FEMORAL REMODELLING AFTER SUBTROCHANTERIC OSTEOTOMY FOR DEVELOPMENTAL DYSPLASIA OF THE HIP

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Children who present late with hip dislocation may require femoral osteotomy after reduction, to correct valgus and anteversion deformity of the femoral neck. After these procedures proximal femoral growth is unpredictable. We have studied proximal femoral growth in 40 children who had been treated by femoral osteotomy.

Preoperatively, the mean femoral neck-shaft angle was 5° greater on the affected side than on the contralateral side. Postoperatively, it was 28° less. There was progressive recorrection; after five years the angle was not significantly different from that on the contralateral side. In our series 70% of the capital epiphyses became abnormally shaped, taking the appearance of a ‘jockey’s cap’. All the growth plates became angulated but this corrected with time.

Correction of the neck-shaft angle probably results from the more normal mechanical environment provided by reduction. The abnormal radiographic appearance of the epiphysis and growth plate is probably due to the rotation produced by the osteotomy.


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Children who present late with developmental dysplasia of the hip (DDH) may undergo femoral osteotomy. This was first described by Hey-Groves (1928), and popularised by Somerville and Scott (1957). At first their correction was usually at subtrochanteric level but later they used intertrochanteric osteotomy, recommending that it should include 10° to 20° of varus and approximately 70° of external rotation.

It has been shown that the varus introduced at the osteotomy corrects with time (Mau 1961; Chuinard and Logan 1963; Lloyd-Roberts and Swann 1966; Karadimas, Hollaway and Waugh 1982; Kasser, Bowen and MacEwen 1985), but Suda, Hattori and Iwata (1995) observed that this took many years to return to normal and was slightly quicker if femoral derotation and varus osteotomy were combined with innominate osteotomy. There have been various explanations for the mechanism by which correction occurs. One is that growth on the medial side of the neck is increased according to Wolff’s ‘law’. Another is that relative tension in the abductor and adductor muscles changes as a result of elevation of the greater trochanter relative to the femoral head. There may well be differential growth at the proximal femoral epiphysis (Pauwels 1980; Gibson and Benson 1982).

In a well-reduced hip after derotation osteotomy, femoral anteversion does not recur significantly. If the hip is not concentrically reduced, however, the femoral anteversion will recur (Gibson and Benson 1982). The mechanisms for recurrent anteversion and its incidence are not well understood.

There is some concern about the unpredictable pattern of growth after femoral osteotomy (Salter 1961; Mau 1961; Jones 1977). As a result, it has been recommended that bony correction of the residual dysplasia should be performed on the pelvic side of the hip (Salter 1961; Pemberton 1965) or by combined pelvic and femoral osteotomy (Klisic and Jankovic 1976).

It is difficult to distinguish between recurrent femoral deformity and the secondary effects that result from residual acetabular dysplasia. We have therefore studied a group of children with unilateral DDH treated by femoral osteotomy in whom acetabular development has been satisfactory without an acetabular operation. We aimed to evaluate the patterns of growth in the proximal femur after subtrochanteric femoral osteotomy.

PATIENTS AND METHODS

The patients had been treated by the methods of Somerville and Scott (1957). We included only children with...
late-presenting unilateral hip dislocation with no other generalised skeletal disease or neuromuscular disorder. All the children were initially treated by traction and this was followed by arthrography. Hip reduction was by either open or closed methods; open reduction included excision of the limbus. Subtrochanteric femoral osteotomy was performed after reduction as a secondary procedure a few weeks later. Follow-up was for a minimum of ten years. The only secondary acetabular or femoral procedures were for the removal of the femoral plate. Children who developed frank avascular necrosis of the ossific nucleus were excluded. The first 40 patients alphabetically who conformed to these criteria were selected for inclusion.

There were 38 girls and two boys; the left hip was affected in 32 and the right in eight. The mean age at diagnosis was 1 year 5 months (3 months to 4 years 6 months). The mean age at osteotomy was 1 year 10 months (5 months to 5 years 2 months) and the mean follow-up was 17 years (10 to 34). Table I shows the number of patients in each of the operated groups and their mean age at osteotomy.

Femoral osteotomy had been performed by a consistent technique, always at subtrochanteric level, and with external rotation of 70° with or without varus of 10° to 20°. All the osteotomies had been fixed with a Sherman plate and four screws; no screw penetrated the trochanteric growth plate. A one-and-a-half-leg hip spica was applied for six weeks and the child was then admitted for mobilisation out of the spica. We considered the patients in four groups according to the operation performed (Table I): derotation osteotomy alone, varus derotation osteotomy alone or open reduction combined with either of the osteotomies.

