Open reduction and internal fixation of extra-articular comminuted distal humerus fractures by double-plating osteosynthesis

Nehad El Mahboub and Waleed Arafat

Department of Orthopaedic Surgery, Faculty of Medicine, Misr University for Science and Technology, Giza, Egypt

Correspondence to Waleed Arafat, MD, Department of Orthopaedic Surgery, Faculty of Medicine, Misr University for Science and Technology, 41 Dokii Street, Giza 12345, Egypt
Tel: +20 2 223420904;
e-mail: warafat73@hotmail.com

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Background
The treatment of extra-articular distal humerus fractures is still controversial; conservative treatment in a cast or a brace may result in good outcomes, but arthofibrosis and loss of range of motion are major disadvantages. Open reduction and rigid internal fixation provide axial stability and early range of motion, but the short distal metaphyseal fragment makes secure and rigid fixation difficult.

Patients and methods
Thirty patients with 30 extra-articular distal humerus fractures underwent open reduction and internal fixation by double reconstruction plates in the Misr University for Science and Technology hospital in the period from January 2006 to January 2010. The age of the patients ranged between 24 and 52 years. The mechanism of injury was a fall from the ground level in 15 patients, a fall from a chair or a ladder in two patients, a road traffic accident in eight patients, and a direct hit to the elbow in five patients. The follow-up period ranged from 12 to 36 months. The patients were evaluated clinically, radiologically, and by the Mayo Elbow Performance Score.

Results
Union was achieved in 28 patients after 8 weeks; two patients with delayed union were treated by a bone graft and no cases of nonunion were encountered. Excellent and good results were achieved in 21 patients, six patients showed fair results, and three patients showed poor results.

Conclusion
The treatment of extra-articular distal humerus fractures by double reconstruction plating provides axial stability, allows early range of motion, and there is a lower risk of stiffness, with no reported cases of hardware failure.

Keywords:
distal humerus, internal fixation, reconstruction plates

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Introduction

Distal humerus fractures are common, representing 2% of all fractures, and ~30% of these affect the humerus. The appropriate treatment of extra-articular distal humerus fractures is controversial. Although functional bracing has been shown to yield good outcomes, some surgeons continue to favor operative fixation [1].

Specifically, they cite concerns of radial nerve injury, difficulty in controlling fracture alignment, and long-term elbow stiffness with bracing [2]. Studies have supported the notion that distal humerus fractures in adults can be optimally treated with open anatomic reduction and stable fixation to allow for early anatomic restoration and upper extremity range of motion. Although an operative intervention is not without complications, detailed attention to anatomic reduction, soft-tissue handling and preservation, stable fixation, and early mobilization can reduce complications [3].

Surgical treatment should be performed in a systematic manner to minimize complications. Using the principles of anatomic reconstruction with stable fixation to allow early range of motion, good to satisfactory outcomes can be expected in most patients. Adult elbows after such an injury are not tolerant to prolonged immobilization and, if arthrofibrosis occurs, it is very difficult to regain function, if not impossible. Therefore, the goal of surgery is to stabilize to mobilize.

Failure of this fixation occurs at the supracondylar level because of high shear forces occurring at that level through elbow motion and poor distal fixation. In cases where fixation is poor, immobilization until early bony union is common and then elbow stiffness occurs. Failure of distal fixation has been pointed as the main factor in nonunion at this level [4].

The aim of this work is to evaluate the results of open reduction and internal fixation of extra-articular comminuted distal humerus fractures by 90–90 double reconstruction plates and early mobilization.

Patients and methods

In the period between January 2006 and January 2010, 30 extra-articular distal humeral shaft fractures were treated

by open reduction and internal fixation using AO (Arbeitsgemeinschaft für Osteosynthesefragen) principles. The study group included 20 women (66.7%) and 10 men (33.3%), average age 39.4 ± 8.0 years (range, 24–52 years). The follow-up time ranged from 12 to 36 months, with an average of 21.4 months. All patients were reviewed at 2, 4, 6 weeks, and every month until the end of the follow-up period. Twenty patients (67%) had fractured their dominant right arm; the rest had fractured their nondominant left arm. In terms of causes of injury, 15 patients sustained a fall from the ground level either with an outstretched hand or with a direct impact around the elbow, two patients sustained a fall from a chair or a ladder, eight patients were in a road traffic accident, and in five patients, a direct hit to their elbows resulted in a fracture. They all presented with a painful and deformed elbow after the accident. All fractures except two were closed fractures; the two open fractures were Gustillo I. Seven patients had primary radial nerve palsy. The time between injury and surgical management ranged from 3 to 42 days (median, 6.5 days).

