OPEN REDUCTION OR EPIPHYSIODESIS
FOR SLIPPED UPPER FEMORAL EPiphySIS

A COMPARISON OF DUNN'S OPERATION AND THE HEYMAN–HERNDON PROCEDURE

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Forty-eight consecutive patients (53 hips) were treated for moderate or severe slips of the upper femoral epiphysis between 1974 and 1984; 46 patients (96%) returned for clinical and radiological assessment at a mean of five years after operation. Twenty-three patients (23 hips) underwent a Dunn's open reduction and 25 patients (30 hips) were treated by epiphysiodesis and surgical osteoplasty as advocated by Heyman and Herndon. The results of the two methods of treatment are compared.

Analysis revealed that 11 hips with moderate slip (30° to 50°) treated by the Heyman–Herndon procedure did significantly better than the 18 hips with severe slip (>50°) treated by the same method. Furthermore, when these hips with severe slip were compared to the hips treated by Dunn's open reduction, all of which were displaced greater than 50°, the latter fared significantly better. The authors conclude that the Heyman–Herndon procedure gave consistently good results for moderate slips, but Dunn's open reduction gave better results for hips with severe slips.

The treatment of advanced slipping of the upper femoral epiphysis remains an unsolved problem despite the fact that it was first described by Paré some 400 years ago (Paré 1572). Most orthopaedic surgeons agree that stabilisation of the epiphysis is required to prevent further displacement.

Wilson (1938) stated that a slip of up to one-third of the metaphyseal diameter is "acceptable" and fixation in situ is all that is needed, a view supported by Newman (1960) and Boyer, Mickelson and Ponseti (1981). Considerable debate still surrounds the treatment of patients with "unacceptable" slip.

Remodelling of the femoral neck has been described (Key 1926; Howorth 1949), and O'Brien and Fahey (1977) recommended that a slip of less than 60° should be treated by pinning in situ. This method of treatment is often technically difficult and associated with a long list of complications (Weiner et al. 1984).

Ferguson and Howorth (1931), and later Heyman (1949), suggested that solid bony fusion across the growth plate was the only certain way of preventing further displacement, and they recommended bone-graft epiphysiodesis. The uncovered metaphyseal hump, which is the primary block to flexion, medial rotation and abduction, may be trimmed (surgical osteoplasty). This procedure produces an immediate improvement in the range of movement, but does not restore normal anatomy (Heyman, Herndon and Strong 1957; Herndon, Heyman and Bell 1963).

Many authors have predicted that with the residual tilt of the capital epiphysis, the resulting biomechanical disturbance may lead to early degenerative changes (Wilson 1938; Howorth 1949; Jerre 1950; Murray 1965; Southwick 1967; Solomon 1976; Dunn and Angel 1978; Fish 1984). Murray (1965) identified a group of predominantly male patients with osteoarthritic hips in whom a tilt deformity of the femoral head was present, and suggested that this may represent the late sequel of an unrecognised slip of the upper femoral epiphysis in adolescence.

To avoid this complication numerous methods of realignment have been reported. Compere (1950), in describing the operative technique of open reduction, drew attention to the important leash of posterior retinacular vessels, which must be protected if aseptic necrosis is to be avoided. Dunn (1964) emphasised the need to shorten the femoral neck and thereby prevent tension on the posterior vessels when the epiphysis is reduced; attention to detail is important; to reduce...
avascular necrosis to a minimum, open reduction should be avoided when patients have acute on chronic slips, or the growth plate is already closed (Dunn and Angel 1978; Fish 1984). Others have recommended extracapsular realignment osteotomies (Southwick 1967; Kramer, Craig and Noel 1976). These create a deformity equal and opposite to that caused by the original disorder, and may make subsequent reconstructive procedures difficult (Rao, Francis and Siwek 1984).

