Morphological Changes of the Fetal Hip Joint and Their Effect on the Stability of the Joint During Its Intrauterine Development

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Background: Hip joint dislocation and dysplasia are frequent congenital malformations with a multifactorial etiology with a major role played by intrauterine mechanical forces during development. Our aim was to define the surface of the femur and acetabulum, and to study the changes in geometrical parameters and the relationships between them during development.
Material and method: In this study we dissected the hip joints of 10 post-mortem fetuses. Fetal age was determined using crown-rump length (CRL) (min. 8.5 cm, max. 30 cm). Then we performed morphological and geometrical measurements on the articular components. We calculated the area of the articular surfaces, then determined the femoral head coverage and compared the antetorsion (AT) of the femur with the AT of the acetabulum.
Results: in the 3 months fetus the surface areas of the femur and acetabulum are almost identical, the femoral head coverage is maximal, and later with age progression the head coverage decreases, as its growth is more intense than that of the acetabulum. During development the increase of femoral AT determines the increase of the acetabular AT.
Conclusions: The decrease in femoral head coverage during development results in a decrease in articular stability. The femoral head's position and compression plays an important role in the development of the acetabulum.

Keywords: hip development, stability, hip joint dislocation and dysplasia

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Introduction

Hip joint dislocation and dysplasia are frequent congenital malformations, with an incidence of 1/1000 newborns. Several theories have been proposed for clarification of the condition, and the most important one is the genetic and mechanical theory [1,2].

The condition for a correct and effective therapy is early diagnosis. The Barlow and Ortolani clinical tests performed in the first 24 hours are frequently false positive, and thus ultrasound examination of the hip gains an increasing importance. Usually this has to be performed in the 2 to 4 postnatal week interval [3,4].

The development of the syndrome is conditioned by the instability of the hip joint that is characterized by the following factors already present during the intrauterine period: shallowness and deformity of the acetabulum, low sphericity of the femoral head, abnormal geometries of the proximal femur, articular capsule laxity and a longer Ligamentum capitis femoris [5].

The development of the joint commences in the 7th intrauterine week, and by the 11th week all components of the hip joint will have been developed. The further events of development are influenced by regional factors like abnormal intrauterine mechanical forces that affect especially the development of the cartilaginous acetabulum [6]. During development the stability of the joint gradually decreases. This is due to shallowing of the acetabulum and decrease of the head's sphericity. After birth the instability decreases as a result of the gradual deepening of the acetabulum and the increase in the femoral head's sphericity [7,8,9].

The aim of our study is the morphological study of the prenatal hip joint and follow-up of the relationships between the joint components during development.

Material and method

We performed the dissection of the hip joints of 10 post-mortem fetuses from the material of the Department of Anatomy and Embryology of the University of Medicine and Pharmacy of Tîrgu Mureș. Fetal age was determined using crown-rump length (CRL) (min. 8.5 cm, max. 30 cm). According to our measurements we had the following prenatal age distribution: one 3 months old, two 4 months old, three 5 months old, three 6 months old and one 9 months old fetus. Gender distribution was as follows: 5 male and 5 female fetuses.

During dissection we removed the muscles and soft tissue components of the joint, and exposed the bony and cartilaginous joint components. This was followed by dislocation of the femoral head, and measurements of the head were performed using a slide caliper to achieve 0.05mm accuracy (h1 vertical, h2 transversal diameter and h3 the distance between the head-neck transition and the largest convexity of the head) (Figure 1). The inner diameters and depth of the acetabulum were also measured (a1 vertical,