All patients were fixed with 90–90° reconstruction plates: one 4.5 mm applied posteriorly and the other 3.5 mm either medially or laterally. The technique was specifically designed on the basis of two principles: (i) fixation in the distal fragments should be maximized and (ii) screw fixation in the distal segment should contribute toward stability at the supracondylar level. Patients were assessed radiographically and clinically using the Mayo Elbow Performance Score (MEPS) [5] during follow-up. MEPS is a 100-point scale with a maximum of 45 points for pain, 25 points for function, 20 points for motion, and 10 points for stability (Table 1). Results are considered excellent if the score is 90 or above, good if it is between 75 and 89, fair if it is between 60 and 74, and poor if it is less than 60.

Table 1 Mayo Elbow Performance Score

Pain (maximum, 45 points)	Stability (maximum, 10 points)
None (45 points)	Stable (10 points)
Mild (30 points)	Moderately unstable (5 points)
Moderate (15 points)	Grossly unstable (0 points)
Severe (0 points)	Function (maximum, 25 points)
Range of motion (maximum, 20 points)	Able to comb hair (5 points)
Arc > 100° (20 points)	Able to feed oneself (5 points)
Arc 50–100° (15 points)	Able to perform personal hygiene tasks (5 points)
Arc < 50° (5 points)	Able to on shirt (5 points)
Mean total (maximum, 100 points)	Able to put on shoes (5 points)

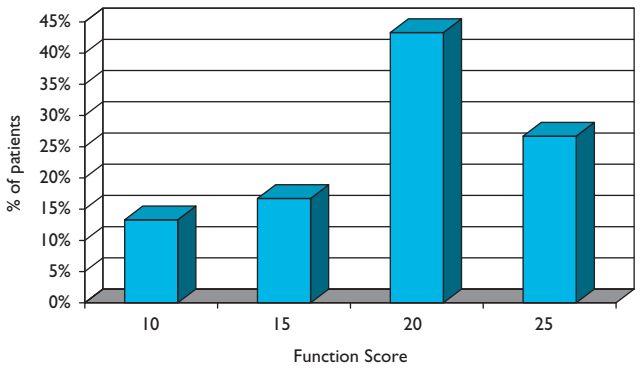
Surgical technique

The patient was placed in the lateral position on the operating table with the injured extremity up. A beanbag was used to stabilize the patient's body, and the injured extremity was placed over a roller. The patient was then prepped and draped. The dorsal posterior surgical approach was chosen for all patients. A longitudinal skin incision was made starting from the tip of the acromion down to the olecranon process and then curved medially around the olecranon distally. Deep fascia was split in line with the incision exposure that involved splitting the fascia between long and lateral heads of triceps; identification of the proper interval is better proximally. The tendinous interval between these muscles was split and then dissected bluntly, and the long head of triceps was retracted medially and the lateral head was retracted laterally. Careful blunt dissection is carried out to identify the radial nerve, lying deep in the spiral groove (with profunda brachii vessels) just above the insertion of medial (deep) triceps; as noted by Gerwin *et al.* [6], the radial nerve crosses the posterior aspect of the humerus at 20–21 cm proximal to the medial epicondyle and 14–15 cm proximal to the lateral epicondyle. Alternatively, the nerve can be found a distance equal to the length of an eight-hole synthes dynamic compression plate above the olecranon fossa on the proximal aspect of the deep head of triceps [6]. A rubber sling was placed around the radial nerve, which was protected throughout the procedure. In seven cases (23.3%), the nerve was trapped in the fracture site. The deep triceps was split longitudinally in its midline and its medial and lateral portions were elevated, exposing the humerus. Distally, the long and lateral head muscles have a common tendon; these two superficial heads were spitted sharply. For the distal medial dissection, the ulnar nerve was identified and separated from the underlying tissues and isolated 5 cm above the cubital tunnel to the point where it entered between the two heads of the flexor carpi ulnaris. Fracture reduction was followed by dual plating a 4.5 mm reconstruction plate placed posteriorly in all cases. The other reconstruction plate (3.5 mm) was applied medially in 10 cases and laterally in 20 cases. After the procedure, adequate fluoroscopic visualization in two orthogonal planes was confirmed. The closure included reapproximation of the triceps aponeurosis with an absorbable suture and superficial layer closure; a hemovac drain was used in all cases.