We present a comparison of two groups of patients with moderate or severe slip treated either by open reduction as described by Dunn (1964) or by epiphysiodesis and surgical osteoplasty as advocated by Heyman, Herndon and Strong (1957). The clinical and radiological results of treatment of these cases of advanced slip are compared.

**MATERIALS AND METHOD**

Forty-eight consecutive patients (53 hips), treated for moderate or severe slip of the upper femoral epiphysis, form the basis of this retrospective review. All patients were referred for primary treatment at one of the Nottingham group of hospitals or at Harlow Wood Orthopaedic Hospital between 1974 and 1984. The average time from onset of symptoms to diagnosis was 15.5 weeks. The left hip was involved in 25 cases and the right in 11. Twelve patients (25%) sustained bilateral displacement, making a total of 60 hips. Of these, seven hips were considered to have mild slip and are therefore excluded from further consideration.

The severity of slip was determined by the degree of displacement as measured on the frog lateral radiograph; from this the head–neck angle was calculated (Fig. 1); occasionally, because of pain, a modified cross-table lateral radiograph was used instead. Where significant remodelling had occurred the outline of the femoral neck on the radiograph of the unaffected hip was drawn on tracing paper, reversed and superimposed on the affected side to give the original line of the neck.

In a mild slip the head was displaced posteriorly less than 30°, in a moderate slip between 30° and 50°, and in a severe slip more than 50°.

There were two major methods of treatment.

**Open reduction.** Twenty-three patients (23 hips) underwent Dunn’s open reduction (Dunn 1964). Each had a severe slip of the upper femoral epiphysis. There were 13 boys and 10 girls; the mean age was 13 years (range 8 to 16.25 years). Twenty-two patients (22 hips) presented for review at a mean of 5.3 years after operation (range 2 to 10.5 years). One girl could not be located but had had a viable femoral head with good function three years after treatment.

**Heyman–Herndon procedure.** Twenty-five patients (30 hips) were treated by epiphysiodesis and surgical osteoplasty of the femoral metaphysis (Heyman et al. 1957).

**Moderate slip.** Ten of these patients (12 hips) were regarded as having a moderate slip. There were 6 boys and 4 girls. The mean age was 12.9 years (range 11.6 to 14 years). One patient failed to attend for review and had been lost to follow-up since three months after operation. The remaining nine patients (11 hips) were reviewed, a mean of 3.7 years after operation (range 1.5 to 7 years).

**Severe slip.** Seventeen patients in this group (18 hips) had a severe displacement of the upper femoral epiphysis; two of these patients had a moderate slip in the other hip. There were 10 boys and 7 girls. The mean age was 14 years (range 10.4 to 17.3 years). All patients were reviewed at a mean of 4.3 years after operation (range 1.5 to 9.7 years).

We considered that a patient had an acute slip if there was sudden onset of severe pain in the hip less than three weeks prior to diagnosis, without any previous symptoms or any radiological signs of remodelling. In chronic slips, the symptoms were usually milder, present.

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**Fig. 1**

Severity of slip as measured on the frog lateral radiographs.

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Method of calculating femoral head ratio (FHR) by the technique of Murray and Duncan (1971). Figure 2 – Patient with severe medial tilt after epiphysiodesis and osteoplasty; FHR = 4.3/1.2 = 3.41. Figure 3 – Patient treated by Dunn’s open reduction with no residual tilt; FHR = 2.5/2.3 = 1.1

Table I. Distribution of the types of slip

<table>
<thead>
<tr>
<th>Type of slip</th>
<th>Dunn’s open reduction (n = 23)</th>
<th>Heyman-Herndon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Severe (n = 18)</td>
<td>Moderate (n = 12)</td>
</tr>
<tr>
<td>Acute</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Chronic</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Acute on chronic</td>
<td>16</td>
<td>10</td>
</tr>
</tbody>
</table>

* All had severe slip

for longer than three weeks and associated with radiological evidence of remodelling of the femoral neck. In some cases an acute slip was superimposed on a chronic one. The distribution of the type of slip is shown in Table I.