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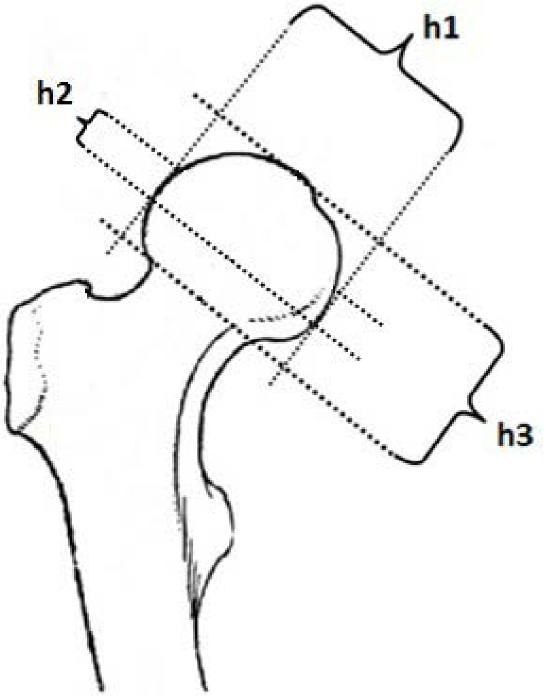

Fig. 1. Femoral head measurements (author's drawing)

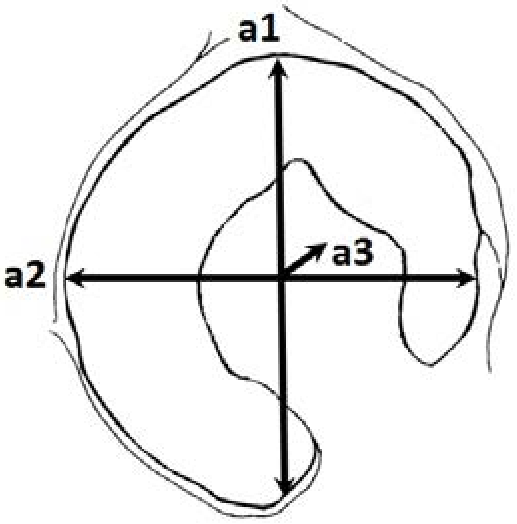

Fig. 2. Acetabulum measurements (author's drawing)

