

FRACTURES OF THE RADIUS AND ULNA IN ADULTS: AN ANALYSIS OF FACTORS AFFECTING OUTCOME

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ABSTRACT

Concurrent data were collected by the authors for 104 fractures of the shafts of the radius and ulna in 102 adult patients to determine the relationship of subjective, objective, radiographic and economic outcome parameters to the method of treatment, type of fracture (open or closed), degree of comminution, and the presence of other injuries. Patients treated by open reduction and internal fixation (ORIF) had less pain, lost less forearm rotation, and returned to the same work following injury more frequently than those treated by closed reduction and casting (CR) or pins-in-plaster (PIP). The greatest advantages of ORIF over other treatment methods were improved skeletal alignment and forearm rotation, the factors most often associated with return to the same work following injury. Except for a longer time to union and a higher rate of infection, the outcomes of open and closed fractures were very similar. The presence of other injuries was a strong predictor of a compromised end result, primarily because of more pain, greater loss of forearm rotation, and less frequent return to the same work. The inclusion of patient satisfaction and work status in the assessment of outcomes and the concept of "functional malunion", an outcome-based interpretation of a radiographic finding, should help in counselling patients as to the likely economic and functional impacts of these injuries.

INTRODUCTION

Union with restoration of normal anatomy is particularly critical to achieve an optimal outcome for diaphy-

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seal fractures of the shafts of the radius and ulna in adults. These goals have most often been met by open reduction and plate fixation^{1-3,5,8,10,13,14,21,24}. In previous studies, however, outcome measures other than union have received scant attention, and the inclusion of fractures of a single bone with fractures of both bones has made interpretation of results difficult.

The purpose of this study was to determine the relationship of outcome to the method of treatment, type of fracture (open or closed), and presence of associated injuries in adults who sustained fractures of the shafts of both bones of the forearm. The outcome measures investigated were patient satisfaction (amount of pain), forearm rotation, radiographic findings, and work status.

MATERIALS AND METHODS

Criteria for inclusion in this study were skeletally mature patients with fractures of the shafts of both the radius and ulna treated at the University of North Carolina Hospitals. All patients were evaluated by one of the authors (thirty-five patients) or by another attending orthopaedist at the University of North Carolina Hospitals (sixty-seven patients). Complete data were available for 102 patients who had sustained 104 diaphyseal fractures of both the radius and ulna. Data collection and radiographic measurements were standardized for all patients.

All patients were followed at least until bone union occurred or the diagnosis of nonunion was made. The mean follow-up was thirty months (range three to 300 months). Seventy-three patients were male and twenty-nine female, with an average age of twenty-nine years (range fifteen to seventy-nine years). In thirty-seven patients, the fracture involved the dominant limb. Thirty-five of the fractures were open and sixty-nine were closed. The grade of soft tissue injury associated with open fractures was not recorded since many of these injuries preceded the advent of the rating system of Gustillo and Anderson⁸. Forty-six patients had sustained other major musculoskeletal or multi-system injuries.

Three methods of treatment were utilized: open reduction and internal fixation (ORIF), closed reduction

Table 1
Method of Rating End Results

Rating	Subjective	Objective	Radiographic	Economic
4	No pain.	Combined loss of forearm rotation <30°.	Fractures united. Combined malalignment (radius and ulna) <20°.	Same job at pre-injury level of performance.
3	Mild pain, present only with overuse.	Combined loss of forearm rotation 31-60°.	Union, with combined malalignment 21-40°.	Same job, but cannot perform at pre-injury level.
2	Moderate pain, present with routine activities.	Combined loss of forearm rotation 61-90°.	Union, with combined malalignment >40°.	Different job necessitated by fractures.
1	Severe pain, prevents or modifies routine activities.	Combined loss of forearm rotation >90°.	Nonunion, synostosis, or osteomyelitis.	Unable to work because of fractures.

and casting (CR), and external skeletal fixation with pins-in-plaster (PIP). The method of treatment was chosen by the attending surgeon based upon his experience and the type of injury. Minimal displacement of a closed fracture was the most frequent indication for closed reduction, and marked comminution was the primary reason for treatment with pins-in-plaster. All reductions were performed under general anesthesia. The definitive treatment was ORIF in seventy-three forearms, CR in eighteen, and PIP in thirteen. Twenty-one patients in the ORIF group were initially treated unsuccessfully by other methods (eighteen by CR and three by PIP).

