REMODELLING AFTER PINNING FOR SLIPPED CAPITAL FEMORAL EPIPHYSIS

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We assessed 70 hips at an average of 7.1 years after pinning for slipped upper femoral epiphysis to determine the frequency of remodelling, what factors influence it and its effect on the clinical outcome. Remodelling was defined by a new classification of the anterior femoral head-neck profile as seen on the lateral radiograph.

Remodelling occurred in 50% of hips with a head-shaft angle of 30° or more; the probability of remodelling was significantly less the greater the degree of slip, but was significantly increased if the triradiate cartilage was open at the time of presentation. We found no significant effect for age, sex, weight or length of symptoms. The range of internal rotation was significantly greater in those hips that remodelled.

We support the treatment of moderate slips in skeletally immature patients by pinning in situ, since the probability of satisfactory remodelling was 75% for slips of 40° or less.

There is still controversy as to the best method of management for different degrees of slip of the proximal capital femoral epiphysis. Fixation in situ is generally thought to produce satisfactory results in mild slips, in the absence of complications of surgery, but the choice of procedure for more severe displacements remains open. In the extensive literature, the results of different methods of treatment are usually related to the initial degree of slip. This ignores the effect which remodelling may have on the radiological outcome and the long-term clinical result.

The salient features of the remodelling process after slipping of the capital femoral epiphysis were first described by Key (1926) and subsequently confirmed and qualified by Forrester-Brown (1941), Jerre (1950), Billing and Severin (1959), O'Brien and Fahey (1977), Boyer, Mickelson and Ponseti (1981), and Moreau (1987). Lacroix and Verbrugge (1951) showed that remodelling occurred by osteoclastic resorption of the exposed femoral metaphysis. Clarke and Harrison (1986) propose a process of epiphyseal growth by which 'spontaneous recovery' may occur.

O'Brien and Fahey (1977) were the first to specifically study remodelling and, with Boyer et al (1981) and Moreau (1987), they related it to the severity of slip. There is, however, no clear definition of remodelling in the literature. O'Brien and Fahey noted 'excellent' remodelling in 83% of their moderate and severe cases and record that "... remodelling of the anterior portion..."
of the femoral neck often progressed to such an extent that the outline gradually became concave and the convexity initially seen with advanced slipping was no longer present". Boyer et al (1981) reported remodelling in half the cases of moderate slip and in three of their five cases with severe slip. Moreau (1987) merely stated that 68% of his moderate and severe cases showed definite signs of remodelling, but radiological details were not described.

O'Brien and Fahey (1977) stated that an open triradiate cartilage was associated with remodelling in nine of their 10 cases and Billing and Severin (1959) considered continued growth of the femoral neck to be important.

We have assessed the extent of remodelling and related it to the radiological and clinical outcome at follow-up. An analysis of the factors which may influence the extent of the remodelling process has also been undertaken.

METHODS

Measurement of slip. The lateral head–shaft angle, as modified by Southwick (1967) (Fig. 1), was measured specifically to allow comparison with the existing literature. Recently, Cohen et al (1986) have cast doubt on the validity of this measurement. They demonstrated great variability of the angle when it was compared with the percentage of epiphyseal displacement and with the head–neck angle calculated by computerised tomography. We also measured the percentage slip and the head–neck angle by the method of Hansson, Hägglund and Ordeberg (1987, 1988) (Fig. 2) for comparison with the method of Southwick in 1967.

Radiographs. At review, standard anteroposterior and Lauenstein lateral radiographs were taken. Serial radiographs were examined to determine the time when remodelling occurred. The timing of triradiate cartilage closure, defined as disappearance of the epiphyseal plate on the radiograph, was recorded (Acheson 1957). In many cases the triradiate cartilage was fused at the time of presentation. The time of proximal capital femoral physeal closure was also noted, defined as radiographic absence of that physis throughout its length.

Definition and assessment of remodelling. Billing and Severin (1959) and Griffith (1976) stated that the direction of slip of the femoral head is directly posterior. These authors and Jerre (1950) all commented on the dramatic way in which rotation can affect the appearances of an anteroposterior radiograph. Because of the inaccuracies introduced by rotation, into anteroposterior radiographs, we have assessed remodelling on the lateral radiographs alone.

We classified the profile of the anterior head and neck into three types (Fig. 3). Type A has a normal configuration, with the convexity of the anterior margin of the femoral head running into a concavity which is the anterior border of the neck. The outline of the femoral head lies anterior to that of the neck. In type B the anterior outline of the head and neck appears as a straight line and the anterior margin of the femoral head and neck are at the same level. In type C the profile is convex, the anterior margin of the femoral head is posterior to the anterior margin of the neck and there is a prominence in the mid region of the neck.

