diaphysis proximally and on the lateral supracondylar ridge distally. The increased locking screw density in the lateral column affords a strong fixation of the distal fragment. Studies have shown that the posterolateral plate is biomechanically superior to the 3.5 mm locking compression plate (LCP) in case of distal humeral diaphyseal osteotomies.¹² The plate can be inserted either by the posterior triceps-splitting or triceps reflecting approaches and requires less soft tissue stripping.^{4,6} Stable fixation and reduced surgical time lead to fewer complications and allow earlier rehabilitation leading to a more predictable result. We studied the the clinical and functional outcomes using the extraarticular distal humerus plate in the management of extraarticular fractures of distal humerus.

MATERIALS AND METHODS

28 consecutive patients with extraarticular fractures of distal humerus presenting within 3 weeks of injury who underwent fixation with the extraarticular distal humerus plate (EADHP) system between January 2012 and June 2015 were included in this prospective study. The study was undertaken after the approval of Institutional Ethics Committee. Patients with Gustilo and Anderson Grade IIIB and IIIC fractures, those with nonunion or having a history of previous infection in arm or elbow were excluded from the study. Of these, two patients were lost to followup leaving 26 patients (21 males and five females) in the study group. The mean age of patients was 37.3 years (range 18–72 years). The right humerus was involved in 14 cases and left side in 12 cases. Roadside accidents were the cause of injury in 92.3% cases ($n = 24$) whereas two patients had a domestic fall. The fractures were classified according to the AO/OTA classification. Nineteen fractures (69.2%) were AO/OTA Type 12-B with a spiral or bending wedge while four patients had Type 12-A (simple) and three had Type 12-C (complex) fractures. There were two patients with open fractures, whereas the rest had closed injuries. Five patients (19.2%) had related radial nerve palsy, out of which two had the posterior interosseous nerve (PIN) palsy and one other patient had brachial plexus injury. Sixteen cases (61.5%) had isolated fractures, whereas multiple injuries were seen in ten patients. Eight patients (30.8%) had associated long bone fractures, of which five patients had lower extremity

fractures and three patients had ipsilateral upper extremity fractures. There were two patients with blunt abdominal trauma, one with spine injury and another with blunt chest trauma and associated spine injury. At presentation, the patients were resuscitated and splintage was given in the emergency department. Radiographs of the arm including the shoulder and elbow were done, and the neurological status was documented.

We used the 3.5 mm LCP extraarticular distal humerus plate (EADHP) system (DePuy Synthes, Gurgaon, India). It is a “J” shaped titanium plate which is precontoured for application on the posterolateral surface of the distal humerus and is available separately for right and left sides. Proximally, the plate uses elongated 3.5 mm combination hole system with locking and nonlocking screw options in the humeral shaft. Distally, it curves along the lateral supracondylar ridge thus avoiding the olecranon fossa and has five screw holes angled medially for achieving a strong purchase in the trochlea and capitellum. The plate head is tapered to minimize soft tissue irritation. The surgery was performed without the use of tourniquet with the patient in lateral position and the arm resting on a padded bar allowing intraoperative C-arm visualization. All surgeries were performed by one of the six attending consultants of our department. The posterior approach was used in all cases. A longitudinal skin incision was made over the posterior aspect of the arm extending distally between the lateral epicondyle of the humerus and the tip of the olecranon 4 cm distal to the elbow joint. Radial nerve was identified and protected between the long and lateral head of triceps prior to plate fixation. Distally, the triceps was incised along the humeral shaft in line with the skin incision. Lag screw fixation and/or encirclage were used in case of wedge or comminuted fractures.

Postoperatively, the patients were given a padded dressing and a sling; posterior splintage was added only if necessitated by the fixation construct. Gentle passive mobilization of shoulder and elbow was started on the 1st postoperative day once the pain subsided. Active and assisted movements of the arm in the sling were encouraged within the 1st week. Further resistive exercises and weight bearing exercises were allowed after the radiological progress of bone union. Patients were followed clinically and radiologically at monthly intervals till fracture union and completion of physical therapy. Union was defined as the absence of pain at fracture site on clinical examination and bridging callus on three cortices on two radiographic orthogonal views. Shoulder and elbow functions were assessed using University of California Los Angeles (UCLA) shoulder rating scale and Mayo Elbow Performance Score (MEPS), respectively.^{13,14} The UCLA shoulder score was graded

into excellent (34–35 points), good (29–33 points), fair (21–28 points), and poor (0–20 points). Function of elbow was graded on the basis of MEPS into excellent (≥ 90 points), good (75–89 a points), fair (60–74 points), or poor (< 60 points).^{15,16}

