Compression-plate fixation of acute fractures of the diaphyses of the radius and ulna

MW Chapman, JE Gordon and AG Zissimos

Compression-Plate Fixation of Acute Fractures of the Diaphyses of the Radius and Ulna*

BY MICHAEL W. CHAPMAN, M.D.,† J. ERIC GORDON, B.S.,‡, AND ANTHONY G. ZISSIMOS, B.S.,†
SACRAMENTO, CALIFORNIA

From the Department of Orthopaedics, University of California, Davis, Medical Center, Sacramento

ABSTRACT: A retrospective study was done of eighty-seven patients who had 129 diaphyseal fractures of either the radius or the ulna, or both, and who were treated with fixation using an AO dynamic-compression plate. Open fractures were internally fixed primarily, and both comminuted and open fractures routinely had bone-grafting.

Ninety-eight per cent of the fractures united, and 92 per cent of the patients achieved an excellent or satisfactory functional result. The rate of infection was 2.3 per cent. Refracture occurred after removal of a 4.5-millimeter dynamic-compression plate in two patients, but there were no refractures after removal of a 3.5-millimeter plate.

The 3.5-millimeter-plate system gave excellent results in patients who had a fracture of the forearm, and it minimized the risk of refracture. Our results demonstrated that immediate plate fixation of an open fracture of the forearm, with a low rate of complications, is possible.

To achieve a satisfactory functional result, a diaphyseal fracture of the radius or ulna needs a nearly anatomical reduction, as well as correction of displacement and restoration of normal length, axial alignment, and rotational alignment. To obtain and hold an accurate reduction usually necessitates open reduction and internal fixation, although other techniques have been advocated. Using compression-plate fixation, Anderson et al., in 1975, reported rates of union of 98 per cent for fractures of the radius and 96 per cent for fractures of the ulna. An excellent or satisfactory result was achieved in 86 per cent of their patients. A review of the English-language literature on compression-plate fixation of the bones of the forearm yielded similar results.

Materials and Methods

The cases of all patients who had an acute fracture of the diaphysis of the radius or ulna, or both, that was treated by plate fixation at the University of California, Davis, Medical Center in Sacramento, California, between January...
1980 and December 1985, were studied retrospectively. In 117 patients (173 diaphyseal fractures), at least one bone was plated. Twenty-nine patients were lost to follow-up, but eighty-eight patients (129 fractures) were followed for at least one year, and they form the basis of this report. The average age of the patients was thirty-three years (range, thirteen to seventy-nine years). There were sixty-eight male and nineteen female patients.

Of the 129 radii and ulnae that were fractured, three radii and one ulna had a segmental fracture, so the total number of fractures was 133. Of these 133 fractures, 129 were treated with plate fixation, three (two ulnae and one radius) were treated with intramedullary fixation (either Rush rods or Steinmann pins), and one (a non-displaced fracture of the distal part of the ulna) was treated closed while an accompanying fracture of the proximal part of the ulna was plated. The three segmental fractures of the radius were each treated with two plates. Each fracture and its plate was evaluated separately, making 129 fractures (129 plates) that were available for review.

Forty-two patients had fractures of both the radius and ulna. Of the eighteen isolated fractures of the radius, fourteen were Galeazzi fractures, and of the twenty-seven isolated fractures of the ulna, ten were Monteggia fractures. Thus, sixty-three fractures of the radius and sixty-six fractures of the ulna that had been treated with a compression plate were evaluated. Fifty-five fractures were in the patients who had a closed head injury; thirty-three (26 per cent), in patients who had one or more concomitant fractures of the ipsilateral upper extremity; and forty-four (34 per cent) were an isolated fracture of the forearm. Most of the fractures were due to a high-energy injury secondary to a motorcycle or motor-vehicle accident.

Two patients had a vascular injury. In one a radial-artery laceration was ligated, and in one an ulnar-artery laceration was successfully repaired. There were no sequelae in either patient.

