Functional outcome after open supracondylar fractures of the humerus

THE EFFECT OF THE SURGICAL APPROACH

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We reviewed 26 patients who had had internal fixation of an open intra-articular supracondylar fracture of the humerus. All operations were performed using a posterior approach, 13 with a triceps split and 13 with an olecranon osteotomy. The outcome was assessed by means of the Mayo Elbow score, the Disability of the Arm, Shoulder and Hand (DASH) score and the SF-36 Physical Function score. Patients with an olecranon osteotomy had less good results.

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Open intra-articular fractures of the distal humerus are high-energy injuries which are often comminuted and associated with extensive soft-tissue damage. They are very difficult to treat.¹⁻⁴ Anatomical reduction, rigid fixation and immediate mobilisation give the best functional outcome.⁵⁻¹¹ In view of the high reported rate of infection, however, delayed fixation may be recommended. Grant et al¹ found infection in 28% after fixation of open fractures of the distal humerus. In a series of open fractures of the humerus, half of which were distal or supracondylar, Mostafavi and Tornetta⁴ recommended treatment by external fixation. They had an incidence of pin-track infection of 44%. Although many series include a small percentage of open injuries, there is little information regarding early fixation of open fractures of the distal humerus.^{6,12,13}

We used one of two posterior approaches to the site of the fracture, either a triceps split or an olecranon osteotomy. Wilson et al¹⁴ reported no differences in functional outcome after treatment of closed intra-articular fractures of the distal humerus through either of these approaches. When the injuries are complicated by an open wound, it is typically posterior, caused by protrusion of the shaft of the humerus through the triceps and skin. It seems logical that incorporating the defect in the triceps into the surgical approach may involve less trauma and give a better functional outcome than compromising the extensor mechanism further by performing an olecranon osteotomy.

Even with rigid fixation and early mobilisation open fractures have a worse outcome than those with closed injuries of a similar pattern.³ We have therefore attempted to determine the effect of the surgical approach on the outcome after early fixation.

Patients and Methods

Between 1981 and 1998 we treated 36 patients with open intra-articular fractures of the distal humerus. At the time of review two had died, three would not participate and five were lost to follow-up, leaving 26 in the study, with a mean follow-up of 51 months (10 to 14¹) after injury. There were 22 men and four women with a mean age of 44.4 years (17 to 78). All injuries were unilateral; 14 were of the right arm and 12 of the left; 17 were in the dominant and nine in the non-dominant arm. Nine patients had other fractures, and three had an associated palsy of the ulnar nerve. The causes of the injury were falls in 14 patients, bicycle accidents in five, motor-vehicle accidents in five and other causes in two. The AO types¹⁵ were C1 in five, C2 in 13 and C3 in eight. According to the classification of Gustilo and Anderson¹⁶ there were 13 grade-I, nine grade-II and four grade-III open injuries.

The patients' health and elbow function were evaluated using three outcome measures: 1) a general health-status measure of the medical outcome, the short-form 36 (SF-36),¹⁷ 2) a limb-specific patient-orientated score, the Disabilities of Arm, Shoulder and Hand (DASH)^{18,19} score; and 3) a surgeon-orientated assessment, the Mayo Elbow score.²⁰ The SF-36 measures patients' self-perceived general level of health and has been used extensively to evaluate

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orthopaedic patients.^{17,21} The DASH is a limb-specific tool for outcome measurement which objectively records the function of the upper arm from the patients' perspective^{18,19} and deals particularly with difficulties in recreational pursuits or work which may not be reflected in problems encountered in activities of daily living. The Mayo Elbow score is a well-recognised outcome measure.²⁰

Radiological assessment. Union was defined as bony bridging seen across three of four cortices at the site of the fracture on the anteroposterior and lateral radiographs. The degree of post-traumatic degenerative change was evaluated on the follow-up radiographs. As there is no described grading system for post-traumatic degenerative changes of the elbow, we used the scale of Knirk and Jupiter²² which was originally designed for intra-articular fractures of the distal radius. Varus, valgus and recurvatum were also recorded.

Operative techniques. The mean time from injury to surgery was 27.9 hours with a median of 6.5 hours (2.9 to 192). Four patients with a delay of more than 24 hours had been referred from other hospitals; excluding these, the mean time from injury to surgery was 6.7 hours.