RESULTS

The mean followup time was 11.6 months (range 4–24 months) [Table 1]. Of the 26 patients, 23 fractures united with a mean time to fracture union of 22.4 weeks (range 16–28 weeks) [Figure 1]. Four patients (15.4%) had a failure of cortical screws in the proximal fracture fragment at followup. Two of these cases required revision fixation with bone grafting due to associated nonunion; in other two cases, fracture had united and patients were asymptomatic

so no intervention was done to address the broken screws [Figures 2 and 3]. Another nonunion was seen in a patient with open Grade II fracture who was discharged early from the hospital against advice. He later presented with a surgical site infection for which wound lavage was done and the wound healed. This patient went on to have nonunion for which bone grafting was done. All three fractures with nonunion went on to unite after revision surgery. In all five patients with radial nerve palsy, the nerve was found to be in continuity. One patient with PIN injury was found to have complete radial nerve palsy postoperatively. However, all patients with radial nerve injury showed spontaneous recovery of radial nerve function within an average time to recovery of 23.2 weeks (range 8 – 48 weeks). No patient complained of painful hardware in our series or required hardware removal.

Table 1: Clinical details of patients along with complications and secondary procedures

Serial No.	Age (in years)/sex	Fracture type	Time to union (weeks)	UCLA score	MEPS	Associated injuries	Complications and secondary procedures
1	47/male	12-B1	20	27	90	Ipsilateral galleazi fracture and brachial plexus injury	Brachial plexus injury recovered
2	23/male	12-B1	24	35	100	None	None
3	52/female	12-B1	48	26	80	None	Nonunion with screw failure, union after revision fixation, and bone grafting
4	23/male	12-B2	24	35	100	Open fracture tibia	Screw failure, united, no intervention
5	23/female	12-B1	20	35	100	None	None
6	51/male	12-B3	24	35	100	None	None
7	25/male	12-B1	24	35	100	None	None
8	18/male	12-B1	24	35	100	None	None
9	28/male	12-B1	20	29	100	None	None
10	28/female	12-B2	24	33	85	None	PIN injury, complete radial nerve injury after surgery, recovered
11	25/male	12-C3	24	35	100	None	None
12	33/male	12-C2	20	35	100	None	None
13	30/male	12-B1	28	35	100	None	Screw failure, united, no intervention
14	32/male	12-B3	24	35	85	Abdominal trauma	None
15	48/male	12-B3	28	35	100	None	None
16	45/female	12-A2	24	32	100	Closed fracture distal femur, distal radius fracture contralateral	Radial nerve palsy, recovered
17	50/male	12-B2	24	33	100	None	None
18	72/male	12-A3	24	35	100	None	None
19	50/male	12-C3	20	35	80	Ipsilateral both bone forearm fracture	Radial nerve palsy, recovered
20	30/male	12-A3	60	35	100	Closed femur fracture, D12 to L1 fracture with paraplegia	Nonunion with screw failure, union after revision fixation and bone grafting
21	40/male	12-B2	24	35	100	Fracture shaft femur and shaft tibia, Abdominal trauma	None
22	32/male	12-B2	24	35	100	None	None
23	45/male	12-B1	28	35	100	Ipsilateral DRUJ injury	Wound infection, healed after wound lavage Nonunion, required bone grafting for union
24	39/male	12-A3	16	35	100	Ipsilateral both bone forearm fracture	PIN injury, recovered
25	28/male	12-B1	16	35	100	None	None
26	52/female	12-B2	16	25	80	Lateral malleolus fracture, D12 fracture, blunt chest trauma	Radial nerve palsy, recovered

UCLA=University of California Los Angeles, MEPS=Mayo Elbow Performance Score, DRUJ=Distal radioulnar joint, PIN=Posterior interosseous nerve