Union was defined as the presence of bridging bone or trabeculae spanning the fracture site. Nonunion was identified by the absence of union within twenty-eight weeks following injury. Standards for alignment and measurement of radiographs were based on Sage's study, which defined normal as nine degrees of radial and six degrees of dorsal bowing of the radius and zero degrees in both planes for the ulna¹⁵.

End result ratings were made on a 1-4 point scale in four categories: (a) subjective, according the level of pain in the injured limb; (b) objective, by the range of forearm rotation; (c) radiographic, utilizing the criteria of union, synostosis, and malunion; and (d) economic, as reflected by the impact of the injury on the patient's employment status (Table 1).

Statistical analysis of the data was performed using the two-sided Fishers' exact test to analyze the association of two non-ordinal categorical variables. To analyze the association of a continuous ordinal variable and a categorical variable, the Kruskal-Wallis Test was used.

Statistical significance was defined as $p < 0.05$. Values for p were calculated for each association tested; numerical values of p for associations that did not reach statistical significance were reported only for selected associations.

RESULTS

Subjective Outcomes

Overall, 77 percent of patients reported no pain, with no difference between patients with open and those with closed fractures. While 82 percent of patients treated with ORIF were pain free at their last examination, only 62 percent treated with CR and 54 percent treated with PIP were painless. Patients with isolated fractures were more often pain free than were those with associated injuries (Table 2).

Objective Outcomes

No patient had significant loss of wrist or elbow motion compared to the uninjured side. The average total decrease in forearm rotation, however, was twenty-nine degrees, with loss of slightly more supination than pronation. There was no significant difference in the loss of forearm rotation between closed and open fractures: 63 percent of each group lost less than thirty degrees of forearm rotation.

The method of treatment had a significant effect on the loss of forearm rotation. Seventy-three percent of patients treated with ORIF lost less than thirty degrees of forearm rotation, while only 50 percent treated by CR and 23 percent by PIP lost less than thirty degrees. Patients with multiple injuries lost more forearm rotation than did those with isolated fractures (Table 3).

Table 2
Subjective Outcomes
 (Percent of patients achieving each subjective rating)

Rating	Overall	Open Fractures	Closed Fractures	ORIF	CR	PIP	Multiple Injuries	Isolated Fractures
4	77	77	77	82	62	54	72	83
3	19	20	19	15	32	46	26	14
2	4	3	4	3	6	0	2	3
1	0	0	0	0	0	0	0	0

Table 3
Objective Outcomes
 (Percent of patients achieving each objective rating)

Rating	Overall	Open Fractures	Closed Fractures	ORIF	CR	PIP	Multiple Injuries	Isolated Fractures
4	63	63	62	73	50	23	52	71
3	13	11	13	8	17	31	17	9
2	9	12	9	8	22	0	9	10
1	15	14	16	11	11	46	22	10

Table 4
Effect of Malalignment on
Loss of Forearm Rotation

n	Combined Malalignment (radius and ulna)	Mean Loss of Forearm Rotation
43	0-15°	21°
41	16-30°	31°
18	> 30°	43°

Radiographic Outcomes

Union occurred in 93 percent of radius fractures and 97 percent of ulna fractures, with an average time to union of 17.7 weeks for the radius and 18.3 weeks for the ulna.

Union was more frequent after closed than after open fractures. This difference was most apparent in radius fractures where 11 percent of open fractures developed nonunions, compared to only 4 percent of closed injuries ($p = 0.171$). Also, the average time to union was 18 percent longer for open than for closed fractures of the radius ($p = 0.027$), and 32 percent longer for open fractures of the ulna ($p = 0.012$). Neither the frequency of nor the time to union varied significantly with the method of treatment.

