ANGULATION OF THE RADIUS IN CHILDREN'S FRACTURES

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A study of 79 children with malunion of forearm fractures is presented. Age at the time of injury, the site of the fracture and the degree and direction of angulation at union were correlated with loss of forearm rotation at review 3.5 to 6 years later. Some guidelines are proposed for the acceptability of angular deformity at union, importance being placed on the avoidance of radial deviation of the radius, and the maintenance of the interosseous gap between the shafts of the radius and ulna.

Forearm fractures are common in childhood, and although the majority have a satisfactory outcome, poor results do occur (Rang 1983). Generally speaking, the younger the child, the more distal the fracture and the less the angulation, the better the result (Gandhi et al. 1962; Fuller and McCullough 1982).

There is, however, little agreement as to how much angulation is acceptable. Cave (1958) considered that midshaft fractures with an angulation of more than 15° would result in loss of function, while in distal third fractures up to 35° was acceptable. Hugheston (1962) recommended that fractures in patients over 14 years of age should be treated as for adults but that, in children under 10 years old with distal third fractures, 30° to 40° was acceptable. Cooper (1964) stated that up to 20° of angulation was acceptable in distal third fractures. Daruwalla (1979) recommended that over 10° midshaft angulation in children over 10 years old was unacceptable, and that in the distal third 15° was acceptable only in children under 5 years old.

Fuller and McCullough (1982) recommended virtually anatomical reduction, by open methods if necessary, for midshaft fractures in children over eight years old but would accept up to 20° of angulation in distal third fractures in patients under 14.

The importance of the direction of angulation has not previously been stressed, though some studies have related residual malunion at review to loss of forearm rotation. However, Högström, Nilsson and Willner (1976) have shown that loss of rotation is not closely correlated to residual angulation, and Nilsson and Obrant (1977) found a significant reduction in forearm rotation 16 years after displaced forearm fractures, well reduced by closed methods and with no residual malunion.

This paper presents the results of a study of mal-united fractures of the forearm and relates the age at fracture and the angle and direction of malunion to the range of forearm rotation 3.5 to 6 years later.

PATIENTS AND METHODS

The radiographs of all forearm fractures in children treated 3.5 to 6 years earlier were reviewed, excluding those within 1 cm of the distal radial epiphysis and those of the proximal third of the shaft. The radiographs at the time of union were studied and the degree and direction of angulation were measured and recorded, as well as the age of the child at the time of the fracture. Examples of such radiographs are seen in Figures 1 and 2. Only angular malunion was considered because rotatory malunion

Fig.1

Fig.2

Anteroposterior and lateral radiographs of a united distal third fracture showing 19° of radial deviation and 32° of dorsal angulation.
Table 1. Results of measurement in degrees of angulation in the distal third and in the midshaft of the normal forearm in 84 children

<table>
<thead>
<tr>
<th>Angulation</th>
<th>Site</th>
<th>Bone</th>
<th>Mean</th>
<th>s.d.</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Midshaft</td>
<td>Ulna</td>
<td>1.7</td>
<td>1.44</td>
<td>Dorsal 5 to ventral 7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radial</td>
<td>1.7</td>
<td>1.34</td>
<td>Radial 10 to 10</td>
</tr>
<tr>
<td>Distal third</td>
<td>Radius</td>
<td>Ulna</td>
<td>2.1</td>
<td>1.96</td>
<td>Radial 9 to 10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radial</td>
<td>1.6</td>
<td>1.34</td>
<td>Radial 10 to 10</td>
</tr>
</tbody>
</table>

is difficult to measure, even on radiographs taken specifically for this purpose (Milch 1944; Evans 1945; Fuller and McCullough 1982; Creasman, Zaleske and Ehrlich 1984).

Normal forearm bones are curved throughout their length. For example, in an anteroposterior view the distal radius curves in an ulnar direction, while the ulna in the same view curves radially. To determine the accuracy of measurement of angulation and to obtain normal values for angulation beyond which deformity could be attributed to the fracture, 84 normal forearm radiographs were studied.

These, taken in a standard manner, were of the uninjured forearms of the patients reviewed for this study, excluding those with a history of fracture in the control forearm. The angulation and its direction in the distal and middle thirds of each bone were recorded (Table 1). Angulations in the fractured arm at the time of union falling outside these normal ranges were regarded as being abnormal and a consequence of the fracture.

Of the 154 fractures which, at union, had an abnormal angulation of at least one bone in one plane, 93 were reviewed 3.5 to 6 years after injury. This low proportion reflects the time since recovery and the wide geographical dispersion of the patients. Nonetheless, this series is, as far as the author knows, the largest yet published.

The children were examined clinically; in addition, wrist movements and forearm rotation of both arms were measured with a goniometer. The difference in the range of rotation between injured and uninjured sides gave figures for net gain or loss of rotation.

To determine the accuracy of measurement of the forearm rotation and the loss of rotation which could be reasonably regarded as abnormal, 50 normal children with no history of forearm fracture were examined on the same apparatus by the same observer. In only one subject was there a difference in forearm rotation between one arm and the other greater than 10°, though the variation between individuals was often larger (Fig. 3). A net loss of 15° or more was therefore regarded as abnormal and related to the fracture.

Taking into account the age of the child at the time of fracture, the degree and direction of malunion was correlated with loss of rotation for midshaft and distal third fractures, both together separately.

