CHANGES IN SHAPE OF THE HUMAN HIP JOINT DURING ITS DEVELOPMENT AND THEIR RELATION TO ITS STABILITY

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Spontaneous dislocation of the hip, from whatever cause, is most likely to occur during the perinatal period and in early childhood. An anatomical explanation offered by Sainton (1892-3) was that the acetabulum was a more shallow cavity at the time of birth than at any subsequent time and the stability of the joint correspondingly more dependent on the integrity of the soft tissues. His observations were confirmed by Le Damany (1912), who carried out an extensive series of measurements on casts taken from the hip sockets of humans and animals at various stages of development. He also made the observation that the human acetabulum was more shallow at birth than in earlier foetal life. In speaking of “shallowness” Le Damany was, of course, referring to shape and not to absolute depth.

Since then, several workers have repudiated these findings, including Gardner and Gray (1950), Laurenson (1965) and Dunn (1969), but Morville (1936) agreed that the socket was more shallow at birth and that full cover of the head was not achieved until about three years of age. However, none of these later workers had carried out any direct measurements but relied either on naked eye impressions or on the indirect evidence of arthrography: it is questionable therefore whether their observations can justifiably be set against Le Damany’s careful anthropometric studies.
To resolve the dispute a further series of measurements of acetabular shape was carried out on fresh human material, and since the chief clinical importance of the findings is in relation to stability, the dimensions of the corresponding femoral heads were also measured, together with the extent to which each was covered by its respective acetabulum.

**MATERIAL AND METHODS**

Dissections were carried out on forty-four hip joints from fifteen foetuses and twenty-nine children who had died without any evidence of a disorder of the locomotor system. The youngest was an embryo of eleven and a half weeks (crown-rump length 55 millimetres) and the oldest child was eleven years.

After removal of the muscles, the capsule was excised but the acetabular labrum was preserved. The ligament of the head was then divided and the joint components were separated. The following measurements were made.

*Acetabulum* (Fig. 1)—1) Diameter: The greatest width of the cavity a₁ was measured with calipers. 2) Depth: This was measured by using two wires. One was placed across the greatest diameter of the mouth of the cavity lying on the fibrocartilaginous labrum, while the second, at right angles to this, marked the distance a₂ between this “bridge” and the deepest part of the socket.

*Femoral head* (Fig. 2)—1) Diameter: The greatest diameter h₁ was measured with calipers. 2) Height: This dimension, h₂, at right angles to the above and representing the distance from the greatest convexity of the head to the articular margin was also measured with calipers.

*Cover of the femoral head* (Fig. 2)—The head was returned to the acetabulum in that position in which it was most completely covered; that is when the axis of the cavity and that of the

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**FIG. 3**

Section through hip joint of twelve-week human embryo displaying the maximum diameter. The head is almost completely enclosed by the cavity.
femoral neck were identical. The line of the acetabular margin was then marked out on the head either by drawing with a fine felt-tipped pen or by marking it with a line of pins. The distance between this line and the convexity of the head was then measured \( h_3 \) so that the proportion of the total height of the head covered by the acetabulum could be calculated \( \frac{h_3}{h_2} \).

In the three earliest specimens, embryos of 55, 56 and 64 millimetres, accurate measurement of the specimen itself proved impossible. Instead, the joint was embedded in paraffin, serial histological sections were cut and measurements were made from the greatest dimensions that these revealed.

**RESULTS**

**Acetabular measurements**—In the three embryos the sections showed that the acetabulum was an extremely deep-set cavity which almost totally enclosed the head (Fig. 3). As growth proceeded, the absolute depth of the cavity increased but its shape began to change. This has been represented by expressing the depth \( a_2 \) as a percentage of the width \( a_1 \), so that if the cavity is deep and represents more than a complete hemisphere the ratio will be greater than 50 per cent and vice versa.

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**Fig. 4**

Changes in acetabular shape in relation to age.

**Fig. 5**

Changes in the shape of the articular position of the femoral head in relation to age.
The changes in this ratio with respect to age are illustrated in Figure 4, where it can be seen that throughout foetal life the acetabulum becomes increasingly shallow until the time of birth when it may represent as little as one-third of a complete sphere. After birth the trend reverses and the cavity steadily deepens as childhood proceeds.