All patients received preoperative intravenous antibiotics. Patients were positioned in the lateral decubitus position with the affected side up. Under tourniquet control, a posterior approach was used and a thorough debridement performed, excising the edge of the traumatic wound and any devitalised soft tissue. Most free bony fragments were discarded, unless a significant portion of the joint surface was involved. Irrigation was carried out with a minimum of ten litres of sterile saline. Typically, a large tear was found in the triceps muscle/tendon. We used either a chevron-type olecranon osteotomy or a triceps-split approach¹⁴ (Fig. 1). In 20 injuries fixation was with two plates, a combination of precontoured plates,²³ 3.5 mm dynamic compression plates, and 3.5 mm reconstruction plates, while six were fixed with a single plate on one column of the humerus with lag screws alone on the opposite side.

Postoperative management included prophylactic intravenous antibiotics for 48 hours and a posterior splint for seven to ten days. Active movement began when a removable resting splint was applied. Active or resisted extension was avoided for six weeks. The same programme of rehabilitation was used in both groups.

Statistical analysis. We compared the groups using a two-tailed Student *t*-test; ($p < 0.05$ was considered significant). The correlations between various categories were investigated using the Pearson product-moment correlation coefficient (*r*). Values less than 0.25 indicated a weak correlation, between 0.25 and 0.50 mild, between 0.50 and 0.75 moderate and more than 0.75 good.¹⁹

Results

Table I gives the SF-36, DASH and Mayo Elbow scores. There were no statistically significant differences between

the mean scores of men and women for all outcome measures. Age, gender, mechanism of injury, grade of open wound and type of fracture (C/1/2/3) had no influence on outcome. The mean Mayo Elbow score was 79 (52 to 100). There were eight excellent, seven good, eight fair and three poor results.

The mean range of flexion-extension of the elbow was 97° (55 to 140). One patient with an ipsilateral injury of the forearm lost 40° of forearm rotation, but this remained normal in the remainder.

Comparison of the SF-36 scores with the US national averages showed significant differences between the physical function ($p = 0.01$) and role physical ($p = 0.002$) scores (Fig. 2). There were no other significant differences in the other categories.¹⁷ The mean DASH score was 23.7 (0 to 57.5) indicating minimal to moderate disability. A DASH score of 0 indicates normal, pain-free function and a score of 100 complete disability. The scores were normally distributed.

The optional module was answered by 19 patients. The mean score of the optional module was 44.1 (0 to 100). This indicates increased difficulty in aspects of daily living and in performing work-related tasks, sports, or other recreational pursuits.¹⁸

Radiological examination. Restoration of bony anatomy was assessed from the postoperative radiographs. The mean immediate postoperative angulation was 2.5° of varus/valgus and 3.3° of recurvatum. The mean postoperative step or gap in the articular surface was 1.4 mm. The mean time to union was 14 weeks (6 to 55). Four patients had delayed union (>16 weeks) at the metaphyseal-diaphyseal fracture line. In two of these union occurred uneventfully but two required autogenous bone grafting.

The degree of post-traumatic degenerative change was evaluated according to the scale of Knirk and Jupiter.²² There were 16 grade-0, five grade-1, three grade-2 and two grade-3 elbows.²² The type of approach had no effect on the quality of reduction or degree of post-traumatic degenerative change. Patients with grade-2 or grade-3 post-traumatic arthritic changes had lower Mayo Elbow scores ($p = 0.03$) and higher DASH scores ($p = 0.04$) than those with grade-0 or grade-1 change.

Associated injury. Patients with associated injuries had lower SF-36 scores in physical function (with, 62; without, 78; $p = 0.08$), but this was not statistically significant. There were no other differences in any of the other categories. There were no significant differences between these two groups with regard to DASH scores (with, 22; without, 24; $p = 0.79$), Mayo Elbow scores (with, 78; without, 80; $p = 0.73$), or range of movement (with, 95°; without, 9°; $p = 0.72$).