Postoperative treatment and evaluation

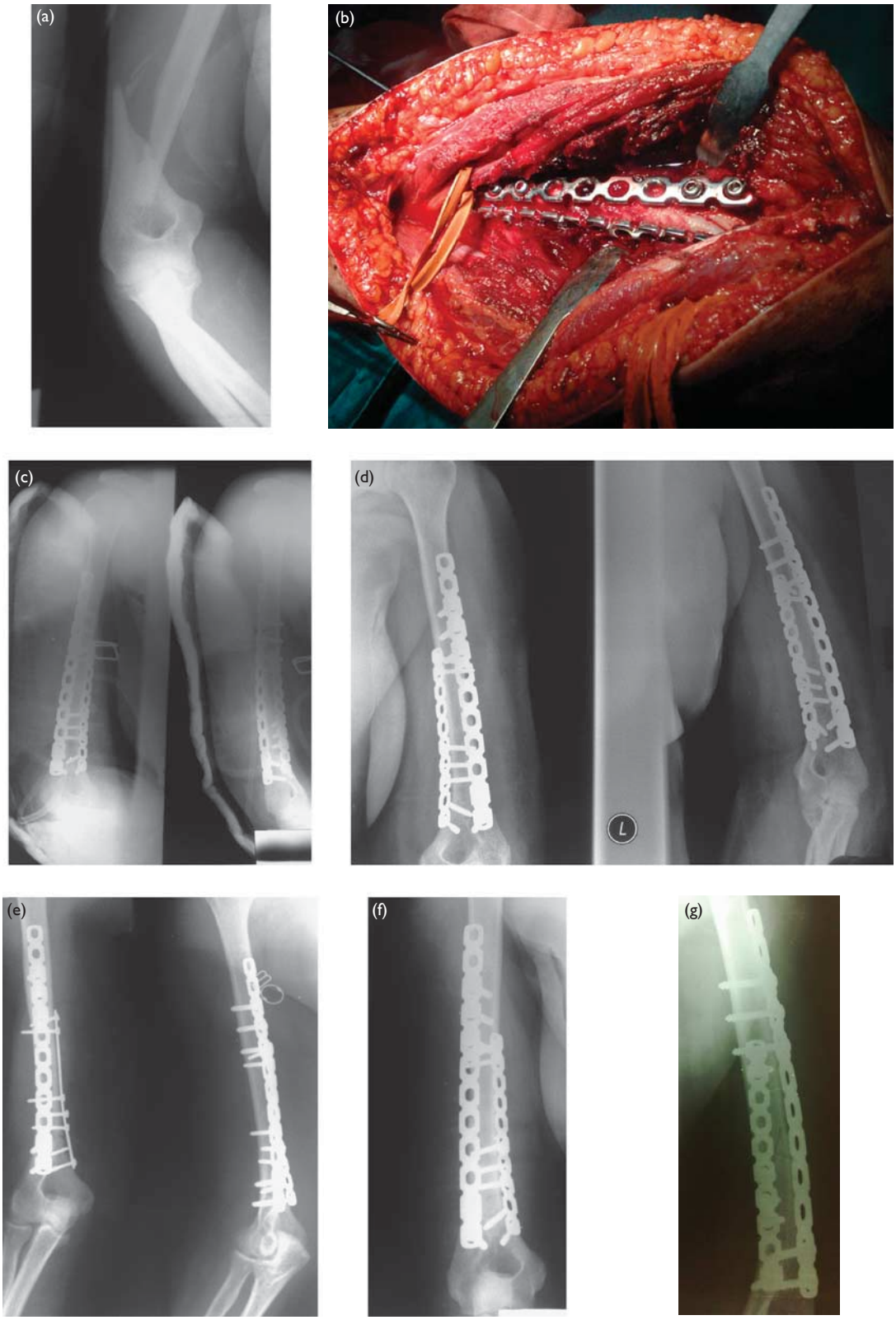
All patients received parenteral broad-spectrum third-generation cephalosporins postoperatively until discharged usually after 3 days. Stitches were removed after 2 weeks. After treatment, a light posterior plaster splint was applied from the posterior axillary fold to the palm of the hand. At the seventh day, the posterior plaster splint

Figure 1



Postoperative function score of the studied group.