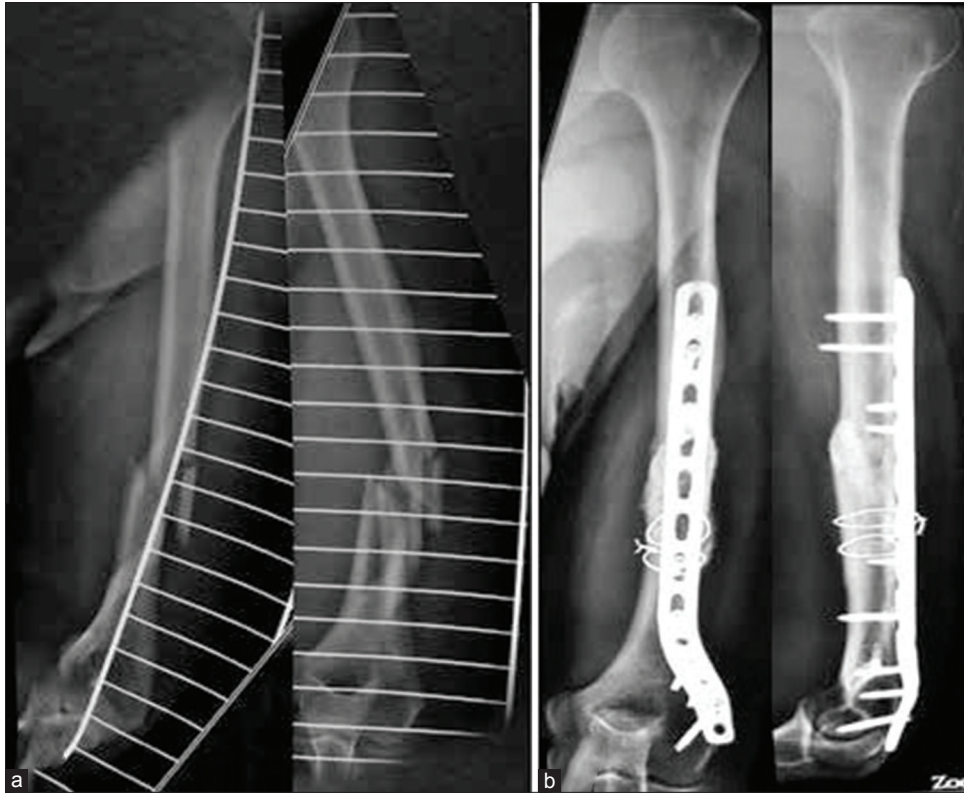


Figure 1: (a) Preoperative X-ray of arm anteroposterior and lateral view showing fracture shaft of humerus (AO12.B.3) (serial no. 6 in Table 1) (b) X-ray of arm anteroposterior and lateral views showing union at final followup

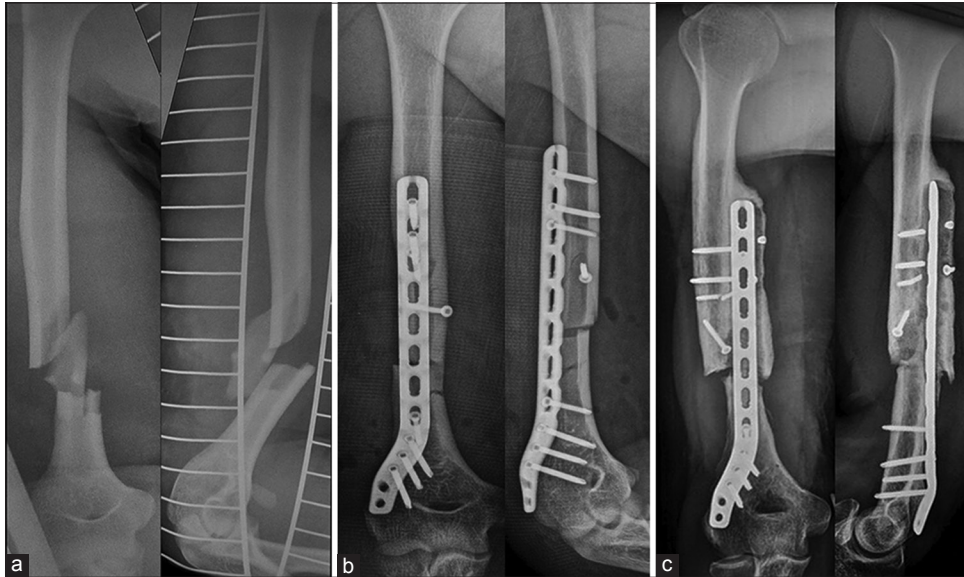


Figure 2: (a) Preoperative X-ray of arm anteroposterior and lateral view showing fracture shaft of humerus (AO12.B.2) (serial no. 4 in Table 1) (b) X-ray at 4 weeks followup showing implant *in situ* (c) X-ray showing screw failure with bone union at final followup