Patients were reviewed clinically and radiologically at annual intervals to skeletal maturity, and then less frequently. Records were made of symptoms, leg length, gait, and the range of hip movement, comparing the dislocated side with the contralateral normal side. A normal hip was defined as one with a CE angle greater than 20° (Wiberg 1939). When the child was able to stand, anteroposterior radiographs were taken with the patellae facing forward, but a lateral view and specific anteversion views were not routinely taken. Gonadal shields were used to minimise irradiation and only 10% of the standard dose for pelvic radiographs were used for each exposure. This resulted in a greyer and grainer image than usual, but it was acceptable for regular review.

We measured the femoral neck-shaft angle (FNSA) and the shaft-epiphyseal angle (SEA) on anteroposterior radiographs of the operated and the contralateral sides before and after operation and then annually (Karadimas et al 1982). FNSA was recorded as the angle of intersection of straight lines through the axis of the neck and the axis of the diaphysis. The SEA was the angle formed between a line drawn parallel to the capital epiphyseal plate and the diaphyseal axis (Fig. 1). The remodelling angle (RA) for the FNSA on the affected side was the difference between the postoperative and the final FNSA.

After the operation a growth arrest line appeared on the radiographs at the site of the capital epiphyseal plate at the time of surgery, and this persisted until the age of five years. Tracings of the radiographs including the position of these growth arrest lines allowed us to determine precisely where the growth had occurred (Fig. 2). When the growth arrest line was poorly defined we used the proximal screw as a landmark, overlaying its image on radiographs.

We studied the shape of the ossific nucleus of the head in...
sequential radiographs, comparing its size with that of the contralateral hip. We classified the shape as round, flat, oval, or 'jockey-cap'-shaped, and noted the presence of any secondary ossific nucleus in the head (Fig. 3). The shape of the proximal femoral growth plate was recorded as either straight or angulated.

Statistical analysis used a paired \( t \)-test or ANOVA giving values as mean ± SEM.

RESULTS

At latest review, no patient complained of hip pain or restricted activity, or had a significant limp. Eighteen of the 40 patients had a clinical limb-length discrepancy, but this was never greater than 1 cm and therefore scanograms were not performed. Of the 40 children, 33 had a full range of hip movement and seven had restriction of terminal flexion of 5° to 10°. All had full abduction. The range of hip rotation was always full, usually with a preponderance of external rotation on the operated side.

The femoral neck-shaft angle (FNSA). Before reduction and osteotomy, the mean FNSA on the operated side was 153° (138 to 175). At union of the osteotomy it was 118° (104 to 134) and at the latest review 138° (118 to 151). The changes in FNSA are related to time after operation for the different groups in Figure 4. We found no statistical difference between the mean neck-shaft angles of the four groups before surgery, but after operation the mean FNSA had been reduced by only 8° more in the patients who had intentional varus correction (\( p = 0.017 \)) than in those who
had been intended to have a rotation osteotomy alone. It is of interest that the operating surgeon had aimed to achieve 15° to 20° of varus correction.

During follow-up, the FNSA steadily increased in all groups but there was less increase in those treated simply by derotation osteotomy, probably because these patients were usually older. We found a significant correlation between the age at operation and the final FNSA ($p = 0.026$); the older the patient at operation the lower the final FNSA.

We then combined the data from all the groups and compared the mean FNSA of the operated hips with that of the contralateral hips (Fig. 5). Preoperatively, the FNSA was 5° greater ($p < 0.001$) on the operated side than on the contralateral side. Soon after operation the mean FNSA had decreased by 36°, but in the subsequent three years the difference decreased rapidly. By five years the mean had reached a plateau at 138°, which was the same as that for the contralateral side, since the FNSA of the non-operated hips had decreased from 148° to 138° during this period.

The remodelling angle (RA). The mean RA on the operated side was 21° (–8 to +47). There was a highly significant correlation ($p < 0.001$) between the amount of remodelling and the postoperative FNSA; the lower the
postoperative FNSA the greater the remodelling (Fig. 6). There seemed to be a tendency for the neck-shaft angle to return to about 140°.

**The shaft epiphyseal angle (SEA).** The mean SEA of the operated hip preoperatively was 71° (54 to 92) (Fig. 7). This was significantly ($p = 0.015$) smaller than the mean preoperative value of 75° (62 to 88) for the contralateral hips. After operation, the mean SEA was 54° and increased to the same angle as the contralateral hip by three years. After this, we found no significant difference in SEA between the operated and the contralateral hips.