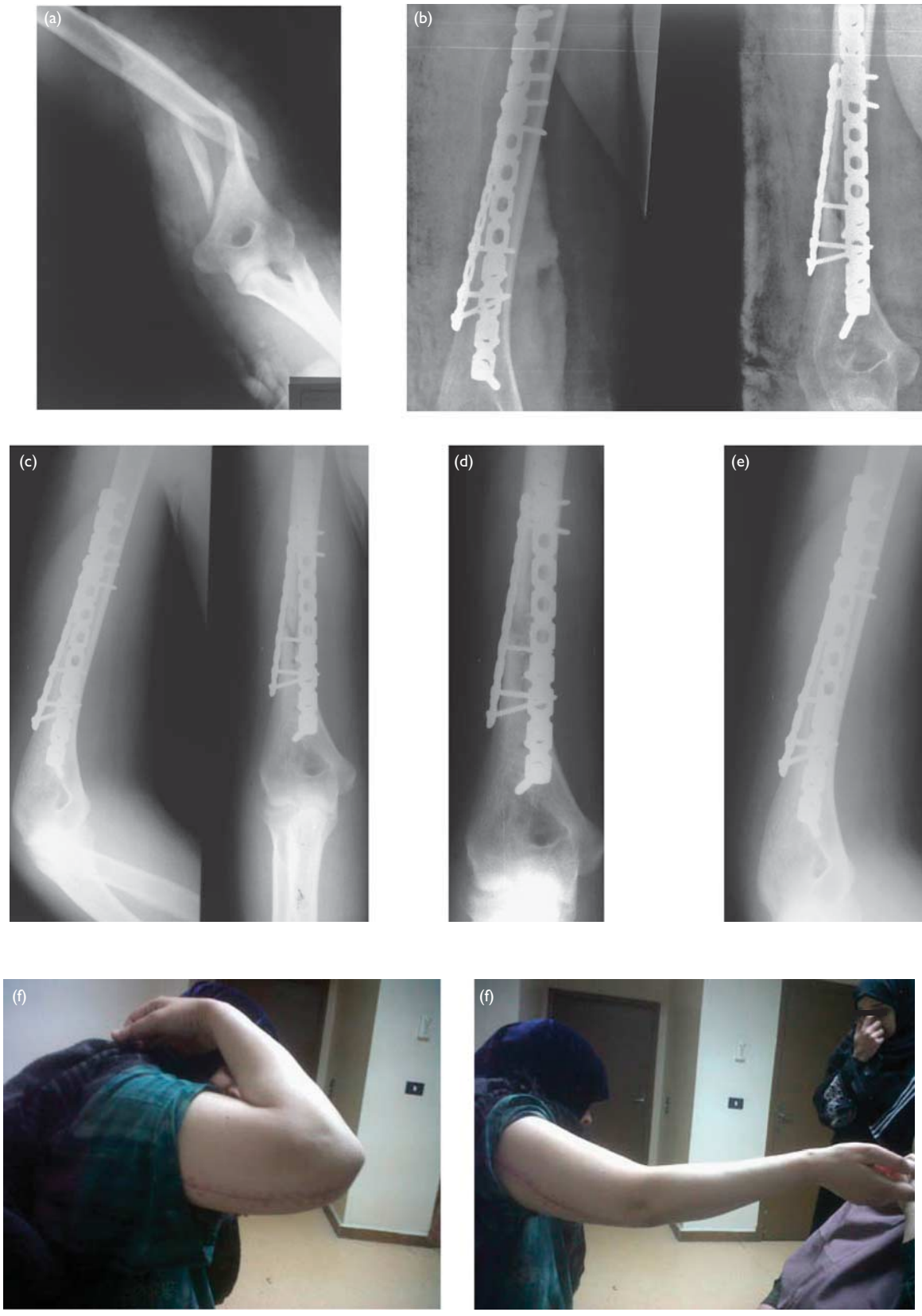
Figure 2



Case 1. (a) Preoperative radiograph. (b) Intraoperative photo. (c) Anteroposterior and oblique postoperative radiograph. Anteroposterior and oblique radiograph after (d) 6 weeks, (e) 4 months, (f) 6 months. (f) Anteroposterior radiograph after 6 months.

