We reviewed 98 children (133 hips) with developmental dysplasia of the hip who underwent arthrography immediately after closed reduction by overhead traction. We followed the patients to skeletal maturity to investigate whether soft-tissue interposition influences acetabular development and avascular necrosis over the long term.

The shape of the limbus and the thickness of the soft-tissue interposition at the acetabular floor, as shown on arthrograms at the time of reduction, were not directly related to the final radiological results or to the incidence of avascular necrosis. Even if marked soft-tissue interposition was found on the initial arthrogram, spontaneous disappearance was noted in 71% up to the age of five years. The final radiological results showed no difference between those in which the interposition disappeared and those with none at the time of closed reduction. However, the requirement for secondary surgery at the age of five years was significantly higher in those with more than 3.5 mm of soft-tissue interposition. In the no-disappearance group (group C) further operation was necessary in 100% and the results were significantly worse at maturity according to Severin’s classification.

We suggest that the indications for open reduction should not be based solely on the arthrographic findings at the time of closed reduction.

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The management of soft-tissue interposition in developmental dysplasia of the hip (DDH) remains controversial. Many authors1–4 have recommended open reduction for the hip which still lies lateral after closed reduction to allow concentric reduction and to avoid pressure-induced avascular necrosis. Severin5 reported that excision was unnecessary since serial arthrograms demonstrated remodelling of the inverted limbus and no adverse effect was observed on acetabular development. Staheli, Dion and Tuell6 supported this view.

Our aim was to investigate the long-term influence of interposed soft tissue on acetabular development and avascular necrosis at the age of skeletal maturity.

Patients and Methods

Since 1964 we have used the Pavlik harness to treat DDH in children aged from three to six months and overhead traction (OHT) in those over six months or with hips which were irreducible in the harness. Between 1964 and 1982, we used OHT to treat 312 hips (238 patients). In 39, closed reduction had failed to retain the hip in the reduced position. They required open reduction and were therefore excluded from the series. A total of 273 hips (217 patients) was satisfactorily reduced, and arthrography was performed immediately after reduction. We excluded 119 patients (140 hips) since they were less than 14 years old at the time of review. We were able to assess 98 patients (133 hips) who had been followed to skeletal maturity (over 14 years of age). All hips had been completely dislocated before OHT. Teratological, paralytic, or septic dislocations were excluded. There were eight boys and 90 girls with a mean age at the time of the reduction of 12 months (3 to 42). The mean age at the time of final follow-up was 18.3 years (14 to 32). The mean duration of follow-up was 17.2 years (13 to 30).

The OHT method which we used differs from that reported by Mau.7 Before OHT, we used horizontal traction for about three weeks. Both legs were then pulled upwards and in a slightly axillary direction. Abduction was increased daily so that nearly full abduction was achieved within two weeks. Immediately after reduction, anteroposterior arthrograms of the hip were taken under general anaesthesia. A hip spica cast was applied with the hips in 100° flexion and 60° to 80° abduction, depending on the position of maximal stability, for one month. This was followed by the use of a positioning brace for three to six months.
The criteria for secondary surgery, usually at the age of five or six years, was an acetabular index of 30° or more or a centre-edge (CE) angle of 5° or less. A Salter-type innominate osteotomy was carried out for persistent acetabular dysplasia, femoral osteotomy for persistent subluxation, and both operations for persistent subluxation with acetabular dysplasia.

**Arthrographic examination.** The arthrograms were classified into four types immediately after closed reduction depending on images taken in full abduction in 90° flexion and lateral rotation, as shown in Figures 1a and 1b. As an indicator of the thickness of the soft-tissue interposition at the acetabular floor, we measured the distance T (Fig. 2), which was considered to include not only the thickness of the cartilage, but also that of the fibrofatty tissue covering the acetabular floor and sometimes the inverted limbus. Tanaka, Yoshihashi and Miura reported that cases in which the distance T was more than 3.5 mm under the age of five years should be considered beyond the normal range.

**Radiological examination.** Radiological examination was usually made once every one or two years until bone growth was completed. The CE angle and acetabular index were evaluated at the age of five years before any secondary operation. The results at skeletal maturity were assessed using the CE angle, acetabular angle, and the classification of Severin (Table I). Avascular necrosis was judged by the classification of Kalamchi and MacEwen. Hips with group-I necrosis were excluded because at skeletal maturity they present no significant deformity of the femoral head.