**Femoral head measurements**—While the femoral head increased in size during development there were also changes in its shape depending on what proportion of a complete sphere it represented. This has been illustrated by plotting the ratio $h_2/h_1$ against age (Fig. 5). There it can be seen that in the embryo the head is quite globular, representing as much as 80 per cent of a complete sphere, but as birth approaches it becomes much closer to a hemisphere. After birth the globular appearance returns to some extent although the head never again attains the sphericity seen in the embryo. Examples of the changes are shown in Figure 6.

**Femoral head cover**—The changes in the $h_3/h_2$ ratio with age are illustrated in Figure 7, which shows that the proportion of the head contained within the acetabulum gradually diminishes as the foetus grows to reach a minimum around the time of birth. After this point it increases again and continues to do so throughout development.

![Fig. 6](image)

Changes in the shape of the femoral head in relation to age. From left to right the ages are: 21-week foetus, 30-week foetus, premature newborn, newborn, 2 years, 4 years. The shape is more nearly hemispherical around the time of birth.

![Fig. 7](image)

Changes in the proportion of the femoral head covered by the acetabulum in relation to age.
DISCUSSION

The results of the acetabular measurements confirm Le Damany's (1912) findings that the human acetabulum is shallower at birth than at any other time during development.

The changes in the femoral head can be regarded as complementary to those in the acetabulum. If it is assumed that there are no articular areas of the femur and acetabulum which do not come into contact at some time or other, then an increase in the shallowness of the acetabulum will permit a smaller area of the femur to be covered with cartilage provided that the range of movement of the joint remains unchanged (Fig. 8). It is to be expected, therefore, that the globularity of the head will first diminish and then increase again pari passu with the changes in the acetabulum.

Deep socket

Shallow socket

Fig. 8
Diagrammatic representation of two joints with an equal range of movement. In the shallower joint the proportion of the head which must necessarily be articular is less.

It can be seen from Figure 5 that these changes did in fact occur, but that the magnitude of the femoral changes was less than those of the acetabulum so that during foetal life the cover afforded to the head by the acetabulum actually decreased (Fig. 7). It follows, therefore, by an extension of the argument illustrated in Figure 8 that the theoretical range of movement of the hip must increase as birth approaches and diminish thereafter.

These changes are consistent with what is known of the early development of the hip. This arises by a process of cleavage in a solid mass of mesenchyme (Bardeen 1905) so that the cavity is initially very deeply set and almost totally encloses the head (Fig. 3). Such a joint will inevitably have a very limited range of movement and a subsequent shallowing of the cavity together with complementary changes in the femur is to be expected. The problem is to explain why the changes should reverse after birth and the range of movement decrease again.

Teleological speculation is probably futile since the changes may not necessarily be purposeful, although Le Damany's finding that similar acetabular changes did not occur in
quadrupeds suggests that they do not have a phylogenetic basis. It is possible that a temporarily increased range of movement is required around the time of birth in order to accommodate the limb within the limited intra-uterine space that is available at that time.

The clinical interest in these findings is, of course, concerned with stability. It is to be expected, a priori, that a shallow hip will be less stable than a deep one, so that the human hip will be most unstable around the time of birth as the clinical evidence suggests. This is the price that must be paid for the increase in mobility at this time. In theory a joint that consists of more than half a sphere will be independent of the soft tissues for its stability and cannot dislocate unless the structure of the acetabulum or the labrum is disrupted. It will be noted that these conditions are not present after the twentieth week of foetal life and before two years of age, which is almost exactly the period during which paralytic dislocation is most likely (McKibbin 1973).

SUMMARY
1. Dissection of forty-four developing human hip joints has shown that while the embryonic acetabulum is a deeply set cavity which almost totally encloses the head it gradually becomes more shallow as birth approaches. During the same period the femoral head becomes less globular and at the end of foetal life is almost hemispherical. The cover afforded to the femoral head by the acetabulum also becomes decreased.
2. After birth these trends reverse: the acetabulum becomes deeper again and the femoral head more globular. This process continues throughout childhood.
3. The findings provide a possible explanation for the increased liability to dislocation of the infantile hip.

REFERENCES