Triceps split approach versus olecranon osteotomy. Although their demographic details were similar (Table II), patients who had the triceps-split approach had a statistically better outcome in the Mayo Elbow scores, the DASH optional module scores and the role-physical and

Fig. 1a

Fig. 1b

Fig. 1c

Fig. 1d

Figure 1a – Diagram showing the posterior view of the left elbow after a skin incision and subcutaneous dissection. The dotted line represents the planned incision through the triceps muscle and tendon. The ulnar nerve is identified and protected throughout by a Penrose drain. Figure 1b – Diagram shows exposure of the site of the fracture after midline split of the triceps muscle and tendon. It is important to reflect the tendon sharply off the olecranon, preserving a contiguous layer medially and laterally to be reattached at the conclusion of the procedure. Visualisation of the anterior aspect of the joint can be improved by flexing the elbow and/or grasping the olecranon with a towel clip and pulling posteriorly. Figure 1c – Diagram showing a posterior view of the elbow after fixation of a bicolumnar, intra-articular fracture of the distal humerus with plates on both the medial and lateral columns. Drill holes have been placed through the olecranon for reattachment of the triceps. At this point the range of elbow movement and reduction of the fracture can be assessed. Since the olecranon is still intact, any narrowing of the trochlear groove through over compression of a comminuted fracture can be readily determined by extending the elbow and observing the olecranon/trochlear articulation. Figure 1d – Diagram showing closure of the triceps split with interrupted sutures, including some placed through drill holes in the olecranon.

bodily-pain scores of the SF-36 ($p = 0.05$, $p = 0.05$, $p = 0.04$ and $p = 0.002$, respectively). Although statistically not significant, patients with the triceps-split approach had a greater range of movement (Fig. 3).

Complications. Two patients developed a superficial infection but did not require further surgery and recovered

after treatment with antibiotics. One patient with a grade-3 open injury developed a deep infection which required multiple debridements followed by implants of antibiotic beads and bone grafting to achieve union. The overall rate of infection was 11% (3 of 26). One case of iatrogenic palsy of the radial nerve resolved spontaneously. The over-

Table I. Details of the outcome including the SF-36, DASH, and Mayo Elbow scores

	Minimum	Median	Maximum	Mean $\pm$ SEM
Length of follow-up (months)	10	47.5	141.0	51 $\pm$ 33
Arc length at final follow-up (degrees)	55	100	140	97 $\pm$ 22
Postop angulation (degrees)	0.0	0.0	10.0	2.9 $\pm$ 4.2
Postop step/gap (mm)	0.0	0.0	12.0	1.4 $\pm$ 2.5
SF-36 score*				
PF	20.0	77.5	100.0	73 $\pm$ 23
RP	0.0	100.0	100.0	61 $\pm$ 47
BP	31.0	74.0	100.0	70 $\pm$ 24
GH	10.0	77.0	100.0	71 $\pm$ 24
VT	10.0	65.0	86.7	62 $\pm$ 20
SF	0.0	90.0	100.0	81 $\pm$ 26
RE	0.0	100.0	100.0	72 $\pm$ 36
MH	4.0	74.0	100.0	73 $\pm$ 20
DASH† (n = 26)	0.0	22.5	57.5	23.7 $\pm$ 16.8
DASH† optional module (n = 19)	0.0	31.3	100.0	44.1 $\pm$ 38.2
Mayo Elbow Score‡	52	80	100	79 $\pm$ 14

* PF, physical function; RP, role physical; BP, bodily pain; GH, general health; VT, vitality; SF, social function; RE, role emotional; MH, Mental health. All scores are out of 100.

† 0 is the best possible outcome and 100 is the worst

‡ 100 is the best outcome

Fig. 2

SF-36 data comparing published control values with study values.

all rate of complications was 31% (8 of 26). The incidence of complications requiring further surgery was 11% (3 of 26). Three patients from the triceps-split group and five from the olecranon group developed a complication which had a detrimental effect on Mayo Elbow scores ($p = 0.01$) and DASH scores ($p = 0.02$). Two patients in the osteotomy group had removal of prominent metal used to fix the osteotomy.

Discussion

There is a very high incidence of bony and soft-tissue complications after open intra-articular fractures.³ No previous reports of the outcome of open reduction and internal fixation of open fractures of the distal humerus have been published, perhaps because of the rarity of the injury.