At final followup, the Mayo Elbow Performance Score (MEPS) ranged 80–100 with 81% cases ($n = 21$) having excellent scores and 19% cases ($n = 5$) having a good score. The mean elbow flexion was 141.2° . Four patients had residual flexion deformity of 10° at the elbow and four patients complained of mild elbow pain, but the arc of

motion was more than 100° in all patients without any loss of elbow function. The UCLA shoulder score was excellent in 70% cases ($n = 19$), good in 15.5% ($n = 4$), and fair in 11.5% cases ($n = 3$). Five patients (19.2%) complained of occasional pain in the shoulder at final followup, while 80.8% patients ($n = 21$) had no pain. Active shoulder



Figure 3: (a) Preoperative X-ray of arm anteroposterior and lateral view showing fracture shaft of the humerus (AO12.B.1) (serial no. 3 in Table 1) (b) X-ray at 8 weeks followup; (c) X-ray at 24 weeks followup showing screw failure; (d) X-ray at 48 weeks showing bone union after revision fixation

forward flexion was more than 150° in 21 patients (80.8%), 120–150° in four patients, and 90–120° in one patient. Twenty two patients (84.6%) were able to carry out normal routine activities, two patients had a slight restriction of activity and another two were able to do only light household work.

DISCUSSION

The indications for operative treatment of humeral shaft fractures are expanding.¹⁷ Functional bracing has been advocated as an effective modality for the management of these injuries; however, this method is technically demanding and there are limitations such as skin problems, malalignment, loss of external rotation at shoulder, and lack of predictability of the final outcome.^{2,18} The incidence of nonunion with functional bracing has been reported to be from 5% to 24%.^{1,19} Pehlivan showed 100% union rates in treating isolated humeral shaft fractures with a custom-made functional brace.²⁰ However, patients with polytrauma, open fractures, and fractures with neurovascular injury were excluded from their study. With increase in high energy motor vehicle trauma, the incidence of complex fractures, open fractures, and multiple injuries has risen leading to a shift toward operative management of humeral shaft fractures.¹⁷

Extraarticular fractures of the distal humerus pose a special problem. Their proximity to elbow joint requires the fixation to be stable and less invasive allowing faster rehabilitation. The fractures in this area are often complex and less suited for treatment with functional bracing, as well as conventional fixation techniques.² There is insufficient space in the distal fragment for stable fixation either with intramedullary nailing or the 4.5 mm plate with cortical or locking screws. A number of techniques have been proposed to overcome this problem. Moran proposed to use the conventional plate at 5° to 8° angle off center from

the long axis of the humerus to enhance distal fixation, but the obliquity of the plate limited optimal proximal fixation.²¹ Dual plating (both parallel and orthogonal) has also been used for these injuries.^{22,23} However, dual plating entails extensive soft tissue dissection, and there is a risk of infection and nonunion. Other plate designs, for example, metaphyseal locking plate, lambda plate, and lateral tibial head buttress plate have been used in isolated studies, but none of them offers a reliable alternative.⁷⁻¹⁰

The EADHP comes from the family of locking periarticular plates which have shown to be successful in the management of fractures around the knee, elbow, and ankle. This implant can be used either as a fixed-angle bridge plate or a neutralization plate with interfragmentary compression. A cadaveric study of the mechanical properties of these plates found that EADHP provided significantly greater bending stiffness, torsional stiffness, and yield strength than a single 3.5 mm LCP plate for osteotomies created 80 mm from the trochlea whereas dual plating was biomechanically superior for distal osteotomies.¹² Prasarn *et al.* used the EADHP in a dual plate construct with 3.5 mm reconstruction plate and reported excellent union rate without significant complications.²³ A few recent studies have shown excellent results with the use of a single EADHP in the management of distal extraarticular humeral fractures.⁴⁻⁶ Single plating technique utilizes less surgical time, and soft tissue disruption is also less which promotes biological fracture healing. The EADHP has even been used for fractures extending into intraarticular region with good results.²⁴

Our patient cohort represents the subset of the population presenting at a tertiary care hospital in an urban setting. Majority of the injuries in our study are high energy roadside accidents, with complex fracture patterns (AO/OTA Type 12-B or 12-C) accounting for 84.6% ($n = 22$) of cases. The mean age of 37.3 years with predominance of males

and a high percentage of concomitant injuries (38.5%) also supports this assumption. Capo *et al.* also reported additional injuries in 76% of their cases including radial nerve involvement in 56% of cases.⁵ This highlights the fact that with increase in high energy trauma, the number of humeral fractures that require operative fixation e.g., Gustilo Type II and III open fractures, those with polytrauma, floating elbow injuries etc., is also increasing.²⁵ In India, the dramatic increase in vehicle ownership and poor traffic discipline are contributing factors for fracture humerus or high energy trauma.