**Statistical analysis.** We compared the two sets of data using the Student’s t-test and three or more sets by one-way
analysis of variance. Fisher’s exact test was used to analyse the association between the arthrographic evaluation and the results at follow-up. This test is appropriate in situations in which the small number in each cell precludes the use of the more common chi-squared approximations. Statistical significance was defined as p < 0.05.

**Results**

The relationship between the arthrographic classification at the time of reduction and the radiological results. At reduction, 26 hips were classified as type 1, 21 as type 2, 37 as type 3 and 49 as type 4 (Table II). At the age of five years, the CE angle and acetabular index of types 3 and 4 were statistically less than those of types 1 and 2 (Fig. 3a). Secondary surgery was carried out in 15% (4/26) in type 1, in 24% (5/21) in type 2, in 43% (16/37) in type 3, and in 49% (24/49) in type 4 at the age of five or six years. A Salter innominate osteotomy was carried out on 12, a femoral osteotomy on five, and both operations on 32 hips. At skeletal maturity, no significant difference was noted in the four arthrographic types with respect to the CE angle, acetabular angle (Fig. 3b) or Severin classification (Table II).

The relationship between the soft-tissue thickness at the acetabular floor (distance T) at the time of reduction

**Table I.** The Severin classification of the hip

<table>
<thead>
<tr>
<th>Group</th>
<th>Normal</th>
<th>Moderate deformity of the femoral head or neck or acetabulum but otherwise as group Ia or Ib</th>
<th>Dysplastic, but without subluxation</th>
<th>Subluxation</th>
<th>Femoral head articulates with a secondary acetabulum in the upper part of the original acetabulum</th>
<th>Redislocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>CE angle &gt; 19°, age 6 to 13 years</td>
<td>CE angle &gt; 25°, age ≥ 14 years</td>
<td>CE angle 15° to 19°, age 6 to 13 years</td>
<td>CE angle 20° to 25°, age ≥ 14 years</td>
<td>CE angle &lt; 20°, age ≥ 14 years</td>
<td>CE angle &lt; 20°, age ≥ 14 years</td>
</tr>
<tr>
<td>II</td>
<td>Moderate deformity of the femoral head or neck or acetabulum but otherwise as group Ia or Ib</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>Dysplastic, but without subluxation</td>
<td>CE angle &lt; 15°, age 6 to 13 years</td>
<td>CE angle &lt; 20°, age ≥ 14 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Subluxation</td>
<td>(a) moderate, CE angle ≥ 0°</td>
<td>(a) moderate, CE angle ≥ 0°</td>
<td>(a) moderate, CE angle ≥ 0°</td>
<td>(a) moderate, CE angle ≥ 0°</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Femoral head articulates with a secondary acetabulum in the upper part of the original acetabulum</td>
<td>(b) severe, CE angle &lt; 0°</td>
<td>(b) severe, CE angle &lt; 0°</td>
<td>(b) severe, CE angle &lt; 0°</td>
<td>(b) severe, CE angle &lt; 0°</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>Redislocation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table II.** The relationship between arthrographic classification and radiological results

<table>
<thead>
<tr>
<th>At the time of reduction</th>
<th>At skeletal maturity (no of hips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape of limbus</td>
<td>Gender (M/F)</td>
</tr>
<tr>
<td>Type 1 (n = 26)</td>
<td>1/25</td>
</tr>
<tr>
<td>Type 2 (n = 21)</td>
<td>2/19</td>
</tr>
<tr>
<td>Type 3 (n = 37)</td>
<td>4/33</td>
</tr>
<tr>
<td>Type 4 (n = 49)</td>
<td>4/45</td>
</tr>
</tbody>
</table>

* p < 0.01 type 1 v 3, type 1 v 4, type 2 v 3, type 2 v 4 and type 3 v 4
† p < 0.01 type 1 v 4, p < 0.05 type 1 v 3
‡ not significant (Fisher’s exact test; Severin I and II v III and IV)
§ not significant (Fisher’s exact test; no necrosis v Kalamchi II, III and IV at full skeletal maturity)

The radiological results based on arthrogram type at the time of reduction showing a) the mean (± sn) CE angle and the acetabular index at the age of five years and b) the CE angle and the acetabular angle at skeletal maturity.
The radiological results at skeletal maturity showed the CE angle in group C to be significantly lower than that in group B (p < 0.05) and lower than that in group A (p < 0.1). The acetabular angle in group C at full skeletal maturity was also higher than in group B (p < 0.1) as shown in Figure 5b. The results of Severin’s classification in group C were significantly worse than those in group B (p < 0.05) (Table V). There was no significant difference between group A and group B with regard to the CE angle, the acetabular angle or the Severin classification (Fig. 5b; Table V).