Seventeen patients had a neurological injury. Twelve radial, two ulnar, and three median nerves were damaged. One of the ulnar and three of the radial nerves were lacerated. All four were repaired, but only one radial nerve had an appreciable return of function at one year. Neura-
praxia was identified preoperatively in three median nerves, nine radial nerves, and one ulnar nerve. There was complete recovery in one median and eight radial nerves and partial recovery in two median and one radial nerve. The ulnar neurapraxia showed slight improvement at one year.

FIG. 2

Distribution of fractures in each one-third of the shafts of the radius and ulna.

**Indications**

*Closed fractures:* Non-displaced fractures were treated non-operatively. In adults, all displaced fractures of the shaft of the radius with more than 10 degrees of angulation, or with subluxation of the proximal or distal radio-ulnar joint, were internally fixed. Displaced fractures of the shaft of the ulna with more than 10 degrees of angulation were generally internally fixed.

*Open fractures:* Primary plate-and-screw fixation was performed in nearly all patients. Some severe Type-IIIB or IIIC open fractures (Table I) were treated with external fixation; they were not included in this study.

**Surgical Technique**

In most patients, even those who had multiple injuries, the operation was performed on the day of injury. In a few severely injured patients, fixation was delayed because it was contraindicated by other injuries at the time of admission.

The radius and ulna are approached through separate incisions. The ulna is exposed by an incision along its subcutaneous border. In the distal one-third of the radius, a volar approach is used, and the plates are placed on the volar surface; in the middle one-third, the dorsal approach of Thompson is used; and in the proximal one-third, either the anterior approach of Henry or the extensile approach of Thompson is used. We prefer the latter approach.

Only that surface of the bone on which the plate is to be placed is exposed by subperiosteal dissection. Soft-tissue attachments to comminuted fragments are maintained if possible. The fracture site is cleaned of blood clot and soft tissue. In unstable fractures, it is technically much easier to fix the plate to one fragment with a single screw before reduction. The fracture is then reduced to the plate-bone combination. This technique necessitates less soft-tissue dissection and makes it relatively simple to handle intercalary, comminuted bone fragments as well. When possible, five separate cortices of solid screw fixation are secured on each side of the fracture. Interfragmentary compression with a screw is attempted in all fractures, either independently or through the plate, depending on the configuration of the fracture and the location of the plate (Figs. 5-A, 5-B, 6-A, and 6-B). When the interfragmentary screw is used independently, a plate containing at least six holes is used, and when the interfragmentary screw is through the plate, no less than a seven-hole plate is used. In comminuted fracture patterns, an eight-hole plate is commonly used.

For patients who have an open fracture, cefazolin sodium is administered intravenously in the emergency room after culture specimens have been obtained. The open fracture wound and the limb are prepared with povidone soap solution. A tourniquet is placed but not inflated, unless troublesome hemorrhage is encountered. The wound is irrigated with two liters of sterile saline solution, using pulsatile lavage. This immediately reduces the level of contamination and cleans the tissues of hematoma, which aids débridement. The ends of the bones are exposed using extensile incisions from the traumatic wounds. A methodical débridement, beginning with the skin and working layer by layer down to the bone, is then carried out. All necrotic tissue is excised. Bone fragments with no soft-tissue attachments are usually discarded. The wound is again irrigated with pulsatile lavage until a total volume of six to ten liters of saline solution has been used, depending on the size of the wound. One hundred thousand units of bacitracin is added to the last two-liter bag of saline solution. Final
culture specimens of tissue are then obtained.

Internal fixation is done as has already been described. After fixation, the traumatic wound is most often left open, but the elective portion of the surgical exposure is usually closed. Antibiotics are administered for two to five days after the operation if there is no evidence of infection and the cultures are negative. Although some traumatic wounds are closed primarily, most are closed between five and ten days after injury. If the wound is clean and if it shows no signs of infection, bone-grafting is done at this time, and the wound is then closed (Figs. 7-A, 7-B, and 7-C). Management thereafter is similar to management for closed fractures.