RESULTS

Of the 93 patients who attended for review 14 were excluded because of a history of fracture on the control side, a subsequent fracture of the side being studied, or hyperactivity which precluded the accurate measurement of rotation.

Of the 79 fully documented fractures, 45 were in the distal third and 34 in the midshaft. There were 49 boys and 30 girls, with 38 fractures of the right arm and 41 of the left. The mean age at fracture was 8.3 years (range 2 to 16 years); for distal third fractures this was 9.3 years (range 4 to 16) and for midshaft fractures 7 years (range 2 to 11).

Thirty of the 79 patients (38%) had loss of rotation of over 15°, 17 of the 34 (50%) with midshaft fractures (Fig. 4) and 13 of the 45 (29%) with distal fractures (Fig. 5). A chi-squared test on the numbers of cases at each level with loss of rotation after fracture gives p=0.06.

**Midshaft fractures.** None of the three children aged three years or less at the time of fracture had significant loss of forearm rotation at review, while all four who were over 10 had lost 15旋转 rotation or more. The 27 patients who were between three and 10 years old were then studied in relation to the degree and direction of angulation.

**Radial deviation.** Of seven cases with abnormal radial deviation of the radius, all three with deviation of more than 15° had loss of rotation, while none of the four with less than 15° had such restriction.
**Angulation of the Radius in Children's Fractures**

**Fig. 4**

Differences in the range of rotation between injured and uninjured forearms in 34 patients after a previous midshaft fracture.

**Fig. 5**

Differences in the range of rotation between injured and uninjured forearms in 45 patients after a previous distal third fracture.

**Dorsal angulation.** Of 17 cases with abnormal dorsal angulation of the radius at union, three had associated radial deviation. With or without these three cases, analysis showed no relationship between dorsal angulation and the loss of rotation (Table II).

**Ulnar deviation.** Neither of the two cases with abnormal ulnar deviation (both associated with abnormal dorsal angulation of 18°) showed loss of rotation at review.

**Distal third fractures.** None of the nine children aged 5.5 years or less at the time of fracture had loss of rotation at review, while five of the six aged over 15 years old did show loss. The 30 children aged 5.5 to 15 years were then studied to assess the influence of the degree and direction of angulation.

**Radial deviation.** Fourteen children had radial deviation at union; eight of them showed loss of rotation at review.

**Dorsal angulation.** Of 22 cases with dorsal angulation of

**Table II.** The association between dorsal angulation at the fracture site (after union) and loss of forearm rotation, showing the number of cases in each group.

<table>
<thead>
<tr>
<th>Site</th>
<th>Group</th>
<th>Angle</th>
<th>Loss</th>
<th>No loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midshaft</td>
<td>All cases</td>
<td>&lt;15</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;15</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Excluding those with radial deviation</td>
<td>&lt;15</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;15</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Distal third</td>
<td>All cases</td>
<td>&lt;15</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;15</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Excluding those with radial deviation</td>
<td>&lt;15</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;15</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

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deviation of the relationship. In three cases there was ulnar deviation of the radius; none of these had loss of rotation at review, despite their being associated with dorsal angulation of 19, 26, and 29° respectively.

As judged by loss of rotation, malunited midshaft fractures seem to carry a worse prognosis than distal third fractures (see Figs 4 and 5). The four cases in the midshaft group with a loss of rotation of more than 30° were all over eight years old at the time of fracture, suggesting that the older the child, the worse the prognosis. The case with a 125° loss of rotation was 11.5 years old at fracture and also had the largest radial deviation (20°). Four cases in the distal third group had a loss of rotation of 30° or more. All were over eight years old at the time of fracture, two being over 15, while one had 20° radial deviation.

DISCUSSION

Some previous studies of forearm rotation have taken 180° as the average value (Fuller and McCullough 1982) or have regarded any loss as being fracture-related (Daruwalla 1979). The results from 50 normal children show that such generalisations are inaccurate. The 100 forearms studied gave a mean total rotation of 202° with a wide difference between individuals ranging from 170° to 240°, but the difference between left and right sides in a normal subject was usually small, being over 10° in only one case (see Fig. 3). It would therefore seemed to be more accurate to compare the injured with the uninjured side, rather than with the mean for the whole group, and to disregard a difference in rotation of less than 15° since this may be due to normal variation. Although this present series appears to be the largest yet published, the figures remain too small to reach statistical significance; nevertheless some interesting observations can be made.

In clinical practice, dorsal angulation of the radius is the deformity which attracts most interest on the post-reduction films. The present study indicates that residual dorsal angulation is less detrimental than radial deviation to the functional result, as judged by forearm rotation. After midshaft fractures, late loss of rotation due to union with radial deviation was first seen after injury at three years of age, as against 5.5 years for dorsal angulation.

Radial deviation of the radius was more closely related to late loss of forearm rotation than was dorsal angulation, in both midshaft and distal third fractures. This may be due to the narrowing of the interosseous gap at the fracture site. In fractures uniting with dorsal angulation alone this narrowing does not occur, which may account for the relatively smaller loss of rotation. The hypothesis that maintenance of the interosseous gap is important in preserving rotation is supported by the five cases in which abnormal ulnar deviation of the radius occurred. None of these had any notable loss of rotation.

It would appear that it is important to maintain the interosseous gap during the treatment of these fractures and that radial deviation of the radius is more important than dorsal angulation.

REFERENCES