**Shape of capital epiphysis.** Before operation, the ossific nucleus of the dislocated was always smaller than that of the contralateral hip (Figs 2, 3 and 8). After operation, the ossific nucleus of the normal contralateral hip enlarged and became steadily more oval, and for the first year or two, similar oval enlargement took place on the operated side. The hips of four patients (10%) developed a second ossific nucleus placed medially, which coalesced to give a jockey-cap appearance. This appearance was seen at early follow-up in 70% even when there was no evidence of a second ossific nucleus.

**Growth plate.** The growth plate and the metaphysis of both the operated and contralateral hips appeared to be flat on the preoperative radiographs (Figs 2, 3 and 8). After femoral rotation osteotomy, the growth plate of the affected hip always appeared to be angulated. This angulation tended to flatten with time but it always persisted. By contrast, the growth plate of the contralateral hip remained horizontal throughout growth.

**DISCUSSION**

We compared our results with those reported by Suda et al (1995). Our populations were different; the children in their study were older at the time of operation. They studied 42 patients with unilateral hip dysplasia; 17 had varus derotation osteotomy alone and 25 also had an innominate osteotomy. They used an intertrochanteric osteotomy and at review 17 hips were dysplastic or subluxated. Despite the differences in the series, they showed similar remodelling of the FNSA. We looked at this in greater detail in an attempt to gain insight into the mechanisms by which the correction occurs.

Anteroposterior radiographs cannot be used to measure...
the true neck-shaft and shaft-epiphyseal angles because both rotation and flexion of the hip affect these apparent angles. All the radiographs which we studied were taken in a standard manner and studied in sequence to allow the best possible comparisons between those taken at different times on different hips. We have shown a tendency for both the operated and the contralateral hip to develop an apparent neck-shaft angle of about 138°. This is a larger angle than the 130° shown by cadaver and three-dimensional studies; the difference is explained by the effect of the anteversion of normal hips.

The surgically-induced varus tends to correct postoperatively. It does not return to the abnormal preoperative level but instead becomes the same as that for the contralateral hip. This finding suggests that a hip which is concentrically reduced has normal forces acting on its head and that this mechanical environment allows the hip to develop normally.

There has been much debate about the mechanism for this change. Our tracings of overlying radiographs (Fig. 2), and the progressive change in shaft-epiphyseal angle (Fig. 7) both indicate that asymmetrical growth at the proximal growth plate is more important than infill on the medial aspect of the proximal femoral neck according to Wolff’s law. The asymmetrical growth may be caused by the alteration in mechanical environment: when the neck is in a varus position (low FNSA) and the capital growth plate is abnormally vertical (low SEA) the joint reaction force will cause a moment on the growth plate which will produce greater compressive force on the medial rather than on the lateral side. Pauwels (1980) has suggested that this will cause a faster growth rate medially than laterally, which will eventually correct the orientation of the growth plate (normal SEA) and cause progressive correction of the varus (normal FNSA) (Fig. 2). Although some shear forces will be induced across the growth plate it is unlikely that they are responsible for the asymmetrical growth because they are evenly distributed across the plate. Varus deformity also causes relative trochanteric elevation and therefore abductor weakness; this may also contribute to the correction of the varus deformity.

Rotational osteotomy places the femoral head so that it is more completely contained within the acetabulum: the aim is to reduce the abnormal anteversion to about 10°. Inevitably, this rotation will move the anterior part of the femoral head to face more medially. Before osteotomy this part of

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Radiographs of a 16-month-old girl with left DDH preoperatively (a), at three months after open reduction and varus derotation osteotomy showing lines of growth arrest, an oval epiphysis and an apparent medial tilt of the growth plate (b), and after 30 months showing recurrent neck valgus, a jockey-cap epiphysis and an angulated growth plate (c).
the head is not subject to normal compressive forces but after operation these forces are distributed more normally. We believe that this may account for the eccentric ossification of the femoral head which leads to the common jockey-cap appearance. The apparent angulation of the growth plate after osteotomy also results from the rotation. The growth plate is normally curved in an anteroposterior direction (Griffith 1976), and medial rotation of the head will tend to make this curve or angulation more apparent on an anteroposterior radiograph.

We found that most of the correction of the surgically-induced varus occurred within three years of operation, when there is more potential for growth. The amount of correction depended on the age at which the operation was undertaken; the older the child the lower the final neck-shaft angle. This finding confirms that it is important to reduce a hip as early as possible; this gives it the best possible chance of normal development.

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REFERENCES