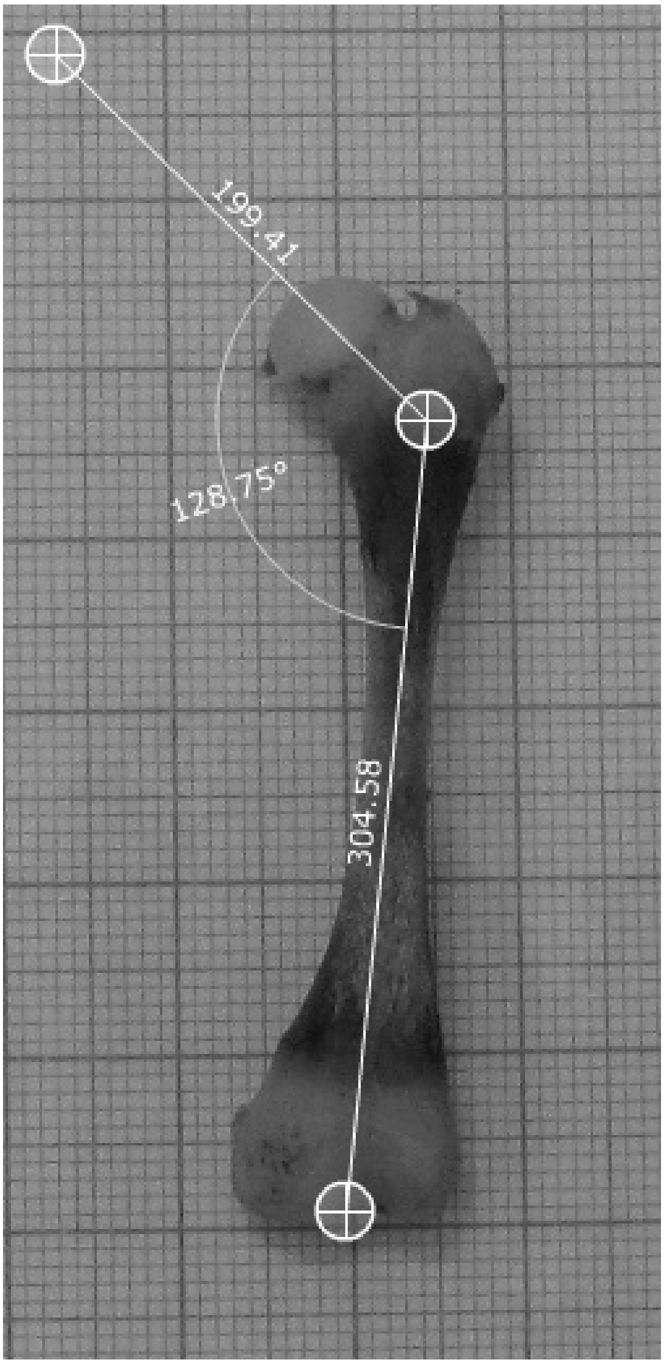

Fig. 4. Collodiaphyseal angle (CD°)

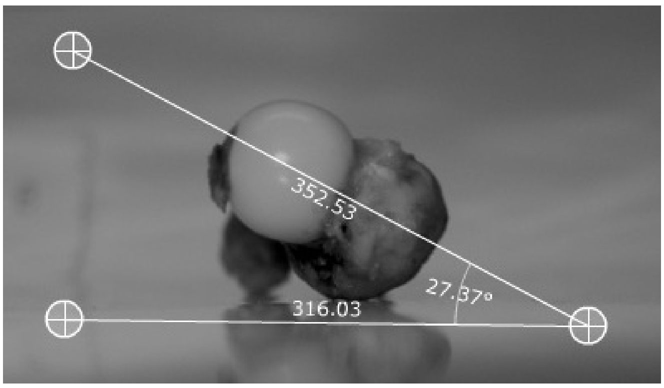

Fig. 3. Antetorsion (AT°)

