Unstable fractures of the forearm in children present problems in management and in the indications for operative treatment. In children, unlike adults, the fractures nearly always unite, and up to 10° of angulation is usually considered to be acceptable. If surgical intervention is required the usual practice in the UK is to plate both bones as in an adult. We studied, retrospectively, 32 unstable fractures of the forearm in children treated by compression plating. Group A (20 children) had conventional plating of both forearm bones and group B (12 children) had plating of the ulna only. The mean age was 11 years in both groups and 23 (71%) of the fractures were in the midshaft. In group B an acceptable position of the radius was regarded as less than 10° of angulation in both anteroposterior (AP) and lateral planes, and with the bone ends hitched. This was achieved by closed means in all except two cases, which were therefore included in group A.

Union was achieved in all patients, the mean time being 9.8 weeks in group A and 11.5 weeks in B. After a mean interval of at least 12 months, 14 children in group A and nine in group B had their fixation devices removed.

We analysed the results after the initial operation in all 32 children. The 23 who had the plate removed were assessed at final review. The results were graded on the ability to undertake physical activities and an objective assessment of loss of rotation of the forearm.

In group A, complications were noted in eight patients (40%) after fixation and in six (42%) in relation to removal of the radial plate. No complications occurred in group B.

The final range of movement and radiological appearance were compared in the two groups. There was a greater loss of pronation than supination in both. There was, however, no limitation of function in any patient and no difference in the degree of rotational loss between the two groups. The mean radiological angulation in both was less than 10° in both AP and lateral views, which was consistent with satisfactory function.

The final outcome for 23 patients was excellent or good in 12 of 14 (90%) in group A, despite the complications, and in eight of nine in group B (90%).

If reduction and fixation of the fracture of the ulna alone restores acceptable alignment of the radius in unstable fractures of the forearm, operation on the radius can be avoided.

Compression plating is widely accepted as the appropriate treatment for fractures of the forearm in adults in order to reduce the incidence of nonunion, malunion and subsequent loss of function. In children, a similar approach is usually unnecessary since healing of the fractures is rarely a problem and anatomical realignment is not required because of the remodelling potential of the immature skeleton. The ability to remodel decreases with increasing age, and over ten years it is less predictable and less effective. In children the correlation between malunion and function is poor, but residual angulation of more than 10° should probably be corrected in a child of nine years and certainly in children aged over ten years.

Various methods of treatment are available in children to achieve near anatomical reduction such as compression plating, intramedullary nailing, external fixation or K-wires incorporated in a plaster cast. Compression plating is the most favoured in the UK. Plating and the subsequent removal of the plate are, however, not without complications. The AO group recommends removal of forearm plates at 16 to 18 months after operation, but these guidelines are intended mainly for adults. No specific advice has been given concerning their removal in children. Our study compares two groups of patients who underwent fixation for displaced fractures of the forearm. In group A
both bones were plated and in group B only the ulna with
the radius realigned by closed manipulation. We have
compared the outcome to determine whether fixation of
the ulna alone was adequate to restore and maintain stability in
fractures of both bones of the forearm.

Patients and Methods

Between 1991 and 1997, we treated 32 children with
displaced fractures of both bones of the forearm in whom
closed manipulation had failed. Of these, 14 had fixation of
the ulna and closed manipulation of the radius to restore
alignment by the senior author (JAR). In two patients
satisfactory radial reduction with the bone ends hitched and
angulation of less than 10° was not achieved and open
reduction of the radius was required. The remaining
patients had conventional plating of both bones of the
forearm. Two groups of patients were therefore available
for this study. Group A (20 patients) had plating of both
bones and group B (12 patients) plating of the ulna alone.
Table I gives the details of both groups. A total of 19
patients had fractures of the right forearm and 13 of the left,
and 71% were in the middle third.

Informed consent was obtained for all patients. We oper-
ated on 22 patients within 48 hours, six within the first
week and four, who were referred from other hospitals,
after one week.

Operative technique. Under general anaesthesia closed
reduction was attempted with fluoroscopic control. If this
failed a volar approach was used for radial plating and
the dorsal subcutaneous approach for fixation of the ulna.
In group B, plating of the ulna was carried out first,
followed by closed manipulation of the fracture of the
radius. Up to 10° of angulation of the radius was con-
sidered acceptable before fixation was required. This was
measured on intraoperative anteroposterior (AP) and lat-
eral radiographs.