Assessment at review

The patients were evaluated subjectively and clinically by one of the authors (EPS). Subjective evaluation consisted of visual analogues to assess pain and function, and hip mobility was assessed by clinical examination using a goniometer. Radiographic assessment consisted of standard anteroposterior and frog lateral radiographs of both hips. The films were assessed by one of the authors (DAC) without any prior knowledge of the clinical outcome. A modification of Hall’s (1957) and Southwick’s (1967) criteria were used to evaluate the results (Table II). The overall result for each patient was determined by the worst grading in any one of the three assessment categories.

The width of the joint space was measured directly from the anteroposterior radiographs using a Perspex template marked with concentric circles 2 mm apart.

The range of movement in the affected hip was compared with that of the opposite normal hip. For patients with bilateral disease the normal range of movements were taken as: flexion 120°, extension 20°, abduction 45°, adduction 30°, medial and lateral rotation in extension 40° each (Southwick 1967).

Tilt ratio. Residual varus was assessed on the anteroposterior radiographs at follow up using the method suggested by Murray and Duncan (1971) and recorded as the femoral head ratio (Figs 2 and 3). The normal value was taken to lie between 0.9 and 1.35. Hips with fixed lateral rotation or collapsed femoral heads were excluded from assessment of this ratio because of inaccuracies in measurement.

Table II. Modification of Hall’s and Southwick’s methods of assessment

<table>
<thead>
<tr>
<th>Grade</th>
<th>Subjective</th>
<th>Mobility</th>
<th>Radiographic assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>No pain or limp</td>
<td>&gt;90°, normal</td>
<td>Round head, with congruent surfaces and normal joint space</td>
</tr>
<tr>
<td></td>
<td>Full activity</td>
<td>&lt;20° deficit in any single plane</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>Slight pain on exertion</td>
<td>75°–90°, normal</td>
<td>No incongruity or joint space narrowing</td>
</tr>
<tr>
<td></td>
<td>Trace of limp</td>
<td>&lt;40° deficit in any single plane</td>
<td>No cysts</td>
</tr>
<tr>
<td></td>
<td>Full activity</td>
<td></td>
<td>Slight hump</td>
</tr>
<tr>
<td>Fair</td>
<td>Moderate pain on exertion</td>
<td>50°–75°, normal</td>
<td>Slight incongruity or joint space narrowing</td>
</tr>
<tr>
<td></td>
<td>Function restricted</td>
<td>&lt;60° deficit in any single plane</td>
<td>Mild degenerative change but viable head</td>
</tr>
<tr>
<td></td>
<td>Definite limp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>Constant pain</td>
<td>&lt;50°, normal</td>
<td>Severe incongruity or joint space narrowing</td>
</tr>
<tr>
<td></td>
<td>Severely restricted activity</td>
<td>&gt;60° deficit in any single plane</td>
<td>Marked degenerative disease or avascular necrosis</td>
</tr>
</tbody>
</table>

Fig. 2

Fig. 3

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Complications. Avascular necrosis was diagnosed when there was radiological evidence of sclerosis, fragmentation or collapse of the femoral head. Chondrolysis was defined as radiological narrowing of the joint space by a minimum of 50%, within six months of the operation, associated with pain and stiffness. Osteoarthritis was recognised by delayed narrowing of the joint space, formation of osteophytes or development of subchondral cysts.

Statistical analysis consisted of chi-square tests with Yates correction, Fisher's exact test and the Mann-Whitney U-test for "between group" analysis.

RESULTS

Dunn's open reduction. The results of the 22 patients who presented for review are given in Table III.

Seventeen patients (77.3%) were rated excellent or good, one patient (4.5%) fair and four (18.2%) poor. All epiphyses united within 12 weeks and the total time spent in hospital, including the period for implant removal, averaged 6.5 weeks. Leg-length discrepancy ranged from 0 to 3 cm, with a mean of 1.2 cm, and no patient required a shoe raise.