The amount of forearm rotation lost was directly proportional to the loss of normal alignment, reaching a mean of forty-three degrees when the combined malalignment of the radius and ulna exceeded thirty degrees ($p = 0.06$) (Table 4).

Overall, 66 percent of patients had less than twenty degrees combined malalignment of the radius and ulna on the final radiographs, with no difference between those patients with open and those with closed fractures. The method of treatment, however, had a significant effect on the final radiographic alignment: 81 percent of patients treated with ORIF had less than twenty-degrees combined malalignment of the radius and ulna on the final radiographs, a result seen in only 50 percent and 8 percent of patients treated with CR and PIP respectively (Table 5).

Table 5
Radiographic Outcomes
 (Percent of patients achieving each radiographic rating)

Rating	Overall	Open Fractures	Closed Fractures	ORIF	CR	PIP	Multiple Injuries	Isolated Fractures
4	66	66	67	81	50	8	52	79
3	13	14	11	8	17	31	17	7
2	11	9	13	4	11	54	18	7
1	10	11	9	7	22	7	13	7

Table 6
Economic Outcomes
 (Percent of patients achieving each economic rating)

Rating	Overall	Open Fractures	Closed Fractures	ORIF	CR	PIP	Multiple Injuries	Isolated Fractures
4	87	94	83	95	67	69	85	88
3	6	3	7	3	17	8	6	5
2	7	3	10	2	16	23	9	7
1	0	0	0	0	0	0	0	0

Economic Outcomes

Ninety-seven percent of patients with open fractures and 90 percent of those with closed fractures returned to the same work after injury. This difference may be attributed to the fact that nearly all patients with open fractures were treated by ORIF, while many with closed fractures were treated with CR or PIP. Patients treated with ORIF returned to the same work following injury more frequently than those treated with PIP or CR ($p < 0.05$). The presence of other injuries had little effect on the ability of the patients to return to the same work following injury (Table 6).

Pain also appeared to influence the patients' ability to return to the same work following injury; however, the strongest correlation was with the amount of forearm rotation lost. Eighty-eight percent of patients who did not return to the same work lost at least sixty-one degrees of forearm rotation; only 21 percent of patients who returned to the same work lost this much rotation.

COMPLICATIONS

Infection: Four deep infections developed (three following open fractures), for an overall infection rate of 4

percent. The infection rate was 1.5 percent in closed fractures and 9 percent in open fractures. No infections occurred in open fractures treated by immediate ORIF. All infections resolved with surgical debridement and appropriate antibiotic therapy.

Nerve palsy: Twelve patients (11 percent) had nerve palsies; eight radial, three median, and one ulnar. Ten palsies were recognized prior to treatment. The frequency of nerve palsies was similar in patients with open fractures (12 percent) and those with closed fractures (11 percent). All resolved spontaneously within six months of injury.

Synostosis: Radioulnar synostoses occurred in seven patients, all with closed fractures. Five of the patients also had closed head injuries; two had isolated forearm fractures. Three patients had been treated with CR, one with PIP, and three with ORIF.

Loss of reduction: Loss of fracture alignment required conversion to another method of treatment in twenty-one patients after primary treatment by CR or PIP. However, no patient lost reduction after ORIF. Eighteen of thirty-six patients treated initially by CR, and three of sixteen treated by PIP lost reduction and required conversion to ORIF. No nonunions occurred in these patients.

DISCUSSION

Full rotation of the forearm following fractures of the diaphyses of the adult radius and ulna is infrequent because of the difficulty in obtaining and maintaining anatomical reduction. Although numerous methods of treatment have been described for these injuries^{1-4,9-11,15,16,19,20,22}, the results are difficult to analyze because of many fracture and treatment variables, lack of precise definitions, and pooling of results for fractures of both bones with those in which only one bone was fractured.