The AO small fragment set (Stratec Medical, Hertford-
shire, UK) was used, and standard 3.5 mm dynamic com-
pression plates or semitubular plates were employed
depending on the size of the bone. The postoperative care
was similar in both groups. An above-elbow cast was
applied for approximately five weeks, after which the
patients were referred for physiotherapy.

The children were placed on the waiting list for removal
of the implant when there was clinical and radiological
evidence of union. Fourteen of group A and nine of group
B had their plates removed electively. They were reviewed
after initial fixation and later after removal of the plates.

Data for patients undergoing fixation of the ulna only
were recorded prospectively by the senior author (JAR).
The information for the other group was obtained from
the records by the first author (ARB). All 23 patients who had
removal of the implant were seen in a special clinic by the
first author (ARB) who had not been involved in their
previous treatment. At this review they were assessed for
subjective symptoms such as pain at rest or with activities
of daily living, ability to participate in physical activity and
in sports. Objective assessment was made of the range of
movement (ROM) of the wrist, elbow and forearm. Fore-
am rotation was measured using a goniometer, previously
described by the senior author. The results were graded
according to the criteria proposed by Daruwalla and Price
et al with slight modification in the scoring for loss of
movement (Table II). Angulation was measured on radi-
ographs using the greatest deformity seen on the AP and
lateral views.

For statistical testing we used a personal computer, SSPS
for Windows 95 software (version 6.1), Student’s t-test
and Fisher’s exact test; p values of less than 0.05 were con-
sidered to be significant.

Results

The results for both groups were analysed clinically as well
as from the information available from the records. All 32
patients were reviewed after the initial operation. The mean
follow-up was for at least one year in both groups. The
mean tourniquet time for fixation of both bones was 98
minutes (80 to 120) and 43 minutes (35 to 60) for the ulna
only.

Eight (40%) patients in group A had complications relat-
ed to fixation. One had a superficial wound infection and
another a deep infection leading to osteomyelitis with a
chronic discharging sinus. The radial plate in this patient
was removed at three months when the fracture had healed.
The sinus resolved in six months after further debridement
and antibiotics. Two patients had transient weakness of
flexor pollicis longus probably related to muscle injury or

<table>
<thead>
<tr>
<th>Gender</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site of fracture</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal third</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Middle third</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Proximal third</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Symptoms</th>
<th>Loss of forearm rotation in degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>No complaints with strenuous physical activity</td>
<td>&lt;15</td>
</tr>
<tr>
<td>Good</td>
<td>Mild complaints with strenuous physical activity</td>
<td>15 to 30</td>
</tr>
<tr>
<td>Fair</td>
<td>Mild complaints with daily activities</td>
<td>30 to 90</td>
</tr>
<tr>
<td>Poor</td>
<td>All other results</td>
<td></td>
</tr>
</tbody>
</table>
neurapraxia of the anterior interosseous nerve. They recovered after a period of nine months. Nerve damage was seen in four patients. Two had sensory loss related to the superficial branch of the radial nerve, one had paraesthesia and weakness of the muscles innervated by the median nerve and one had numbness and clawing of fingers due to damage to the ulnar nerve. In these the diagnosis was confirmed by EMG and nerve-conduction studies. In the patient with damage to the ulnar nerve, motor function recovered completely at nine months, but at final review there were persistent paraesthesiae along the ulnar border of the forearm. No complications were seen in patients in group B. The difference in the rate of complications between the two groups was significant (Fisher’s exact test, p = 0.013).

Healing of the fractures, assessed clinically and radiologically, was complete at a mean interval of 9.8 weeks (8 to 16) in group A and 11.5 weeks (8 to 17) in group B. Of the 32 patients, 23 had the plate removed. Three patients were lost to follow-up and six were awaiting removal of the plate at the time of review. The mean interval between the initial operation and removal of the plate was 14.5 months in group A (3 to 24) and 19.4 months in group B (11 to 25). Seven patients had the plate removed within nine months of initial surgery. The mean operative time for removal of the plate was 90 minutes in group A (60 to 110) and 35 minutes in group B (20 to 49) in group B.