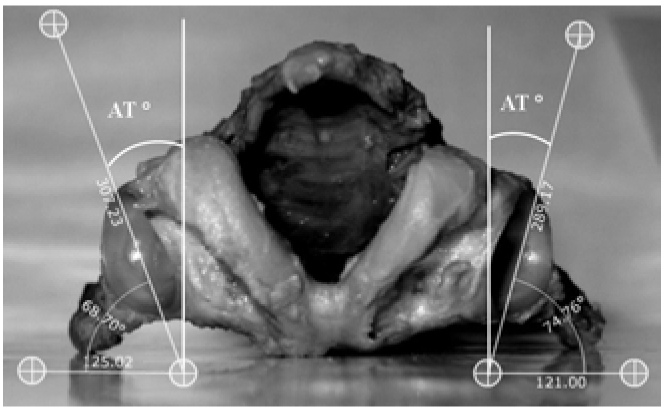

Fig. 5. Antetorsion of the acetabulum

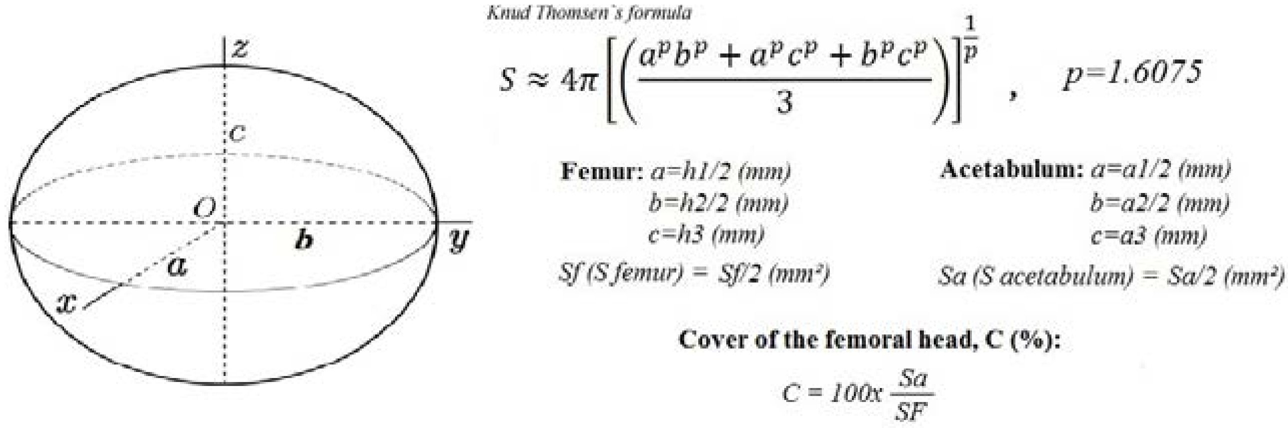

Fig. 6. Surface measurements of the head of the femur and acetabulum; femoral head coverage (author's drawing)

a2 transversal diameter and a3 depth measured from the labrum) (Figure 2).

Following proper positioning, we photographed the articular components, and we performed geometrical measurements using a software called ScreenScale. In case of the proximal femur, we determined the angle of antetorsion (AT°) and the collodiaphyseal angle (CD°) (Figure 3, 4).

We placed the hip bone on the two superior anterior iliac spines and the two pubic tubercles, and then we determined the antetorsion angle (AT°) of the acetabulum, i.e. the 90° supplemental angle of the angle made up by the supporting plane and the line traced through the anterior and posterior margins of the acetabulum (Figure 5).

Morphologically the acetabulum and the femoral head are like two ellipsoid bodies engaging each other. The surface of an ellipsoid can be calculated using the Knud-Thomsen formula, and we employed this formula to calculate the surface areas of the femoral head and the acetabulum (Figure 6). The resulting surface comprises not only the cartilaginous surface, but the in case of the acetabulum the area of the acetabular fossa, and in case of the femoral head the area of the fovea capitis femoris as well. We calculated the ratio of the surfaces of the two components to determine the% coverage of the femoral head.

Statistical calculations on the obtained geometrical and morphometry values were performed using GraphPad software (GraphPad Software Inc., San Diego, U.S.A.).

Results

In case of the 3 months old fetus, the surface of the femoral head is almost identical to the acetabular surface (femur surface: 13.29 mm², acetabular surface: 12.51 mm²). During fetal growth, the surface of the head increases, while the increase of the acetabular surface falls behind the growth of the femoral head surface. The difference between the two surfaces is most definite in case of the 9 months old fetus (femur surface: 680.17 mm², acetabular surface: 454.57 mm²) (Figure 7). Accordingly, the femoral head coverage is at its maximum at the beginning of development, and shows a gradual decrease with age progression (3 months fetus femoral head coverage 94.13%, 9 months fetus 66.83%) (CC= –0.49) (Figure 8).

As fetal age progresses the collodiaphyseal angle of the femur shows a mild increase (CC= 0.29), and antetorsion shows a marked increase (CC=0.51). The increase of the femoral antetorsion is followed by the increase in acetabular antetorsion (Figure 9).

