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Morphogenesis of the Hip Joint. Plastination-Histological and Electron Microscopic Studies

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Hip joints of 4-6 months old human fetuses were examined with the plastination histological technique. In addition, transmission and scanning electron microscopic analysis of the elements of hip joints of Wistar rat embryos was performed. Attention was paid to the structural changes taking place during the differentiation of the skeletal anlagen, the synovial membrane, the internal joint structures (i.e. the labrum acetabulare, the lig. transversum acetabuli, the lig. capitis femoris, the capsule) and the extra articular ligaments.

Key words: hip joint, morphogenesis, plastination-histological technique, electron microscopy.

Introduction

The hip joint is a leading link of the kinematic chain of the lower limb. Because of the erect posture of man, it also fulfils supportive functions. This has affected both its normal structure and its pathology – coxarthrosis for instance is one of the most frequent diseases of the locomotory apparatus. Also very frequent are the congenital dysplasia and luxation of the hip joint. For their clarification, information on the morphogenesis of this joint is necessary.

The morphogenetic studies available of the hip joint have been carried out with routine histological techniques and concern mainly the skeletal elements (Gardner and Gray, 1950; Strayer, 1971; Doskocil, 1984; Tillmann, 1990). In our study the plastination histological technique was used, for it preserves the relationships between tissues possessing different density and thus provides the opportunity for the differentiation not only of the skeletal elements but also of the other joint structures to be investigated (Fritsch, 1989; Fritsch and Hegemann, 1991; Vassilev I., 1997). In addition, transmission and scanning electron microscopic (TEM and SEM) analysis of hind limb anlagen of animal embryos was performed, for it provides information on the ultrastructural changes of the cell populations and the extracellular matrix during the development of joints (Roy and Ghadially, 1964; Wassilev W, 1972; Vidinov, 1979).

Materials and Methods

With the plastination-histological technique, hip joints of 3-6 months old human fetuses of the two sexes were examined. After fixation and dehydration in toto, the pelvises were impregnated in vacuum with epoxy resin (Biodur R E12, E6 and E600) and cut with diamond saw (Well, Manheim) in 300-600 μm thick cross, saggital and frontal sections. The sections were polished and then stained with Azur II-Methylene blue (Fritsch and Hegemann, 1991).

The electron microscopic analysis of the developing hip joint structures was performed on 14-21 days old Wistar rat embryos. The samples were processed according to the routine TEM and SEM technique and examined with electron microscopes Hitachi 11 A (60 kV) and Philips SEM 505 (10-30 kV).

Results

The limb anlagen are made up of mesenchymal cells interconnected through their outgrowths. The intercellular spaces are optically empty (Fig. 1). Later, the cells differentiate in chonroblasts rich of organelles. In addition, matrix with collagen fibers is formed, and the cartilaginous skeletal anlagen occur. Between them the joint intermediate cleft is situated, in which the joint cavity, outlined by the joint capsule, is formed (Fig. 2). From the internal part of the capsule an abundantly vascularized synovial membrane differentiates (Fig. 3).

The skeletal elements of the joint occur after birth and are at first cartilaginous. The femur possesses a round head and a short neck with numerous vascular canals in them (Fig.4). At first the acetabulum is shallow. In the hipbone quick mineralization takes place. The acetabular labrum differentiates as a fibrous ring with a wide basal portion

