MOVEMENT OF THE FEMORAL HEAD AFTER SALTER OSTEOTOMY FOR ACETABULAR DYSPLASIA

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A Salter innominate osteotomy is used to treat acetabular dysplasia, but reports of its effects on the position of the femoral head are few and conflicting. Lateral shift would increase the resultant forces acting on the joint and be detrimental.

We studied 15 Salter innominate osteotomies and demonstrated that a correctly performed osteotomy does not significantly alter the distance from the centre of the femoral head to the midline of the body. Stereophotogrammetry was used in three patients to delineate the axis of rotation of the distal acetabular fragment and determine the locus of movement of the centre of the femoral head about it. Our results explain why the Salter osteotomy does not lateralise the femoral head.

A dysplastic hip with subluxation will develop early osteoarthritis due to stress loading of its superolateral surfaces (Wiberg 1939). We found that about 35% of patients with osteoarthritis admitted for total hip arthroplasty had this type of osteoarthritis, comparable with the 39% reported by Harris (1986) and the 25% by Wedge and Salter (1974). Various osteotomies have been designed to increase the true articular cover of the femoral head, including those of Salter (1961), Pemberton (1965), Wagner (1976), Eppright (1975), the double osteotomy of Sutherland and Greenfield (1977), and the triple osteotomy of Steel (1973).

Reynolds (1986) considered that \ldots none of these procedures corrects the lateral displacement of the dysplastic hip. On the contrary, all of them may increase the displacement from the midline, in theory adding to the load on the joint\ldots With reference to the Salter osteotomy, Utterback and MacEwen (1974) also discussed the significance of this lateral shift, but Rab (1976, 1978) suggested from biomechanical studies that a 12 mm medial shift occurred. While medial shift would be beneficial to the hip by decreasing the moment of the forces acting on it, lateral shift would be detrimental (Pauwels 1980).

The direction of any shift of the femoral head by a Salter osteotomy requires elucidation. We therefore made a prospective study of 15 patients having Salter innominate osteotomies.

PATIENTS AND METHODS

In 1986 and 1987, the senior author (TMO'B) performed 15 Salter osteotomies on 10 female and three male patients with acetabular dysplasia. The two having bilateral procedures had an interval of three months between each operation; eight of the 11 unilateral operations were on the left. The patients were aged 3 to 38 years (mean 17 years, 5 months). Three hips had previous femoral varus derotation osteotomies; none had open reduction.

Before operation, anteroposterior radiographs of the pelvis were taken with the hips in neutral position, and also in abduction and internal rotation. Innominate osteotomies were carried out as described by Salter (1961, 1972), and fixed with threaded pins. The manoeuvre described by Wedge and Salter (1974) was used to open the osteotomy, but proved to be ineffective in the three patients who had previously had femoral osteotomies. More anteroposterior radiographs were taken in the operating room at the end of the procedure and right and left oblique views of the operated hips were also obtained.

Further anteroposterior radiographs of the pelvis were taken before discharge from hospital, at six weeks, and at three months; regular review has continued with special reference to the remodelling of the distal fragment.
The pins used for internal fixation were removed after 26 to 224 days (mean 94 days), depending on the age of the patient.

**Radiographic analysis.** We studied the pre-operative and at least two postoperative sets of radiographs in each case. A line from the spinous process to the pubic symphysis marked the midline of the body (Fig. 1 (AB)). A Mose template was used to locate the centres of the femoral heads and their diameters and the centre-edge angles of Wiberg (1939) were recorded. All measurements were corrected for changing magnification using the ratio of the diameters of the femoral heads on different films.

We also measured the distances of the centre of the femoral head from the midline (CD); from a line between the pubic symphysis and the greater sciatic notch (Rab's axis, Fig. 2 (i)); from a line joining the pubic symphysis to the inferior margin of the sacro-iliac joint (ii); and from a line joining the centre of the opposite femoral head to the upper border of the sacro-iliac joint (iii). These measurements enabled us to assess the movement of the femoral head in relation to the landmarks of the pelvis. Tracings of suitable pairs of pre- and postoperative radiographs were also made to demonstrate the vertical shift of the femoral head. To investigate the changes in the appearance of the obturator foramen after Salter osteotomy, we also measured the angle (Θ) between the midline and a line from the junction of the body of the pubis with the inferior pubic ramus to the upper outer angle of the obturator foramen (Fig. 1 (EF)).