Six patients (42%) in group A had complications; one had a staphylococcal wound infection which resolved with antibiotics, three had sensitivity of the scar related to the radial approach which was still painful at final follow-up, one had sensory disturbance related to the superficial radial nerve, and one had a pure motor involvement of the median nerve which had not completely recovered at the last review. No complications were seen in group B. Again this difference was significant, although the numbers were small (Fisher’s exact test, p = 0.04).

The mean follow-up after removal of the plate was 15.5 months in group A (3 to 48) and 11.11 months in group B (6 to 15).

At the final review the range of movements of the wrist, elbow and forearm were recorded in both arms. The ranges of pronation and supination were measured by using a rotational goniometer (Table III). There was no significant loss of elbow or wrist movement in either group.

The mean normal range of pronation was 90.21° (70 to 110) and of supination 105.7° (80 to 120) in group A. The corresponding ranges in group B were 89.44° (75 to 110) and 100° (80 to 120), respectively.

There was greater loss of pronation than supination in both groups. In group A there was a mean loss of pronation of 16% (mean value 76.41°) and of supination of 13% (mean value 93.14°). In group B the mean loss of pronation was 18% (mean value 73.55°) and of supination 8% (mean 92.7°). Comparison of the loss of movement in the two groups is shown in Table III. Based on the criteria in Table II there were two fair, two good and ten excellent results in group A. There was one fair, two good and six excellent results in group B. No child complained of any limitation in activities of daily living and all could participate in strenuous activities.

Radiographs were taken in the AP and lateral planes for all 23 patients (Fig. 1). The mean radiological angulation was comparable in both groups after removal of the plate (Table IV). Five patients reported unsightly scars more than 5 mm wide on the volar aspect of the forearm related to the removal of the radial plate. There were no complaints in either group following removal of the ulnar plate.

**Discussion**

Fractures in children tend to be treated more conservatively than those in adults. Union is rarely a problem and a certain amount of malunion can be tolerated because of the ability to remodel. This remodelling capacity depends on age, the site of the fracture, the direction of the angulation and its magnitude and has been studied by various authors.\(^\text{10,13,14,28-31}\)

The best method of management of unstable fractures of the forearm in children remains controversial. Internal fixation has been advocated after poor results in older children following conservative treatment.\(^\text{32-34}\) The AO group popularised compression plating which gives rigid fixation and early return of function.\(^\text{24}\) Although fixation can provide accurate reduction, the soft-tissue exposure may lead to complications such as infection, neurovascular injuries, scarring and delayed union or nonunion.\(^\text{20,35}\) Rates of complication of 10% to 30% have been reported.\(^\text{35,36}\)

Removal of the plates may also be associated with significant complications. Scarring from the previous surgery and bone growth over the plates may make their removal difficult.\(^\text{31,23,36,37}\)

There are recent reports of good results obtained with intramedullary fixation.\(^\text{16,17,38,39}\) The use, however, of these

**Table III.** Comparison of loss of forearm rotation in the 14 patients in group A and the nine in group B who had removal of the plate. Loss of more than 15° of forearm rotation is considered significant.

<table>
<thead>
<tr>
<th>Loss of forearm rotation (degrees)</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pronation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;30</td>
<td>2</td>
<td>1*</td>
</tr>
<tr>
<td>15 to 30</td>
<td>1*</td>
<td>1</td>
</tr>
<tr>
<td>&lt;15</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

* indicates same patient affected in each group

**Table IV.** The mean angular deformity of the radius (degrees; range) on radiographs of the 14 patients in group A and the nine in group B who had removal of the plate.