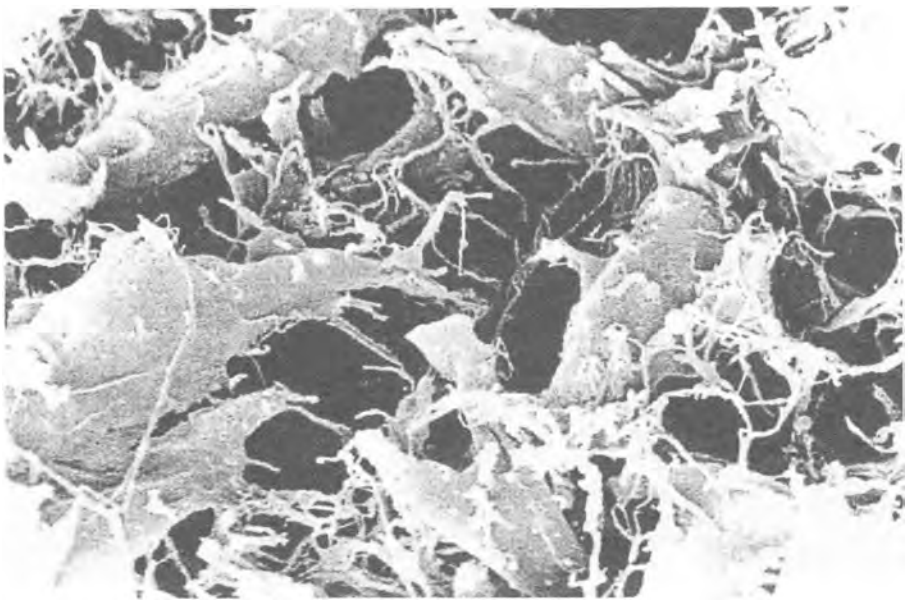

Fig. 1. Mesenchymal cells of a limb anlage of a 15 days old rat embryo. SEM

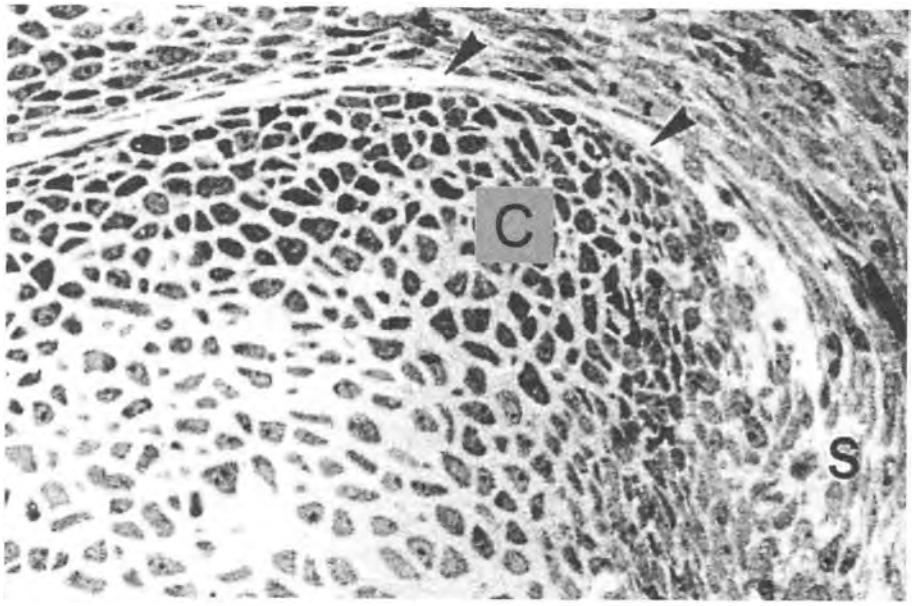

Fig. 2. Cartilaginous skeletal anlage (C), joint cleft (arrowheads) and joint capsule with synovial membrane (S) of an 18 days old rat embryo

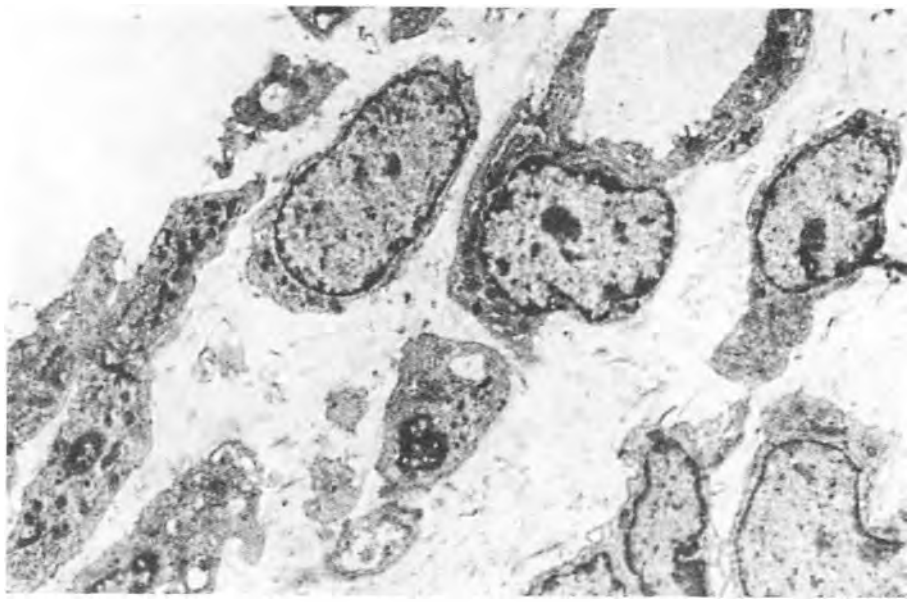

Fig. 3. Synovial membrane of the capsule of the hip joint of a 20 days old rat embryo. TEM