Open fractures, comminuted fractures, and fractures with bone loss at the fracture site are grafted with bone from the anterior iliac crest (Figs. 6-A, 6-B, 6-C, 7-A, and 7-C). Occasionally, local bone from the olecranon or styloid process of the radius is used. The wound is closed in the usual manner, but the deep fascia is always left open and the muscle is closed over the plate.

Sixty-eight (53 per cent) of the 129 fractures had bone-grafting: thirty-eight, with autogenous iliac bone; twenty-four, with bone that was harvested from the injured arm; and six, with synthetic hydroxyapatite.

A 3.5-millimeter AO dynamic-compression plate and 3.5-millimeter AO cortical screws were used in 117 fractures (91 per cent). At the surgeon’s discretion, three fractures were fixed with a 4.5-millimeter AO narrow dynamic-compression plate; five, with a semitubular plate; and four, with a third-tubular plate.

Eighty-seven fractures were fixed on the day of injury; four, within forty-eight hours after injury; nine, between days three and seven; fifteen, between days seven and fourteen; and fourteen, more than fourteen days after injury. Cefazolin sodium was given perioperatively and postoperatively to 91 per cent of the patients.
### Table I

<table>
<thead>
<tr>
<th>Type</th>
<th>Size of Wound&lt;sup&gt;t&lt;/sup&gt; (cm)</th>
<th>Velocity of Injury</th>
<th>Muscle Damage</th>
<th>Bone-Stripping</th>
<th>Vascular Injury&lt;sup&gt;t&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>&lt;1</td>
<td>Low</td>
<td>Minimum</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>II</td>
<td>&gt;1</td>
<td>Medium</td>
<td>Moderate</td>
<td>Minimum</td>
<td>None</td>
</tr>
<tr>
<td>IIIA</td>
<td>&gt;10</td>
<td>High</td>
<td>Major</td>
<td>Moderate</td>
<td>None</td>
</tr>
<tr>
<td>IIIB</td>
<td>&gt;10</td>
<td>High</td>
<td>Major</td>
<td>Severe#</td>
<td>None</td>
</tr>
<tr>
<td>IIIC</td>
<td>&gt;10</td>
<td>High</td>
<td>Major</td>
<td>Severe#</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* Based on modification of the criteria of Gustilo et al.9,20.
† Size is less important than soft-tissue damage.
§ Needing surgical repair.
§ Includes segmental fractures, farm injuries, high-velocity gunshot wounds, and shotgun wounds.
# Plastic-reconstructive operative treatment was often needed.

The wound was closed primarily for sixteen open fractures (33 per cent), ten of which were Type-I and six, small Type-II wounds. For the remainder of the fractures, delayed primary closure was possible in nineteen (39 per cent), eleven (22 per cent) needed split-thickness skin-grafting, one received a myocutaneous flap, and two healed by secondary intention.

### Postoperative Care

Immediately postoperatively, the forearm was placed in a bulky, soft dressing that incorporated plaster splints and supported the wrist and hand. As soon as swelling and discomfort permitted, the dressing was removed and the limb was placed in some type of splint or plaster cast. In unreliable patients, protection in a long plaster cast was necessary until the fracture had united. In most patients, a Münster-type cast was used to permit early flexion and extension of the elbow, and the wrist was braced with hinges for early motion; in more reliable patients, a cylindrical-type cast was used for the forearm, and this also allowed early supination and pronation. A few very reliable patients needed no additional support.

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**Fig. 5-A**

Figs. 5-A and 5-B: A closed Galeazzi fracture in a twenty-five-year-old man.

Fig. 5-A: Preoperative anteroposterior and lateral radiographs.