The relationship between the changes in soft-tissue interposition after reduction and the radiological results. Of the 73 hips which had arthrography twice or more, 32 were classified as group A, 29 as group B and 12 as group C. At the age of five years, the CE angle and acetabular index of the hips in groups B and C were significantly less satisfactory than in those in group A (p < 0.01) as shown in Figure 5a. Secondary surgery was carried out in 38% (12/32) in group A, in 79% (23/29) in group B, and in 100% (12/12) in group C. The radiological results at skeletal maturity showed the CE angle in group C to be significantly lower than that in group B (p < 0.05) and lower than that in group A (p < 0.1). The acetabular angle in group C at full skeletal maturity was also higher than in group B (p < 0.1) as shown in Figure 5b. The results of Severin’s classification in group C were significantly worse than those in group B (p < 0.05) (Table V). There was no significant difference between group A and group B with regard to the CE angle, the acetabular angle or the Severin classification (Fig. 5b; Table V).

Table III. The relationship between soft-tissue thickness in the acetabular floor and the radiological results

<table>
<thead>
<tr>
<th>At the time of reduction</th>
<th>At skeletal maturity (no of hips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance in mm</td>
<td>Gender (M/F)</td>
</tr>
<tr>
<td>≤3.5 (n = 55)</td>
<td>4/51</td>
</tr>
<tr>
<td>&gt;3.5 (n = 59)</td>
<td>3/56</td>
</tr>
</tbody>
</table>

* p<0.01
† not significant (Fisher's exact test; Severin I and II v III and IV)
‡ not significant (Fisher's exact test; no necrosis v Kalamchi II, III and IV at full skeletal maturity)

and the radiological results. The 114 hips in which we could measure the distance T on the initial arthrogram were divided into two groups, one in which distance T was 3.5 mm or less and the other in which it was more than 3.5 mm. At the age of five years, the CE angle and acetabular index of hips in which the distance T was greater than 3.5 mm were statistically less satisfactory than those in which it was less, as shown in Figure 4a (p < 0.01). Secondary surgery was carried out on 29% (16/55) of the former group and 63% (37/59) of the latter. At skeletal maturity, there were no significant differences in the CE angle, acetabular angle, Severin classification, or the incidence of avascular necrosis between the two groups (Table III).

The relationship between the initial arthrogram and the radiological results at skeletal maturity according to the age of reduction. All patients were divided into three groups according to whether the age of the patient when the hips were reduced was less than 12 months, between 12 and 18 months or more than 18 months. The relationship between the arthrographic features at the time of reduction and the radiological results at skeletal maturity was evaluated for each age group (Table IV). The CE angle at skeletal maturity was poor in the hips reduced in patients older than 18 months. The incidence of avascular necrosis was high in the hips reduced in patients younger than 12 months. In each age group, however, the arthrographic features at the time of reduction could not be related to the CE angle, the acetabular angle or the incidence of avascular necrosis at skeletal maturity.
Discussion

Arthograms have traditionally been used at the time of reduction but their usefulness has been the subject of controversy. The shape of the limbus, which is easily recognised on the arthrogram, has been used as an indicator of outcome. Somerville\(^1\) reported that the inverted limbus caused delay in reduction. Mitchell\(^2\) believed that classification of the shape of the limbus was helpful in establishing the cause of failed reduction. Forlin et al\(^3\) suggested that...
the medialisation ratio, the percentage of the horizontal radius of the cartilaginous femoral head that lay medial to Perkins’ line, and the shape of the limbus could be used as indicators of outcome at a mean follow-up of five years.