In three other patients, we made an intra-operative stereophotogrammetric study to delineate the axis of rotation of the distal acetabular fragment, using three radiopaque 6 mm clips placed on the distal acetabular fragment. Clip A was on the iliopubic eminence, clip B on the greater sciatic notch just below the level of the osteotomy and clip C on the anterior inferior iliac spine. Anteroposterior and right and left iliac oblique radiographs were taken before and after osteotomy. From these radiographs, a computer-assisted three-dimensional Cartesian co-ordinate system was constructed with its origin at the mid-point of the anterior surface of the pubic symphysis. The plane of rotation for each clip was mapped out and the axis of rotation obtained from the intersection of the three planes, using a graphics program to display the three-dimensional rotation on a computer screen.

**RESULTS**

**Radiographic results.** After osteotomy the CE angle of Wiberg (1939) was restored to an angle equal to that of the normal opposite side in 10 of our 11 unilateral cases, and increased to a lesser degree in the other (Fig. 3). In the two patients with bilateral involvement, the CE angles had increased from 13° to 25° (Table I). The downward shift of the femoral head varied from 0 to 17 mm (mean 7.2 mm).

The distance from the centre of the femoral head to the body midline remained unchanged in 12 hips, and moved medially by 2.5 mm in two. In one hip which had previously undergone a femoral varus derotation osteotomy there was 4 mm lateral movement.

**Stereophotogrammetric analysis.** Using parametric co-ordinate equations for the axes of rotation, separate three-dimensional isometric graphs were drawn. In the case illustrated in Figure 4 the axis of rotation of the
Anteroposterior pelvic radiographs before and three months after innominate osteotomy. The increase in the CE angle of Wiberg and the change in configuration of the left obturator foramen are well shown.

Figure 4a – Three-dimensional isometric graph to show the positions of the clips before (a, b and c) and after osteotomy (a', b' and c') relative to the axis of rotation. O is the origin of the Cartesian co-ordinate system with X representing the horizontal axis in the frontal plane, Y the horizontal axis in the sagittal plane, and Z the vertical axis. Figure 4b – The axis of rotation makes an angle of 67.4° with the horizontal in the sagittal plane and (Figure 4c) an angle of 31.5° with the horizontal in the frontal plane.

Table 1. Measurements before and after Salter osteotomy of 15 hips

<table>
<thead>
<tr>
<th>Case</th>
<th>Age Yr Mth</th>
<th>Transverse shift of femoral head (mm)</th>
<th>CE angle (degrees)</th>
<th>Angle of obturator foramen</th>
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<td>Before</td>
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distal fragment of the osteotomy passed through a point 6.9 mm behind and 0.56 mm below its origin at the midpoint of the anterior surface of the pubic symphysis. It made an angle of 31.5° to the horizontal in the frontal plane, and 67.4° to the horizontal in the sagittal plane. In the other two stereophotogrammetric analyses the axes of rotation were 32° and 20° respectively in the frontal plane and 70° and 40° in the sagittal plane.

To check these results we reversed the analysis and calculated the co-ordinates of the markers after osteotomy by pre-multiplying the pre-operative position vector of each clip by the $4 \times 4$ rotation matrix. The predicted co-ordinates matched the actual co-ordinates very closely. The angle of rotation of each clip was measured as 34.5°, which corresponded closely to the size of the wedge grafts measured on the oblique radiographs.