Fig. 5-B: Postoperative radiographs showing acute fixation with a six-hole, 3.5-millimeter dynamic-compression plate. Note the bicortical screws in the end holes and the separate interfragmentary screw.
Determination of Union, Delayed Union, and Non-Union

Using the criteria of Anderson et al., fractures that had healed by six months were classified as unions; those that healed after six months without an additional operative procedure, as delayed unions; and those that failed to unite after six months or that needed an additional operative pro-

Fig. 6-A

Figs. 6-A and 6-B: A closed Monteggia fracture in an eighteen-year-old man.
Fig. 6-A: Preoperative anteroposterior and lateral radiographs.

Postoperative radiographs showing acute fixation with a seven-hole, 3.5-millimeter dynamic-compression plate, augmented by an olecranon bone graft. Note the unicortical screws on each end of the plate and the use of the center hole as the site for an interfragmentary screw.
The time at which healing of the fracture had begun was determined by the first appearance of callus on anteroposterior and lateral radiographs of the forearm. The radiographic criterion for union was the presence of periosteal callus bridging the fracture site or of trabeculation extending across it.

The time to union was defined as the length of time between plate fixation and the first radiographic evidence of healing. Because most of the fractures were anatomically reduced and rigidly internally fixed, healing was usually by primary union of bone, without the formation of callus. The fracture site was often hard to see on the initial postoperative radiographs, making it difficult to judge the time of early union; however, a time to union was established for all patients.

Definition of Infection

Infections were classified as acute superficial, acute deep, or chronic osteomyelitis. Superficial infections involved the skin and subcutaneous tissues, but did not penetrate the deep fascia or muscle. Deep infections were below the deep fascia and involved the fracture and the site of the implant. Two sets of criteria were used to diagnose infection: local signs of infection, combined with a positive culture, or local as well as systemic signs of infection, even in the absence of a positive culture. Infections that necessitated operative intervention with bone débridement and that yielded positive cultures of bone were designated as chronic osteomyelitis.

Functional Results

Using the criteria of Anderson et al., the results were
Fig. 7-B: Postoperative radiographs showing acute fixation with ten-hole, 3.5-millimeter dynamic-compression plates on the radius and ulna. These were augmented by an iliac-crest bone graft at the time of delayed primary closure, three days after injury.

Fig. 7-C: Anteroposterior and lateral radiographs showing union at thirty-three months. A normal range of motion was achieved.

graded as follows. An excellent result meant union of the fracture, loss of flexion and extension at the wrist or elbow of less than 10 degrees, and loss of pronation and supination of less than 25 per cent. In a satisfactory result, there was union of the fracture, loss of flexion and extension at the wrist or elbow of less than 20 degrees, and loss of pronation and supination of less than 50 per cent. A result was unsatisfactory when there was union of the fracture and either loss of flexion and extension at the wrist or elbow of more than 20 degrees or loss of pronation and supination of more than 50 per cent. A failure was a non-union or unresolved chronic osteomyelitis.

Removal of the Plate

The plate was removed after union of the fracture only in patients who had symptoms that were associated with the plate or who specifically requested its removal. Removal was rarely done before twelve months postoperatively. Care was taken, at the time of removal, to leave all ridges of bone that had formed about the plate and screws. Except for the immediate postoperative period, no protection was used, and the patients were allowed to return to the activities of daily living, but they were cautioned to avoid heavy use of the extremity. Unrestricted use was generally permitted approximately six months after the plate had been removed.

Results

Union of the Fracture

For all of the fractures, sufficient follow-up data were available to evaluate the union. Union occurred in 125 (97 per cent) of the fractures; delayed union, in two (1.5 per cent); and non-union, in two (1.5 per cent). The average
time to union was twelve weeks (range, eight to twenty-four weeks).

Of the sixty-eight fractures that had bone-grafting (open fractures and those that had loss of bone or were comminuted), only one (1.5 per cent) failed to unite. Ninety-seven per cent of the ulnae and 100 per cent of the radii that had bone-grafting united. The average time to union in both bones was twelve weeks. The difference between the rates of union in the fractures that had bone-grafting and those that did not was not statistically significant. All seventy-nine fractures in which interfragmentary screws were used united.

**Functional Results**

At the one-year follow-up, functional results were available for 129 fractures in eighty-seven patients (Table II). Seventy-nine patients (91 per cent) had an excellent or satisfactory result, six (7 per cent) had an unsatisfactory result, and two had a result that was rated as a failure. Five of the six who had an unsatisfactory result had one or more concomitant injuries in the same extremity that contributed to the loss of motion in the wrist or elbow.

**TABLE II**

<table>
<thead>
<tr>
<th>Fracture</th>
<th>Exc.</th>
<th>Satis.</th>
<th>Unsatis.</th>
<th>Failed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulna only (n = 27)</td>
<td>18 (67%)</td>
<td>4 (15%)</td>
<td>5 (18%)</td>
<td>0</td>
</tr>
<tr>
<td>Radius only (n = 18)</td>
<td>18 (100%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0</td>
</tr>
<tr>
<td>Radius and ulna (n = 42)</td>
<td>36 (86%)</td>
<td>3 (7%)</td>
<td>1 (2%)</td>
<td>2 (5%)</td>
</tr>
<tr>
<td>Total (n = 87)</td>
<td>72 (83%)</td>
<td>7 (8%)</td>
<td>6 (7%)</td>
<td>2 (5%)</td>
</tr>
</tbody>
</table>

**Complications**

**Infection:** No acute postoperative infections developed. Two deep infections developed late (at eleven weeks in an open fracture and at nineteen weeks in a closed fracture) for a rate of infection of 2.3 per cent in all patients and 2.9 per cent in open fractures. Both of the infections resolved with treatment, and chronic osteomyelitis did not develop.

**Iatrogenic neurovascular injury:** There were no vascular injuries secondary to the operation. A distal radial-nerve palsy was noted postoperatively in one patient, but it was not clear from the medical record whether this had been present preoperatively. The palsy resolved without treatment. No compartment syndromes were found postoperatively.

**Synostosis:** One synostosis between the proximal aspect of the radius and the ulna occurred in a patient who had a closed Monteggia fracture that had been treated with a 4.5-millimeter AO narrow dynamic-compression plate. This patient had a closed head injury as well. The functional outcome was unsatisfactory due to the loss of pronation and supination. Because he was seventy years old and functioned satisfactorily in the activities of daily living, the patient declined additional treatment, and the synostosis was not excised.

**Early failure of fixation:** Two patients had early loss of fixation, both of the ulna. In the first patient, both the radius and the ulna had been fixed with a 3.5-millimeter AO dynamic-compression plate. The screws in the plated ulna loosened at three weeks, for reasons that the medical record did not make clear. Fixation was repeated with a 3.5-millimeter AO dynamic-compression plate, and the fracture united. In the second patient, a semitubular plate had been applied to an isolated fracture of the ulna. This patient had not followed the prescribed postoperative regimen, but had removed the cast and begun lifting weights within two weeks after injury. The plate failed by fatigue fracture. The fracture was treated with repeat internal fixation, and it progressed to satisfactory union.

**Removal of the plate, and refracture:** Thirty-four plates (26.4 per cent) were removed after the fracture had united: two 4.5-millimeter AO narrow dynamic-compression plates, one semitubular plate, and thirty-one 3.5-millimeter AO dynamic-compression plates. After removal of the plate, no refractures occurred in the patients who had had a semitubular or 3.5-millimeter AO plate. However, both bones from which a 4.5-millimeter AO narrow dynamic-compression plate had been removed refractured through a screw-hole; they healed after repeat fixation with a 3.5-millimeter AO dynamic-compression plate. No patient who did not have removal of the fixation device had a refracture.

**Discussion**

Because this study was retrospective, no concurrent control group was available for comparison with our series. We compared our results with those of Anderson et al., which served as a historical control.