Other studies have reported rates of nonunion, malunion, and other complications comparable to those in this investigation^{1,3,5,6,13,14,16,18,22,24}. The present study adds outcome measures based on the patients' impressions of their results and their ability to return to work following injury. Hadden et al.⁸ reported on 109 patients with fractures of the forearm, sixty-four of whom had fractures of both bones of the forearm; however, the outcome results were combined for all patients and were not stratified by the bone fractured, whether the fracture was open or closed, or the method of treatment. Fifty-five percent of patients with united fractures were pain free, 91 percent returned to the same occupation, and 3 percent were unable to work because of their forearm fracture. By comparison, 77 percent of patients in this study (82 percent of those treated with ORIF) were pain free at the time of their last evaluation. No patient in this series was unable to work because of his/her forearm fracture, and 93 percent of all patients (98 percent of those treated with ORIF) returned to the same work following injury. The inclusion of patient satisfaction and work status in the assessment of outcomes supplies information about the long term results of these fractures not previously available and permits counseling of patients as to the economic implications of their injuries.

While some authors have stated that closed methods of treatment for displaced diaphyseal fractures of the radius, ulna, or both forearm bones produce unacceptable results^{1,3,13}, Sarmiento et al.¹⁶ reported excellent functional results after closed treatment in forty-three patients. Although ORIF improved the overall outcomes in our study, it is clear that the greatest advantage of ORIF over other methods of treatment was in minimizing malalignment of the forearm and the resulting loss of forearm rotation. The rotation lost following CR and PIP was nearly double that lost following ORIF. Correspondingly, almost 90 percent of patients treated with ORIF had less than forty degrees of angular malalignment, but only 67 percent of patients treated with CR and 39 percent of patients treated with PIP achieved this result. Although alignment of the radius

and ulna has been measured by various methods^{1,11,15,17,18,23}, all studies, including this one, have shown that loss of normal alignment of the radius and ulna closely correlates with loss of pronation and supination^{1,11,17,18,23}. Angular malalignment and the related loss of forearm rotation were the factors in this study most often associated with inability to return to the same work following injury. Although malalignment is measured radiographically, it is a major determinant of function following fractures of the forearm. The term "functional malunion" describes the upper limit of angular malalignment that was associated with return to the same work following injury. Patients in this study who had combined angular malalignment of the radius and ulna of less than forty degrees were limited in forearm rotation by no more than sixty degrees and usually returned to the same occupation. The rationale for defining malunion in terms of function is to provide an outcome-based application of a radiographic finding.

Except for a longer time to union and a higher infection rate, the results of treatment for open and closed fractures were very similar. The infection rate in this study was comparable to that reported by others^{3,6,13,14,19,21}. The incidence of transient nerve palsies was unaffected by the presence of an open injury, although we expected more frequent nerve injury following open fractures because of more extensive soft tissue injuries.

The 44 percent of patients in this series who sustained multiple trauma is similar to the 40 percent incidence reported by Chapman et al.³. Patients in this series with other injuries lost more forearm rotation, and therefore had poorer end result ratings, than patients with isolated forearm fractures. The greater loss of forearm rotation resulted largely from more frequent synostoses in polytraumatized patients—(11.1 percent) compared to those patients with isolated fractures (3.7 percent). Interestingly, all five synostoses in patients with multiple trauma occurred in the setting of closed head injuries. The formation of ectopic bone following forearm fractures in patients with closed head injuries has been well documented^{1,7,12,24,25}.

SUMMARY

For this series of 102 adult patients, the end results following treatment of fractures of the shafts of the radius and ulna were good to excellent regardless of the method of treatment chosen. Except for a longer time to union and a higher infection rate, the outcomes of open and closed fractures were very similar. The presence of associated injuries was a strong predictor of a compromised end result. These patients had more pain, greater loss of forearm rotation, and longer times to

union. Treatment with ORIF resulted in better outcomes than treatment with either CR or PIP, largely because ORIF minimized malalignment and the resulting loss of forearm rotation. These two factors were closely associated with the inability to return to the same work following injury.

The addition of patient satisfaction and work status to the assessment of outcomes following fractures of the shafts of the radius and ulna in adults supplies previously unavailable information about the long term results of these injuries. The concept of "functional malunion" provides an outcome-based interpretation of a radiographic finding that more closely associates the radiographic alignment of the forearm with expected functional limitations.

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