was removed periodically, and gentle active and active-assisted exercises were carried out. Splints were continued for 1 month only in two patients because there was a doubt about the stability of fixation. By the second week, the posterior plaster splint could be removed, and the arm was supported by a sling with active motion in

Figure 3



Case 2. (a) Preoperative radiograph. (b) Postoperative radiograph. (c) 1 month postoperative radiograph. (d) Anteroposterior radiograph after 3 months. (e) Oblique radiograph after 3 months. (f) Elbow flexion and extension.

the elbow depending on pain. Vigorous stretching by a therapist, forced motion, whether active or passive, and manipulation under anesthesia, which may cause increased periarticular hemorrhage and fibrosis, heterotrophic calcification, increased joint irritability, and decreased rather than increased motion, were contraindicated. No continuous passive motion machines were used.

Bone healing was judged clinically by the absence of localized tenderness over the fracture site and radiologically by the presence of callus crossing the fracture site and/or disappearance of the fracture line. The absence of clinical and radiological evidence of union after 12 weeks indicated that union was delayed.

Statistical methods

Data were analyzed using the SPSSwin statistical package version 15 (SPSS Inc., Chicago, Illinois, USA). Numerical data were expressed as mean and SD or median and range as appropriate. Qualitative data were expressed as frequency and percentage. The χ^2-test (Fisher's exact test) was used to examine the relation between qualitative variables. For quantitative data, comparison between two groups was carried out using the Mann–Whitney test. A *P*-value of less than 0.05 was considered significant.

Results

At the 3-month follow-up, the mean arc of motion was 115° (range, 70–135°) and the mean elbow flexion was 125° (range, 95–140°). The mean extension loss was 6° (range, 0–15°). Pronation and supination of all patients were full. Motion arc was greater than 100° in 14 patients (46.7%).

Seventy percent ($n = 21$) of the patients achieved excellent and good results postoperatively; six patients (20%) scored fair and three (10%) scored poor in terms of the results postoperatively. Detailed MEPS results are shown in Table 2. The MEPS ranged from 40 to 100, with a mean score of 79.7 ± 16.4. Almost half of the patients had a function score of 20 (Fig. 1).

Union was achieved in 28 patients (93.3%) after 8 weeks. The two patients with delayed union were treated by an autogenous bone graft without revision of fixation. No nonunion or hardware failures occurred in this series.

Seven patients (23.3%) had associated radial nerve palsy. At radial nerve exploration, four nerves showed no lesion at exploration, two showed contusions and elongation, and one nerve was entrapped in the fracture, requiring neurolysis.

Postoperatively, one patient developed radial nerve palsy and recovered after 3 months and another patient (with medial reconstruction plate) experienced persistent ulnar nerve symptoms after the operation. Mild symptoms of ulnar nerve developed immediately after the operation, which decreased in subsequent follow-up visits. Eighteen months after the initial operation, a second operation was performed for neurolysis of the ulnar nerve, with an improvement in the condition at the last follow-up.

No heterotopic bone formation was reported in this series. Wound healing with primary intension was achieved in 27 patients (90%) and wound complications developed in three patients (10%). One patient had deep infection; he was diabetic and had mild abrasion at the time of surgery. Generalized cellulitis with deep collection developed around the elbow 2 weeks after the operation and was treated by wound debridement with antibiotics after culture and sensitivity (ampicillin and cloxacillin) and daily dressing. Infection had been controlled after 4 weeks postoperatively. The other two patients had only a superficial infection, which was controlled, and the fracture healed uneventfully. As shown in Table 3, the outcome of surgery was not affected by age ($P = 0.774$), time from injury to treatment ($P = 0.328$), or sex ($P = 0.091$). Figures 2 and 3 show photos of two of the patients studied.