**Characteristics of the Patients and the Fractures**

Because the University of California, Davis, Medical Center is a regional trauma center, a high percentage of our patients are severely injured. In this series, multiple injuries were sustained by 40 per cent of the patients, 25 per cent of whom had a closed head injury, and there was a 26 per cent incidence of associated major injuries in the same extremity. Although Anderson et al., did not report the incidence of associated injuries, the higher incidence of open fractures in our series (38 per cent compared with 11 per cent) suggests that our patients were more severely injured. Anderson et al. reported that 26 per cent of the fractures in their series had comminution of more than one-third of the cortex of the bone. In our series, 53 per cent of the fractures were comminuted. These data suggest that our series comprised a much more severe group of fractures; therefore, the outcomes would be expected to be worse.

**Union of the Fractures**

There was no statistically significant difference between the rate of union in our series and that in the series of Anderson et al., and from this standpoint, the differences...
in the ways that the patients in the two series were managed did not seem to matter. However, our over-all rate of union of 98.4 per cent in these particularly difficult fractures (Table III) supports the use of bone-grafting in comminuted and open fractures, when compared with the results that have been reported by others.\footnote{1,3,4,15,27,31-33,35,41,42} It should be noted that, using the treatment combination of plate fixation, interfragmentary screw fixation, and bone-grafting, 100 per cent of the fractures in our patients united.

**Functional Outcomes**

The rate of excellent functional outcomes in our series was somewhat higher than that reported by Anderson et al.\footnote{2} If combined excellent and satisfactory results are compared, however, the two outcomes are nearly identical. The philosophy of surgical treatment and postoperative care was similar in both series.

**Rate of Infection**

The rate of infection in our series was lower than that reported by Anderson et al.\footnote{2} (2.3 per cent compared with 2.9 per cent), although the difference was not statistically significant. It should be noted that, in our series, immediate internal fixation of open fractures was performed, whereas in the series of Anderson et al., internal fixation was delayed. Several studies\footnote{9,11,30} have indicated that, with good technique, immediate internal fixation of open fractures of the forearm can be done with an acceptable rate of complications.

We concluded that primary internal fixation of open fractures of the forearm does not increase the rate of infection compared with delayed fixation. The potential advantages of immediate internal fixation include more effective management of the soft-tissue injury, with restoration of stability (which in turn improves wound care); limitation of dead space due to shortening and malposition; and earlier initiation of range-of-motion exercises for rehabilitation.

**Removal of the Plate, and Refracture**

We followed the same philosophy relative to removal of the plate as did Anderson et al.\footnote{2}. Refracture occurred after removal of the two 4.5-millimeter AO narrow dynamic-compression plates, but not after removal of the thirty-one 3.5-millimeter AO dynamic-compression plates. This difference was significant ($p < 0.001$, by chi-square two-tail test). Extrapolating from the data of Anderson et al.\footnote{2}, it appears that they had a 22 per cent incidence of refracture after removal of the plate — the same rate of refracture as was reported by Hidaka and Gustilo.\footnote{22} In both of those series, the 4.5-millimeter AO plate was used. We concluded that the 4.5-millimeter AO plate-and-screw system is too large for most fractures of the forearm, and we recommend that the 3.5-millimeter AO system be used. Because there were no problems in the patients from whom the plate was not removed, we concluded that removal of the plate is not mandatory, although the long-term effects of retained plates are not known.

**Conclusions**

Internal fixation with the 3.5-millimeter AO dynamic-compression plate, using interfragmentary compression, provided excellent results when fixing diaphyseal fractures of the radius and ulna. Routine bone-grafting of comminuted and open fractures produced results comparable with those for closed, non-commminuted fractures. Immediate internal fixation of open fractures, combined with meticulous irrigation and débridement, resulted in rates of complications and functional results that were comparable with those associated with delayed internal fixation. Although removal of the plate is not necessary in the short run, it is safe, and the risk of refracture is low, when the 3.5-millimeter AO dynamic-compression plate-and-screw system is used.

**References**