The preferred surgical exposure for the fixation of intra-

Table II. Details of the two groups

	Olecranon group (n = 13)	Triceps group (n = 13)	p value
Mean age in years	42.4	46.4	0.43
Male:female	10:3	12:1	0.65
Type-C fracture	13	13	N/A
Mechanism	10 fall/MVA*	9 fall/MVA*	0.61
Dominant limb	8	9	0.65
Grade-I open injury	7	6	0.77
Mean follow-up in months	49	53	0.39
Associated injuries	5	4	0.61

* motor-vehicle accident

articular fractures of the distal humerus is posterior; and the extensor mechanism must be reflected.^{24,25} The conventional olecranon osteotomy provides a wide exposure but has considerable disadvantages such as added surgical time, delayed or nonunion, and local irritation caused by the fixation.^{25,26} Triceps-splitting procedures are simpler to per-

Fig. 3a

Fig. 3b

Fig. 3c

Comparison of patients who had a triceps-splitting approach with those who had an olecranon osteotomy showing a) the SF-36 score, b) the DASH score and c) the Mayo Elbow Performance scores and the total arc of movement.

form but critics suggest that they offer a limited exposure and the possibility of postoperative dehiscence.²⁷ We have previously suggested that while the rate of reoperation in patients who had olecranon osteotomy was higher because of subsequent removal of metal, the quality of reduction, subjective outcome and objective muscle strength were similar to those who had a triceps-splitting approach.¹⁴

In our series, the soft-tissue wound was typically posterior and associated with a large tear in the triceps at the level of the metaphyseal/diaphyseal fracture. This defect is produced by the shaft of the humerus as it protrudes while the elbow flexes. This is different from similar injuries in children in which the shaft of the humerus protrudes anteriorly after a hyperextension injury and the anterior structures are damaged.²⁷

It would seem appropriate to incorporate any traumatically-induced disruption of the extensor mechanism into the surgical approach for fixation of the fracture. For

instance, if an intra-articular fracture of the distal humerus had an associated fracture of the olecranon, the extensor mechanism could be reflected proximally, the distal fracture fixed and the olecranon then repaired. Considerable disruption of the triceps, however, is more common, as seen in our series. We feel strongly that debriding this defect, extending it and then repairing it at the conclusion of the procedure is preferable to disrupting the extensor mechanism again by performing an olecranon osteotomy. The use of a triceps-splitting approach did not affect the quality of the reduction, but local irritation over the elbow from implanted metal used to fix the osteotomy was common.

There is a significant rate of infection after immediate fixation of open fractures. A previous report¹ has described a high rate of deep infection of 28% after immediate fixation of open fractures of the distal humerus, but 45% of the fractures in this series were grade-III injuries which are

associated with a higher rate of infection. Mostafavi and Tornetta⁴ recommended the use of an external fixator for open-shaft and supracondylar fractures, primarily caused by gunshot wounds, but they reported a rate of pin-track infection of 44%. In our series infection was low despite a median time to surgery of over six hours and only one patient required reoperation for this reason. Although the intra-articular portion of the fracture usually healed uneventfully, other complications included delayed union of the metaphyseal/diaphyseal fracture line and bone grafting to obtain union in two patients.

Considering the severity of the injury, the functional outcome in our series, as measured by general health, limb-specific, surgeon-based and radiological outcome measures, was good. The SF-36 scores showed decreases in two of the 'physical' categories compared with population controls, but were otherwise within normal limits. The DASH scores showed a mean of 23.7, indicating mild to moderate disability,⁹ and the mean Mayo Elbow score was 79, with only three patients having a poor result. The mean arc of movement in the flexion-extension plane was 97°, which corresponds to a 'functional' range for most individuals.²¹

The limitations of our study include its retrospective nature, the relatively small numbers and a lack of objective testing of muscle strength. Since patients were not randomised to one surgical treatment or another, it is possible that surgeon bias is responsible for the differences seen between the groups. One group of surgeons, however, always used the triceps-split approach, and the other the olecranon osteotomy, so that the clinical details and severity of injury between the two groups were similar (Table II). Our previous studies with similar closed injuries has suggested that the strength of extension of the elbow and the outcome are similar after a triceps-split approach when compared with an olecranon osteotomy. Thus, if the outcome was surgeon-dependent, a similar difference would have been expected in the closed injuries, but this was not seen.

Our findings suggest that immediate open reduction and internal fixation of open, intra-articular fractures of the distal humerus is a safe and effective technique with a low rate of complications, good limb-specific outcome and reliable restoration of the status of the general health. Patients whose fractures were fixed by a triceps-splitting approach, incorporating any traumatic defects in the triceps into the approach, had improved limb-specific and pain scores compared with those who had a more conventional olecranon osteotomy.

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