Those hips in which there was no metaphyseal prominence on the anterior aspect of the femoral neck (types A and B) were defined as being completely remodelled; type C represented failure of remodelling.

Statistical analysis was performed by the statistical services section of the Australian Bureau of Statistics (Adelaide) using Statistical Analysis System (SAS). The data was analysed using a range of statistical techniques including correlations, the t-test, the chi-square test, analysis of co-variance and logistic regression.

PATIENTS

Between 1971 and 1986, 110 patients were treated at the Adelaide Children's Hospital for slipped capital femoral epiphysis. Of these, 75 attended for review but six were excluded from further analysis because of inadequate radiographs. A total of 69 patients with 88 affected hips remained; 18 were excluded for the following reasons: no initial displacement (10); avascular necrosis (3); chondrolysis (2); early osteotomy (1). The seven hips in which avascular necrosis and chondrolysis occurred were all acute slips. Full radiographic measurements were therefore undertaken in 70 hips. There were 33 males and 28 females giving a male to female ratio of 1.2:1.
The mean follow-up was 7.1 years with a range from 2 to 17 years. A detailed history and clinical examination was undertaken in all patients together with calculation of the Iowa hip score (Larson 1963).

Nine hips, all with moderate to severe acute slips, had received treatment prior to pinning. Four had been treated in traction with improvement of the position in one; five had been 'gently' manipulated under anaesthesia with an improvement of the position in two. These cases were included in our analysis as they were free of complications.

**RESULTS**

**Method of measurement of slip.** The method of Hansson et al (1988) was found to be satisfactory, but measurements could not be made in 13% of cases as the calcar femorale was too indistinct. Pearson's correlation coefficient for head–shaft angle to percentage slip was 0.86, and for head–shaft angle to head–neck angle 0.88. The correlation between head–neck angle and percentage slip was 0.90.

In view of this close correlation, the head–shaft angle (Fig. 1, Southwick 1967) was used in the analysis of results, allowing comparison with previously published work. Cases were grouped according to the same classification, namely: mild 0° to 29°, moderate 30° to 60° and severe greater than 60°. There were 34 mild, 35 moderate and one severe slip. As there was only one hip in the severe group, it was included with the moderate cases throughout the statistical analysis.

**Remodelling and degree of slip.** Remodelling occurred in 90% of mild slips and in 50% of the moderate and severe slips. Remodelling was dependent on the degree of slip, there being a significantly higher probability of remo-

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**Table 1. Remodelling in moderate slips**

<table>
<thead>
<tr>
<th>Slips in degrees</th>
<th>Mean</th>
<th>s.d.</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remodelled</td>
<td>35.5</td>
<td>4.9</td>
<td>30 to 46</td>
</tr>
<tr>
<td>Not remodelled</td>
<td>42.2</td>
<td>8.8</td>
<td>30 to 62</td>
</tr>
</tbody>
</table>

\[ T = 2.77, \text{d.f.} = 26.5, p < 0.01 \]
modelling in mild slips \((p < 0.0001)\). Among the moderate cases, the mean degree of slip in hips that remodelled was significantly less than in those that failed to remodel \((p < 0.01, \text{Table I})\). No hip with a head–shaft angle greater than 46° remodelled.

**Remodelling and triradiate cartilage status.** Remodelling was significantly more likely to occur if the triradiate cartilage was open at presentation; this applied both to the whole series of patients \((p < 0.003)\) and when the moderate slips alone were considered \((p < 0.01, \text{Table II})\). In this latter group, the triradiate cartilage was found to be open at presentation in 50% of hips that remodelled, but in only 11% of those that failed to remodel (Figs 4 and 5).

**Logistic regression model.** This analysis was used to examine in more detail all the factors that might have an influence on the occurrence of remodelling.

**Degree of slip and triradiate cartilage status.** The probability of remodelling was found to be greatest for a mild slip with an open triradiate cartilage and least for a moderate slip with a fused cartilage (Model 1, see below). The probability of remodelling for a given degree of slip depending on whether the triradiate cartilage was open or closed was also calculated (Model 2, see below). This model demonstrated that in slips with a head–shaft angle greater than 20°, the probability of remodelling was very considerably reduced if the triradiate cartilage was fused at presentation (Fig. 6, Table III).