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP view</td>
<td>5 (0 to 12)</td>
<td>8.2 (4 to 15)</td>
</tr>
<tr>
<td>Lateral view</td>
<td>4 (0 to 8)</td>
<td>3.5 (0 to 6)</td>
</tr>
</tbody>
</table>

\[\text{VOL. 83-B, NO. 2, MARCH 2001}\]
Radiographs of a ten-year-old patient showing a) fractures of both bones of the forearm b) five weeks after fixation of the ulna only with the radius aligned by closed manipulation and c) approximately 12 months after removal of the plate. There is good remodelling of the fracture of the radius and residual angulation of less than 10°.
devices in only one bone is associated with loss of reduction and some authors recommend stabilisation of both bones.\textsuperscript{40,41}

Single bone fixation has previously been reported using plates and intramedullary wires by Flynn and Waters.\textsuperscript{42} In their study, seven children had radial plating, nine intramedullary fixation of the ulna and one of the radius. There were four incomplete fractures and five open injuries. The authors did not mention their criteria for acceptable reduction, but recommended fixation of the ulna first.

To our knowledge no previous clinical study has been reported comparing fixation of the ulna alone with fixation of both bones. Biomechanical data have been published which suggest that ulnar plating alone can provide adequate stability when both forearm bones are fractured.\textsuperscript{43} The results from our study suggest that plating of the ulna alone gives acceptable results in unstable fractures of the forearm provided that the radius is well aligned. Radial angulation of up to 10° was considered acceptable. Ulnar fixation alone restores the length of the forearm and provides a stable strut for manipulation of the radial fracture.

In two cases acceptable closed reduction of the radius could not be achieved. In both surgery had been delayed (8 and 12 days after injury). It is possible that the soft-tissue swelling and oedema precluded satisfactory radial manipulation. In all the other patients ulnar fixation was carried out within 48 hours of injury. The operation time necessary for insertion of the ulnar plate and for its removal was nearly half that for both bones. The healing time of the fracture was also not affected by ulnar fixation alone, and union was seen in all patients.

There were no complications in the ulnar plating group, but a complication rate during insertion and removal of nearly 40% was seen when both bones were plated (group A). One case of injury to the ulnar nerve was seen in group A probably sustained during plating of the ulna. The other complications, although transient, were all related to radial fixation.

All operations to remove implants were undertaken by experienced surgeons, and we feel that the presence of a senior surgeon may reduce the rate of complications which has been previously reported.\textsuperscript{36}

There were no refractures in our series. At the final review, 23 patients had their plate removed, seven within nine months of the initial operation. All these children were less than ten years old, and considerable bony overgrowth was present over the plate. We feel that the strict AO guidelines on the timing of removal of the plate may cause unnecessary delay in children.\textsuperscript{44,45} We recommend a nine-month interval between the initial surgery and removal of the implant in children aged less than ten years old.

Loss of rotation of the forearm of 15° was considered to be significant.\textsuperscript{13} The senior author has shown that a loss of rotation of 10° can be attributed to the natural difference in the range of rotation between both forearms.\textsuperscript{13} The scoring system was therefore modified for the loss of range of movement.

Three children had more than 30° loss of pronation, two in group A and one in group B. None had subjective symptoms with strenuous activity and compensated very well for restriction of forearm rotation. All other children were unaware of their loss of forearm movement and continued to participate in all types of physical activity.

Although the relationship between angular deformity and forearm rotation is variable, the general consensus is that restriction of forearm rotation is dependent on the direction, magnitude and level of the deformity in the forearm.\textsuperscript{13,46,47} Up to 10° of angulation is associated with an acceptable limitation of rotation, and loss of 20° of forearm rotation is still compatible with good function.\textsuperscript{48}

It has been shown that anatomical alignment by operative intervention does not guarantee full return of movement.\textsuperscript{32} In our study, all patients had angular deformities of less than 10° in both the AP and lateral radiographs. We did not assess rotational deformity on radiographs since this is difficult to measure and needs comparative views of the opposite forearm.\textsuperscript{49,50} It is possible that some restriction of movement in our patients could be related to malrotation of forearm bones after union of the fracture.

Since children are very active we used immobilisation in a plaster cast for five weeks in both groups to protect the operated forearm. We do not think this has a long-term affect on the range of movement of the forearm.

We consider that, in most unstable fractures of the forearm in children, plating of the ulna alone with manipulation of the radius produces excellent results, with a reduction in the operating time and rate of complication when compared with plating of both bones.

We wish to thank sincerely all patients and staff at Grimsby General Hospital for their kind co-operation in this study. We would also like to thank Miss Vicki Allgar, Medical Statistician, St James’s University Hospital, for her help in giving advice. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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