The complications are listed in Table IV. The poor results were due to segmental avascular necrosis in three patients and whole-head avascular necrosis in one; all four had had acute on chronic slips. Two of the patients with segmental necrosis were virtually asymptomatic with a surprisingly good range of movement. Nevertheless, the collapse of the femoral heads and subsequent joint incongruity (Figs 4 and 5) was thought to preclude a good long-term result.

There were no cases of chondrolysis. Two superficial wound infections were noted and both settled on antibiotic therapy. Two patients had a mild residual varus tilt deformity (10%), but the tilt ratio could not be measured accurately in two other patients with avascular necrosis. Varying degrees of osteoarthritis were noted in five hips (23%).

Problems relating to the metal implants were noted on 10 occasions. This ranged from penetration of the joint surface by one or more of the fixation pins in four patients to lateral pin discomfort in a further four patients. In one case the pins loosened and backed out and for this reason threaded pins are now preferred. Inability to remove one of the implants occurred on one occasion.

Heyman-Herndon procedure. Moderate slip. The results of the nine patients (11 hips) are shown in Table III. All

<table>
<thead>
<tr>
<th>Table III. Results from the two procedures (51 hips)</th>
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<tr>
<td>Grade</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Excellent</td>
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<tr>
<td>Good</td>
</tr>
<tr>
<td>Fair</td>
</tr>
<tr>
<td>Poor</td>
</tr>
<tr>
<td>Total</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Table IV. Complications from the two procedures</th>
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<tbody>
<tr>
<td>Complications</td>
</tr>
<tr>
<td>Avascular necrosis</td>
</tr>
<tr>
<td>Chondrolysis</td>
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<tr>
<td>Wound sepsis</td>
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<tr>
<td>Implant problems</td>
</tr>
<tr>
<td>Graft failure</td>
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<tr>
<td>Osteoarthritis</td>
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</tbody>
</table>

Fig. 4
Fig. 5
Segmental necrosis after Dunn's open reduction. Figure 4 - Anteroposterior view. Figure 5 - Frog lateral radiograph.
of the 11 hips with a moderate slip had an excellent or good result. Apart from one superficial wound infection, there were no serious complications. Residual varus, as measured by the femoral head ratio, was observed in four hips (36%).

Severe slip. The results of the 17 patients (18 hips) are shown in Table III. Six hips (33%) were rated excellent or good, eight (45%) fair and four (22%) were poor.

The average time for fusion was 10 weeks whilst the average time spent in hospital was eight weeks. Leg-length discrepancy ranged from 0 to 4.5 cm with a mean of 2.1 cm; no patient accepted a shoe raise.

Complications are listed in Table IV. Two girls developed segmental avascular necrosis. One, a 10-year-old with Down’s syndrome, had an acute slip. The other, with an acute on chronic slip, required a second procedure when the initial epiphysiodesis failed and she subsequently developed segmental necrosis. The other poor results were due to two cases of chondrolysis, both of whom had acute on chronic slips; neither had made any significant recovery when reviewed two years and 18 months respectively after operation. A further case of cartilage necrosis was noted in a boy who had sustained a severe acute on chronic slip seven years previously; a moderate recovery in joint space occurred but mild degenerative changes were noted at the time of review.

Two superficial infections occurred, both of which settled with wound toilet and antibiotics. There was no evidence of further displacement after operation, although there was one case of failure of incorporation of the graft. Varying degrees of osteoarthritis were seen in seven cases (39%). Residual varus was observed in 14 hips (88% of the 16 hips measured), but the tilt ratio could not be measured accurately in two patients, one of whom had segmental avascular necrosis, the other having a fixed lateral rotation deformity.