Our short-term results were in agreement with previous studies. The results at the age of five years suggested an adverse initial effect of soft-tissue interposition on acetabular development. As a result more secondary surgery was required in hips in group B and group C than in group A. At skeletal maturity, after this extracapsular surgery, we could find no relationship between the arthrographic features and the final radiological results. Liu, Kuo and Lubicky reported a statistically significant relationship even after secondary surgery at a mean follow-up of six years. Staheli et al. suggested that the number requiring further operation was greater in the hips with an inverted limbus, but that there were no significant differences between the hips with an inverted limbus and those with a non-obstructive limbus in the final clinical and radiological results at a mean follow-up of nine years. We agree with their opinion and emphasise the importance of follow-up until skeletal maturity when evaluating the remaining potential for acetabular development. Noritake et al. pointed out the importance for acetabular growth of the secondary ossification in the acetabular rim which appears between the age of eight and 12 years.

Age at reduction is considered one of the important factors which affects acetabular development. We therefore investigated the relationship between the initial arthrogram and the final radiological results in the three different age groups depending on whether the hip was reduced when the child was aged less than 12 months, between 12 and 18 months, and after 18 months. Although the radiological results in hips reduced in patients aged over 18 months were poor at skeletal maturity, there was no direct relationship between the initial arthrographic features and the final radiological results in any age group.

Chuinard suggested that the femoral head cannot be relied upon to compress the intervening soft tissue and to seat itself normally. By contrast, Severin indicated that the soft-tissue interposition would be seen to recede on a second arthrogram if the hip was maintained in an appropriate position. These studies of the changes in soft-tissue interposition have concentrated on morphological changes. Race and Herring measured the width of the medial pool of contrast medium to assess the qualitative change in reduction. We think that this width can be altered by the amount of contrast medium used as well as the presence of interposed soft tissue. In our study, we measured the distance to obtain an objective measure of the changes in soft-tissue interposition. The T value closely correlated with the shape of the limbus (Table II), and we believe a change in this value indirectly reflects a change in the shape of the limbus.

We are aware of no reports which relate the change in soft-tissue interposition to the long-term radiological results. Marked soft-tissue interposition at the time of reduction with distance T greater than 3.5 mm, showed spontaneous disappearance in 71% of repeat arthrograms up to the age of five years (Fig. 6). Secondary surgery was needed in some hips in group B (the disappearance group) but the results at skeletal maturity did not differ from those hips in which the distance T was normal at the time of reduction (group A).

Persistent soft-tissue interposition at the time of repeat arthrography (group C) did, however, lead to poor results, despite both pelvic and femoral osteotomies.

Lonnerholm carried out repeat arthrography in 130 children within one month of reduction, but did not address the significance of its use. Forlin et al reported that repeat arthrograms, when the cast was changed after reduction, did not provide prognostic information. In our study, when the repeat arthrogram was obtained early or less than six months after reduction, some soft-tissue interposition had not yet disappeared. Since interposition did not disappear for more than 16 months after reduction in any patient, we think that it should be possible to determine whether intervening soft tissue will disappear within the first two years after reduction.

Many authors have described how an inverted limbus can be associated with avascular necrosis. In our study, the arthrographic features at the time of reduction were not
related to the incidence of avascular necrosis. With regard to the age at reduction, the incidence of avascular necrosis was high in hips reduced in patients younger than 12 months of age. We believe that, in this age group, the femoral head may be more easily damaged than in older age groups. Even in this age group there was no statistical relationship between the initial arthrographic features and the incidence of avascular necrosis.

Despite a lack of supporting evidence, traction before reduction has been widely accepted as a means of preventing avascular necrosis. We were unable to show this with regard to the method of OHT used in our study.

We believe that open reduction can be associated with the risk of avascular necrosis, coxa magna and damage to the articular cartilage. Recently, Morcuende et al\(^1\) described the long-term outcome of open reduction through an anteromedial approach (Table VI). They reported an incidence of 43% of avascular necrosis and that the rate of superolateral physeal arrest (type-II necrosis by Bucholz and Ogden\(^2\)) was particularly high. They emphasised that a follow-up of at least ten years was necessary because the true prevalence of this superolateral physeal arrest may not be evident until six to 11 years after the hip has been reduced.

In our study, the rate of type-II necrosis (Kalamchi and MacEwen\(^13\)) was also high. When marked soft-tissue interposition was not resected, the incidence of ischaemic necrosis was 11% when adequate traction had been used before reduction (Table VI).

We believe that the indication for open reduction in hips with marked soft-tissue interposition should be carefully considered. Open reduction should not be carried out simply on the arthrographic findings at the time of the reduction. At present we would restrict open reduction to those hips in which retention of the reduced position is impossible or to those in which the soft-tissue interposition does not disappear after three years of age.

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