The change in position of the centre of the femoral head was also studied using a $4 \times 4$ rotation matrix in the three cases having stereophotogrammetry. The locus described by rotating the position vector of the centre of the femoral head about the axis of rotation is illustrated in Figure 5; the centre of the femoral head has moved closer to the midline by 0.2 mm. From the orthographic projection, it can be seen that almost the whole of the locus of the centre of the femoral head lies medial to its position before osteotomy, implying that any rotation about the axis will automatically move the centre of the femoral head medially. This result was consistent in each of the three cases.

**DISCUSSION**

The technique and results of innominate osteotomy have been well described (Salter 1961, 1966, 1972), but there has been little study of the biomechanical changes produced by this three-dimensional adjustment. Utterback and MacEwen (1974) referred to "... a measurable lateral displacement of the entire acetabulum with an effective increase of distance from the body midline to femoral head". Reynolds (1986) also maintained that various procedures, including the Salter osteotomy, increase the displacement of the femoral head from the midline. By contrast, Radin and Paul (1974) believed that the Salter osteotomy did not significantly alter the magnitude or direction of the resultant forces on the hip.

More scientifically, Hansson et al (1978) performed stereophotogrammetry on a 17-year-old girl with tricho- rhinophalangeal syndrome having a Salter osteotomy for acetabular dysplasia, but the radiographs indicate a less than ideal result with persistent lateral subluxation which may explain the 2 mm lateral displacement which they found.

Rab (1976) performed a Salter osteotomy in a cadaver, but chose a line from the pubic symphysis to the greater sciatic notch as the axis of rotation, and designated the axes of rotation of the centre of the femoral head and the anterior inferior spine as the intersections of perpendiculars from these points to the first axis. He reported that the acetabulum was displaced 10 mm distally, 12 mm medially, and 15 mm posteriorly. He assumed that the centre of the hip followed the same path, but as we have shown this assumption was incorrect.

Both Wedge and Salter (1974) and Tachdjian (1982) considered the asymmetry of the obturator foramen produced by a Salter osteotomy to indicate the rotation of the distal fragment at the symphysis pubis (see Fig. 3). We found, however, that the angle of lateral rotation about the line from the junction of the pubic body with the inferior pubic ramus was equal to the change in CE angle in 12 of our 15 cases, thus demonstrating the three-dimensional nature of the rotation of the osteotomy.

In our cases the downward movement of the femoral head ranged from 0 to 17 mm (mean 7.2 mm) as compared to the 10 mm reported by Rab (1976) and the 21 mm by Hansson et al (1978). Our smaller figure may be accounted for by the presence of some posterior shift of the head as well as the upward and outward movement of the proximal iliac fragment, and widening of the sacro-ilial joint. Ferré and Schächter (1974) have cautioned against displacement of the proximal segment after Salter osteotomy: they fear that it may cause a significant loss of forward redirection of the acetabulum. We feel that these changes are unimportant: we obtained an adequate increase in CE angle and good femoral head cover in all cases. Moreover, these proximal changes would conveniently negate the 'long-leg effect' (Utterback and MacEwen 1974) that is said to result in adduction of the operated hip and a tendency to uncover the femoral head.

In our clinical series, we have demonstrated that the distance between the centre of the femoral head and the midline generally remains unchanged. This is important
in reassuring the surgeon that a correctly performed Salter osteotomy does not increase the moment of forces acting on the hip. In fact, a minor degree of medialisation, as seen in two of our cases, may decrease the force. We have demonstrated the three-dimensional nature of the operative procedure; this explains why an increase in the CE angle is not accompanied by lateralisation of the femoral head.

An innominate osteotomy should be a technically precise procedure and, in the older patient, rotation of the distal fragment is greatly facilitated by the manoeuvre of Wedge and Salter (1974). We found, however, that a previous femoral derotation osteotomy made this technique ineffective, presumably because of slackening of the tension on the anterior capsule of the joint.

We have shown the benefit of the Salter innominate osteotomy, even in mature patients, in increasing acetabular cover, finding an average increase in the CE angle of 20°. The long-term effect in decreasing the incidence and severity of osteoarthritis will require careful assessment over several decades, but we have found no theoretical objection and can support its use in adolescent and adult patients with dysplasia.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES


