LEG LENGTH DISCREPANCY AFTER FEMORAL SHAFT FRACTURES IN CHILDREN

REVIEW AFTER SKELETAL MATURITY

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We reviewed and radiographed 30 skeletally-mature patients after isolated closed femoral shaft fractures in childhood which had been treated conservatively. When the fracture had occurred between the ages of 7 and 13 years, the limb overgrew about 1 cm regardless of sex, upper limb dominance, age, fracture site or configuration. Excessive fracture overlap at the time of injury, but not at union, increased limb overgrowth. Angulation of the fracture remodelled in children injured under 10 years of age, but in older patients this sometimes added to limb shortening. Rotational deformities were minor and gave no symptoms.

Treatment of the 7- to 13-year-old patient should aim at 1 cm overlap at union, with correction of angular deformity being more important in children over 10 years of age. This management of fractures will give a maximum leg length discrepancy of 1 cm at skeletal maturity.

Leg length discrepancy is the most frequent complication of the treatment of femoral shaft fractures in childhood. This is due to longitudinal overgrowth, thought to be due to increased vascularity associated with healing rather than to a compensatory mechanism (Reynolds 1981). Cerebral dominance may have a minor influence (Meals 1979).

Anatomical reduction with internal fixation leads to limb overgrowth (Barfod and Christensen 1959) and therefore is indicated only when the fracture occurs in a short limb or in a patient with multiple injuries (Ziv and Rang 1983). If the orthopaedic surgeon can predict subsequent overgrowth it may be possible to allow appropriate overriding of the bone ends before union. Various authors recommend differing amounts of overlap: 3 cm (Neer and Cadman 1957), 2 cm (Barfod and Christensen 1959; Bathfield, Versfeld and Schepers 1979), 1.5 to 2 cm (Edvardsen and Syversen 1976), 1.5 cm (Shapiro 1981) and 1 to 1.5 cm (Griffin and Green 1972). This broad range can be explained by variation in the

method of assessing limb length and by differing periods of follow-up.

Clinical measurement has been shown to be accurate only to the nearest 5 to 10 mm (Greville and Ivins 1957) and follow-up has usually been for a minimum of two years, which did not allow for assessment at skeletal maturity. Only Shapiro (1981) has reported radiological measurements at skeletal maturity. Although most overgrowth occurs in the first 18 months after fracture (Bathfield et al 1979; Reynolds 1981), 25% may take place in the second 18 months (Bathfield et al 1979), and increase in length continues until skeletal maturity (Shapiro 1981). In some cases this may allow final equalisation of leg length (Irani, Nicholson and Chung 1976; Reynolds 1981). Other factors such as age at the time of injury and the site and configuration of the fracture, may influence overgrowth.

We report the clinical and radiological findings in 30 skeletally-mature adults who had sustained femoral fractures in childhood.

MATERIALS AND METHODS

Of 267 children admitted for treatment of a femoral shaft fracture between 1969 and 1983, 172 could not be traced, because of the difficulty of long follow-up in a particularly mobile population. Of the remainder, 53 had incomplete records or radiographs, and 12 were excluded because they had sustained other leg fractures, or the fracture was pathological.

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Thirty patients between the ages of 16 and 28 (mean 20 years), were studied in detail from complete clinical records and radiographs taken immediately after injury, in traction and at union. All had been discharged from follow-up for many years.

All 30 were interviewed and examined (by MMS) for upper limb dominance, symptoms, sporting activities, clinical deformity and leg length discrepancy. Anteroposterior and lateral radiographs of the femur were taken and scanograms (Tupman 1962) made with a radiopaque ruler marked in 1 mm increments. The initial radiographs were measured for the amount of overriding of the fracture ends before traction, taken as the mean of that on anteroposterior and lateral radiographs. The same measurements were made at union. Bowing greater than 10° in either plane was recorded at union and at final review.

Leg length discrepancy was measured clinically and on the scanograms from the head of the femur to the tibial surface of the ankle, a negative measurement indicating that the fractured limb was short. The lengths of the femur and tibia were also recorded, using the medial femoral condyle as the central landmark. This allowed us to determine the actual amount of overgrowth of the leg and femur in each case, by adding the amount of overriding at union to the leg or femoral length difference after skeletal maturity. The results were subjected to statistical analysis.

RESULTS

The mean age at fracture of the 30 patients was 10.7 years (range 7 to 15 years) and all showed right-sided dominance. Only five fractures were in girls, all in a similar age range. Seventeen fractures were left-sided. The cause of injury was: traffic accidents (20) domestic

Fig. 1

Number of cases related to site in femur and age at time of fracture.

injury (6) and sport (4). The distribution of age and site is shown in Figure 1. Fifteen were transverse, 10 were short oblique, four were long spiral and one was a greenstick fracture. Minor comminution, was seen in four middle-third and three proximal-third fractures.

The average overlap of bone ends at presentation was 2 cm (range 0 to 4 cm). All were treated conservatively, 20 by skeletal and 10 by skin traction for an average of six weeks (range 2 to 12 weeks). In 19 cases, this was followed by a spica plaster or a cast brace for an

Fig. 2

Leg length discrepancy at skeletal maturity related to age at time of fracture. Each patient is marked to show the range of results.

Fig. 3

Mean limb overgrowth at maturity (as defined in the text) related to the age at fracture.

average of five weeks (range 4 to 8 weeks). The average overlap at union was 1 cm but this ranged from 0 to 3.5 cm. Eight fractures had united with bowing of 15° to 20° (mean 18°), three were anterior, two medial, two posterior and one with lateral bowing.

Review was at 4 to 18 years after fracture (mean 9 years). All femoral and tibial physes had closed. Eight patients complained of some leg weakness after strenuous exercise but seven of these were still playing contact sports. Three of these eight patients felt that their leg was short, and were indeed those with most shortening (1.5 to 2.6 cm). Two of them were also the only patients with significant residual bowing (15° anterior and 20° lateral). The other five patients with subjective weakness did not differ from the remainder of the series.

Six patients had rotational deformities, demonstrated by differing arcs of limb rotation at the hip on each side. Five had loss of lateral rotation (15° to 40°) and one, loss of medial rotation (10°).

Clinical leg length measurements correlated with radiological measurement ($p < 0.0005$) but only within ± 0.5 cm. The average radiological leg length difference was -0.15 cm (range -2.6 to $+1.3$ cm). Femoral length discrepancy averaged -0.3 cm (range -2.9 to $+1.3$ cm). The average tibial overgrowth was 0.18 cm (range -0.9 to $+0.9$ cm). After fracture at 7 to 13 years of age, limb overgrowth averaged 1.1 cm (range 0 to 2.4 cm), and in these tibial overgrowth accounted for only 20% of the total. However, this was significantly increased in those with greater femoral and limb overgrowth ($p < 0.05$). In children over 13 years of age, leg discrepancy was -1 cm to $+0.9$ cm (mean -0.2 cm).

The side, dominance, site, type, mechanism and treatment of the fracture or even the age at fracture did not significantly effect the ultimate length discrepancy at

skeletal maturity (Fig. 2). In the over 13 age group at fracture, shortening at union was not made up by subsequent changes.

The wide range of leg discrepancy was in part explained by variations of overriding at fracture union. However, when the limb overgrowth was examined with respect to age at fracture (Fig. 3), we again found no correlation, but in the younger patients there was a constant pattern: 1 cm overgrowth with a narrow range.

The amount of overriding of the fracture ends at presentation positively influenced both femoral and limb overgrowth at maturity ($p < 0.05$) and overriding at union ($p < 0.005$). It did not affect tibial growth. In contrast, greater overriding at union had no such influence but ultimately inversely affected leg length discrepancy ($p < 0.0005$) (Fig. 4).

Significant bowing of the femur at union was present in eight cases. If this occurred under 10 years of age it completely remodelled without leg length discrepancy (four cases). At 10 years or older, two bowed femurs remodelled but two remained unchanged, and all four had significant shortening (1.2 to 2.4 cm, mean 1.7) as there was no longitudinal overgrowth.

DISCUSSION

Overgrowth of the lower limb after a femoral fracture in childhood has been much discussed, especially with reference to the extent of overlap or overriding which should be allowed at union. Recommendations have varied from 3 cm (Neer and Cadman 1957) to 1 to 1.5 cm (Griffin and Green 1972). Our series, though small, is representative of other larger series (Griffin and Green 1972; Meals 1979; Reynolds 1981; Shapiro 1981), and was adequate to allow us to make statistically significant observations. Shapiro (1981) showed that overgrowth continues for up to four years after fracture and that 9% continue to overgrow until they are skeletally mature. Our follow-up was to skeletal maturity and used radiological measurement for accuracy.

We found that age at fracture did not influence limb overgrowth, confirming the findings of Edvardsen and Syversen (1976), Meals (1979), Reynolds (1981) and Shapiro (1981) but differing from Barford and Christensen (1959), Staheli (1967) and Bathfield et al (1979). Proximal-third femoral fractures have been reported to overgrow more (Barford and Christensen 1959; Staheli 1967), but like Bathfield et al (1979) and Shapiro (1981), we found that site and fracture configuration did not influence overgrowth. We could not confirm the observation of Meals (1981) that the fractured femur on the non-dominant upper limb side had greater growth. We found mean tibial overgrowth of 2 mm, or 20% of limb overgrowth; this increased with greater femoral overgrowth and therefore may not be a normal variation (Edvardsen and Syversen 1976).

Fractures in patients over 13 years of age did not

Fig. 4

Leg length discrepancy related to the overlap at the time of union; there is a highly significant correlation ($p < 0.0005$), and it is shown that 1.1 cm overlap at union will give a minimal length discrepancy at maturity.

overgrowth; overlap is not required at union. The initial overlap before traction was applied directly affected femoral and limb overgrowth, a new observation. More overlap at presentation involves more periosteal stripping; this may explain the increased overgrowth.

After fracture between the ages of 7 and 13 years, femoral fractures seem to have a relatively constant overgrowth of 1 cm regardless of age. This amount of overlap at union will therefore give less than 1 cm discrepancy at skeletal maturity and the patients will probably be asymptomatic, since in our series only the three patients with greater than 1.5 cm discrepancy complained that the leg felt short. Rotational deformities gave no problem; even if they were present they gave no symptoms (Brouwer, Molenaar and van Linge 1981). Angular deformities remodelled in children under 10 years of age at fracture, but if they are not recognised in older children they may contribute to apparent shortening which will not be compensated by overgrowth.

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