The average time to union with EADHP has been reported as 15.7 weeks (range 9–34 weeks) and 7.3 months (range 3–13 months) by Fawi *et al.* and Capo *et al.*, respectively.^{5,6} In our study, the average time to fracture union was 22.4 weeks (range 16–28 weeks). This variation can be explained by the mechanism of bone healing of these fractures. Most of these fractures show direct bone healing with minimal bridging callus. This may not be evident in the initial postoperative radiographs and can lead to interobserver variation in interpretation of time of union of these fractures.¹⁶

Radial nerve was identified in all cases prior to plate fixation, and there was no secondary radial nerve palsy in our series. One patient with posttraumatic PIN palsy developed complete radial nerve palsy postoperatively which recovered on followup at 8 weeks. Other studies have also documented the safety of radial nerve function with the EADHP.^{4,6}

Though the EADHP has been designed to enhance fixation in the distal fragment, four patients in our study had a failure of screws in the proximal fragment. This can be explained by the fact that 84.6% ($n = 22$) of the fractures in our series were complex fractures with either wedge fragments or extensive comminution. These fractures required the use of lag screws or encirclage after which two to four consecutive empty holes were left in the fixation construct across the fracture site. The 3.5 mm screws in the proximal fragment (usually three in number) also couldn't be spaced out to decrease the screw density as it would entail more soft tissue dissection. This increased the stress distribution on 3.5 mm screws in the proximal fragment thus predisposing to screw failure. Moreover, the distal 3.5 mm locking screws take purchase in a strong lateral pillar of distal humerus which affords strong fixation, and hence is less prone to failure. We recommend protection of the fixation through sling support and assisted mobilization till radiological evidence of fracture union, especially in cases where there is a long segment of consecutive empty holes in the fixation construct. A modification in the design

of the plate to allow for 4.5 mm screws in the proximal screw holes can also be beneficial. Yang *et al.* and Spitzer *et al.* reported no hardware failure in their series with the use of metaphyseal plates which utilize 4.5 mm screws for diaphyseal fixation.^{7,8} The use of EADHP as a bridge plate using the principles of relative stability and biological fixation also needs to be studied. A longer plate with lesser screw density, more uniform screw distribution, and minimal disturbance of the comminuted or wedge fragments may lead to better outcomes.

Four secondary procedures were required in our series with a reoperation rate of 15.4%. One patient with an open fracture was discharged against advice and went on to have two secondary procedures for wound infection and nonunion. Other authors have also reported satisfactory results despite higher reoperation rates with EADHP.⁴

All patients in our series had a satisfactory return to elbow function with 81% cases ($n = 21$) having an excellent MEPS score. This is despite that four patients had associated musculoskeletal injuries to the ipsilateral limb. Early physical therapy and elbow mobilization exercises were started and all of our patients had a functional elbow arc of motion of more than 100°. All patients in our study were satisfied with their shoulder function with 88.5% cases ($n = 23$) having a good to excellent shoulder function and 80.8% patients ($n = 21$) having active shoulder forward flexion of more than 150°. These outcomes are consistent with other modern studies which show only mild to moderate residual impairment after management of these injuries with EADHP.^{4,6}

The limitations of our study are the lack of control or comparison group and a small sample size with two patients lost to followup. In addition, our patient group mainly had high energy fractures with comminution and associated injuries. This cannot be directly compared with injuries due to low energy falls. A randomized control study comparing EADHP with other fixation options will shed more light on this subject. Moreover, the use of EADHP as a bridge plate and as a rigid device needs to be studied and compared.

CONCLUSION

Our study supports the use of EADHP as an effective modality in treating extraarticular distal humeral fractures. It addresses the difficulties encountered while managing these fractures and provides a stable fixation with predictable and satisfactory results and an early return to function.

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Conflicts of interest

There are no conflicts of interest.

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