**Other factors.** Age, length of symptoms, sex, side and weight had no significance in relation to the likelihood of remodelling. Although not significant, the mean age at presentation of patients with moderate slips that remodelled was less than the mean age of those that failed to remodel.

**Statistical models**

**Model 1.** Head–shaft angle categorical \((H/S; 0 = \text{mild slip}, 1 = \text{moderate slip})\): \(\Theta\) = probability of not remodelling, \(1 - \Theta\) = probability of remodelling; \(T\), triradiate status, \(0 = \text{not fused}, 1 = \text{fused}\).

\[
\log \left( \frac{\Theta}{1 - \Theta} \right) = 3.65076 + 2.00874 T + 2.1155 H/S
\]

**Model 2.** Head–shaft angle continuous \((H/S = 0\) to 90°).

\[
\log \left( \frac{\Theta}{1 - \Theta} \right) = -6.10944 + 1.75102 T + 0.125135 H/S
\]

**Timing of remodelling.** In those cases that progressed to complete remodelling the process was always complete by the time of femoral physeal fusion. Even in those hips which failed to remodel completely (type C) partial remodelling was always seen. These changes were most apparent during the first six weeks after an acute slip during which time the anterior metaphyseal prominence was usually rounded off proximally and diminished in size.

**Capital femoral physeal fusion.** Accurate timing of the closure of the femoral physis was made difficult by the infrequency of radiographs taken during the later stages of follow-up. However, an estimate was made which showed that the average time from presentation to fusion was 12 months. In the group with moderate slips, closure occurred at an average of nine months from presentation.
in those hips that failed to remodel, and at 16 months from presentation in those that remodelled.

**Clinical outcome.** All patients had a good or excellent clinical outcome with Iowa hip scores in excess of 90 points. One patient had an external rotation deformity in extension of 10° and seven patients had 5° to 15° external rotation deformity in flexion. These residual deformities were not considered a handicap by any of the patients.

The range of internal rotation in extension was reduced by an average 9° (30%) in those hips that remodelled and by 19° (72%) in those that failed to remodel (p < 0.0001).

**DISCUSSION**

A new radiological classification of the outcome following slipping of the capital femoral epiphysis has been proposed, based on the Lauenstein lateral radiograph, and remodelling has been defined in terms of this classification. Remodelling occurred in 50% of cases with a head–shaft angle of 30° or more, a result which broadly agrees with the findings of Boyer et al (1981). The incidence of remodelling was much less than that found by O'Brien and Fahey (1977). This may be because a more specific definition of remodelling has been used. The incidence of remodelling will also depend upon the severity of slip in the group studied.

We have shown that the likelihood of remodelling is inversely related to the severity of slip at presentation. It is also significantly increased, as O'Brien and Fahey (1977) showed, if the triradiate cartilage is open at the time of presentation.

The age of the patients at presentation did not significantly affect the chances of remodelling, although there was a trend suggesting that the younger the patient at presentation, the more likely remodelling was to occur. An open triradiate cartilage may simply indicate a greater general potential for remodelling due to skeletal immaturity, and may be directly related to closure of the proximal capital femoral physis itself (Acheson 1957).

This study confirms the opinion of Billing and Severin (1959) that resorption of the anterior metaphyseal prominence occurs rapidly. Partial remodelling occurred in all our cases, and Billing and Severin (1959) are the only authors to have reported a case in which this failed to occur. O'Brien and Fahey (1977) implied that remodelling continued after proximal capital physis fusion. In our cases, remodelling virtually ceased at the time of physisal closure although a little further resorption did occur subsequently in the vicinity of the physis. In only one case did the final radiological grade change following fusion. These findings suggest that continued growth at the physis is important in the remodelling process, possibly related to diametrical physal growth (Clarke and Harrison 1986).

The radiological classification used in this study will enable comparison to be made between those patients that remodel and those that do not, and will allow the effect of remodelling on the long-term clinical outcome to be assessed.

This study reaffirms the importance of early clinical diagnosis and treatment, for the final radiological outcome was directly related to the degree of slip at presentation. In patients with moderate slip and an open triradiate cartilage we recommend pinning in situ. The aim of surgical treatment should be the prevention of further slipping while allowing continued growth and remodelling to take place. This philosophy contradicts the majority of methods of fixation in current use which are aimed at promoting epiphysal fusion. The 'hook pin' described by Hansson (1982) is a device which has been shown in practice to allow growth to continue (Hagglund et al 1988) and it will be of considerable interest to see whether this method of fixation increases the likelihood of remodelling.

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REFERENCES