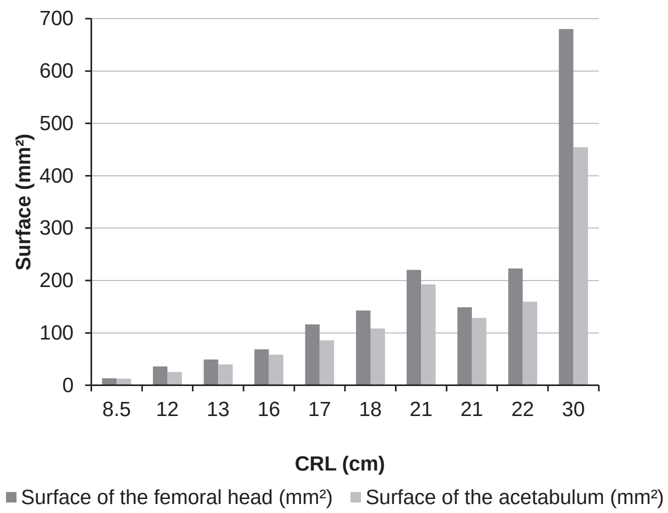

Fig. 7. Surface calculation results

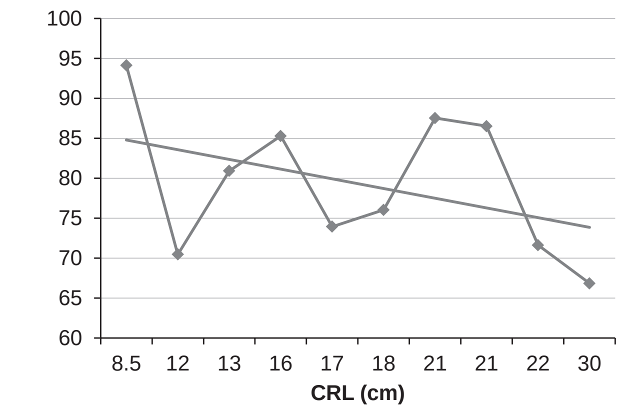

Fig. 8. Femoral head coverage (%)

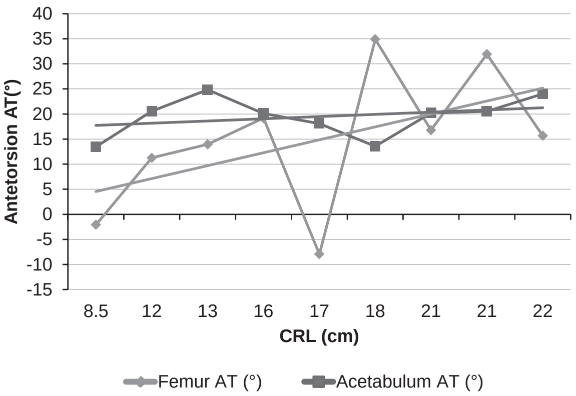

Fig. 9. Femoral and acetabulum antetorsion

Discussions

A femoral head with low sphericity and a shallow acetabulum decrease the stability of a stable joint [5, 7, 9]. The decrease we calculated, which was occurring with progression of fetal age in the articular surfaces and femoral head coverage also suggests a decrease in joint stability. During intrauterine development the joint stability decreases, and it peaks at birth. Based on bibliographical data the forces acting on the developing hip joint may cause femoral head dislocation, if the soft tissue components do allow it. If the abnormally positioned femoral head exerts pressure on the acetabulum for a long period of time, it may cause deformities. If the femoral head returns to its normal position the acetabular deformity may disappear. This is called the reversibility of the acetabulum. This is possible until the 3rd postnatal month, when acetabular ossification commences [10].

According to bibliographical reports, mechanical forces play a significant role in the development of the hip joint, both in the prenatal and the postnatal period. In most of the cases, the forces occurring during intrauterine development cause the deformity of the anterosuperior quadrant of the acetabulum [11]. Considering the constrained position of the fetus (kyphosis of the spine, also followed by the cranio-caudal arch of the hip bone, and the flexion of the hip joint) it is clear that in case of increased femoral antetorsion, the compressive forces increase at the anterosuperior area of the acetabulum. According to Hueter-Volkmann's law, growth is inhibited in areas that are subjected to increased pressure, i.e. in the anterosuperior quadrant of the acetabulum as well. Additionally, as a result growth is stimulated in the posterior area of the acetabulum. Summing up these processes explains not only the localization of the more frequent acetabular deformities, but the increase in acetabular antetorsion during development as well.

Conclusions

Intrauterine development of the hip joint leads to a decrease in joint stability. The surface of the femoral head has a higher growth rate than the acetabulum, which leads to a decrease in coverage.

The adequate compression of the femoral head plays an important role in acetabular development, regarding both morphological characteristics and spatial orientation.

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