Discussion

The trend in the treatment of distal humerus fractures has shifted toward operative fixation, which leads to 75% excellent to good results [7]. Distal fractures, if treated conservatively in a cast, may affect the functional range of

Table 2 Postoperative detailed Mayo Elbow Performance Score

Pain	None		Mild	Moderate	
	16 (53.3%)		9 (30.0%)	5 (16.7%)	
Range of motion	Arc > 100		Arc 50–100	Arc < 50	
	14 (46.7%)		14 (46.7%)	2 (6.7%)	
Stability	Stable		Moderately unstable	Gross unstable	
	23 (76.7%)		6 (20.0%)	1 (3.3%)	
Function: ability to	Comb hair	Feed oneself	Perform personal hygiene tasks	Put on shirt	Put on shoes
	28 (93.3%)	30 (100.0%)	23 (76.7%)	21 (70.0%)	13 (43.3%)

Table 3 Relation of age, time from injury to treatment, and sex with the outcome of treatment

	Excellent + good ($n = 21$)	Fair + poor ($n = 9$)	*P*-value
Age (mean ± SD, years)	38.8 ± 9.1	39.7 ± 7.7	0.774
Time from injury to treatment [median (range), days]	7 (3–42)	6 (3–42)	0.328
Sex (male/female)	5/16	5/4	0.091

motion of the shoulder and elbow [8]. Open reduction and plating of these fractures will allow earlier rehabilitation and mobility [7].

Schatzker listed four reasons why the humerus should be plated posteriorly: (i) the posterior surface of the distal humerus provides a flat surface suitable for plating; (ii) placement of the most distal screws from a posterior approach allows direct visualization and avoids the antecubital fossa; (iii) posterior placement allows for the plate to extend distally, allowing additional screw placement; and (iv) a posterior approach provides the option of double plating [9]. In this study, the posterior approach of the humerus was used in all cases.

Different plate orientations on the posterior humerus have been described. Moran described the placement of a straight 4.5 mm dynamic compression plate, using an anterolateral approach, at an angle of 5–8° off the long axis of the humerus to treat these fractures. This technique limits proximal fixation in larger fractures and potentially creates prominent hardware [10]. In this study, double reconstruction plates were used in all cases, one 4.5 mm and the other 3.5 mm; the plates were 90–90 one at the posterior surface and one at the other border, and proximal extension of the fracture could managed in this way.

Levy and colleagues have reported excellent results in 15 patients using an alternative method of osteosynthesis with a modified lateral tibial head buttress plate. This plate had an angular offset of 22°, which allowed the plate to contour to the posterolateral column and also to extend proximally up the humeral shaft [11]. In this study, excellent and good results were achieved in 70% of cases.

In distal metaphyseal humeral fractures, the balance of screws proximal and distal to the fractures appears asymmetrical in terms of the amount of fixation; thus, double-plate fixation may be required for achieving adequate control of the smaller fragment [12]. In this study, all the cases were fixed by double reconstruction plates and with care to allow adequate numbers of screws in the distal fragment to achieve a balanced construct and the orientation of the screws in the two plates to facilitate good purchase.

The use of locked plate techniques is another option; Tejwani and colleagues reported that the double-plate construct was significantly stiffer than the one locked plate construct in anterior bending, posterior bending, and lateral bending [13,14]. In this study, no cases of hardware failure were encountered.

Plates should be applied without circumferential soft-tissue stripping, gentle tissue handling, and the least amount of bone devascularization required to expose the radial nerve for its protection and to allow the plate to be positioned on the bone. Butterfly fragments should not be stripped of muscular attachments; excessive stripping of the soft tissue from the bone can contribute toward delay union or nonunion [15]. In this study, unnecessary soft-tissue stripping was avoided and no cases of nonunion were encountered.

Intramedullary devices have been described for the treatment of these fractures [15,16]. However, diaphyseal canal fit and difficulty in controlling comminuted fragments have resulted in high rates of malunion and nonunion. Fractures distal to the locking screws have also been reported. Biomechanical studies have reported superior bending properties of humeral fractures fixed with a plate and screw system versus intramedullary devices [17].

Conclusion

For extra-articular distal humeral fractures, operative treatment achieves more predictable alignment and potentially quicker return of function. Double plating provides a more rigid fixation by the increase in the number of screws in the small distal fragment, allows early elbow mobilization, there is a lower risk of stiffness, and a high union rate can be achieved, with no reported cases of hardware failure.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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