Analysis of results
The hips with severe slip that had undergone open reduction fared significantly better than those treated by the Heyman–Herndon procedure (p < 0.02), but no better than the hips with only a moderate slip (p = 0.22) (Fig. 6). Furthermore, the hips with a moderate slip treated by epiphysiodesis and surgical osteoplasty did much better than the severe slips treated by the same procedure (p < 0.001).

Residual varus was found in 88% of hips with severe slip but only 36% of those with moderate displacement (p < 0.01); after open reduction only 10% of the hips were varus (p < 0.001).

DISCUSSION
It is widely accepted that for a mild slip of less than 30° pinning in situ or epiphysiodesis will give excellent results in the majority of cases. However, the successful treatment of moderate and severe slips remains the subject of debate.

We confirm the findings of Heyman et al. (1957) and Melby, Hoyt and Weiner (1980) that epiphysiodesis causes reliable obliteration of the growth plate and avoids the troublesome complications of pins. We also agree that surgical removal of the prominent metaphyseal hump leads to a greatly improved range of movement. Although remodelling of this bony prominence has been reported by O’Brien and Fahey (1977) in 10 out of 12 patients with slips ranging from 30° to 60°, Boyer et al. (1981) reported that remodelling occurred in only 50% of their cases. Nature is unpredictable and we advocate removal of this prominence at the same time as epiphysiodesis if it is causing a significant block to movement. In our series, all hips that had sustained a moderate slip had an excellent or good result, with no
failure of fusion or significant complication, when treated by this method. We conclude that a realignment procedure probably is not necessary for a slip of less than 50°.

Unfortunately, the same cannot be said for a severe slip. In our study 18 such hips treated by epiphysodesis and osteoplasty did significantly worse than the moderate group. When dealing with a severe slip, as much as 50% of the width of the femoral neck must be removed in order to excise the bony prominence completely. This will reduce considerably the surface area of bone through which a bone peg can be inserted and may also compromise the strength of the femoral neck, leading to a risk of fracture. We recommend a realignment procedure in such cases.

Extracapsular osteotomies such as Southwick’s (1967), or wedge osteotomy at the base of the femoral neck (Kramer et al. 1976), only give a maximum correction of 60° and 50° respectively and therefore would not fully correct the majority of these severe slips. Although claiming to reduce the incidence of avascular necrosis, Southwick reported only chronic slips, with the majority of displacements measuring between 30° and 60°.

Despite earlier reports emphasising avascular necrosis following open reduction (Wilson, Jacobs and Schecter 1965), more recently Dunn and Angel (1978) and Fish (1984) have shown that, in chronic slips with the growth plate open, open reduction is associated with only a small risk of avascular necrosis. This operation requires great attention to detail, meticulous preservation of the posterior retinacular vessels, with shortening of the femoral neck sufficient to relax any tension in these structures when the epiphysis is reduced.

The incidence of avascular necrosis following Dunn’s procedure in our series was 18%. All the hips affected had severe, acute on chronic slip. Despite this, the results were significantly better in terms of hip function and restoration of normal anatomy than those treated by the more conservative Heyman–Herndon procedure. Realignment at the level of the physis is the only method that can achieve complete correction in patients with a severe slip and does not prejudice future reconstructive surgery (Rao et al. 1984). Although the potential benefit of satisfactory open reduction on late degenerative changes has not been proved, Boyer et al. (1981) have shown that the long-term prognosis for mild slips pinned in situ is excellent both in terms of function and radiological assessment. It is hoped that, in addition to producing better short-term results, restoration of the normal alignment will decrease the incidence of late osteoarthrosis.

We should like to express our gratitude to Mr G. W. Baker, Mr H. McKim Thomas, Mr A. Moulton and Mrs R. C. Mulholland for allowing us to examine their patients. We should also like to thank Mrs Pamela Tsuka for her patient secretarial assistance, Mrs T. Hewitt and Mrs D. Beesley for seeking out the patients and Mr Geoff Lythe, for the illustrations.

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