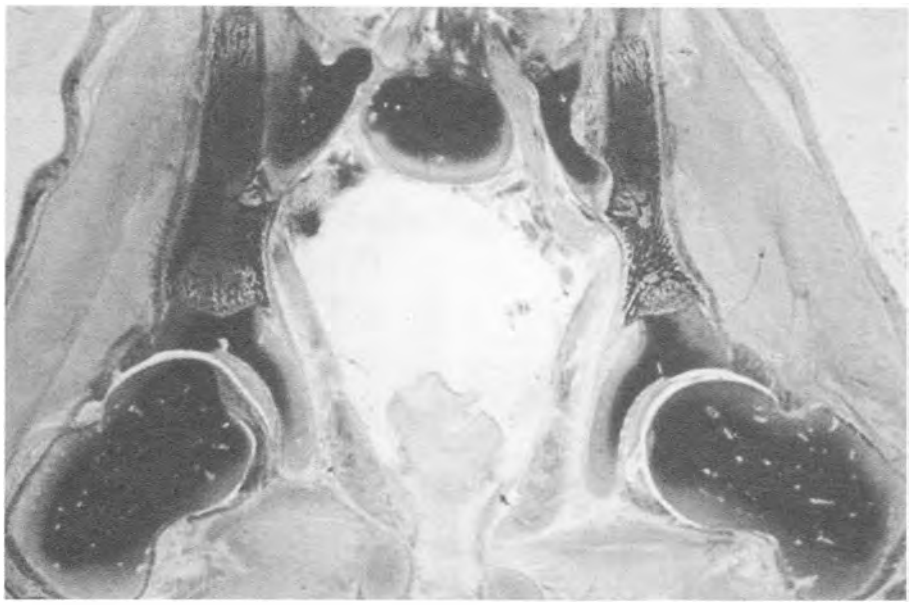

Fig. 4. Hip joints of a 4 months old human fetus. Plastination section

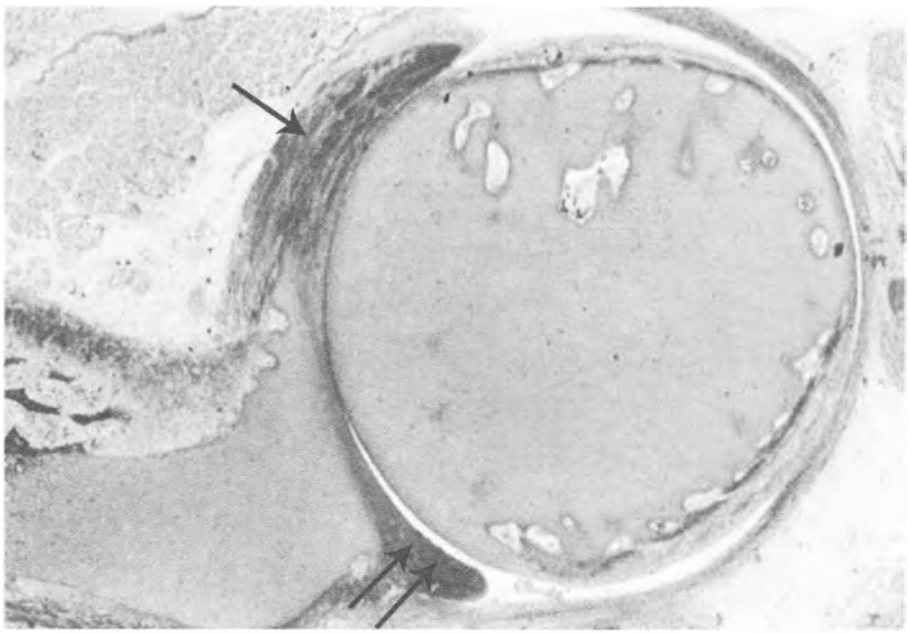

Fig. 5. Cranial (single arrow) and caudal (double arrows) portion of the labrum acetabulare of a 4 months old human fetus

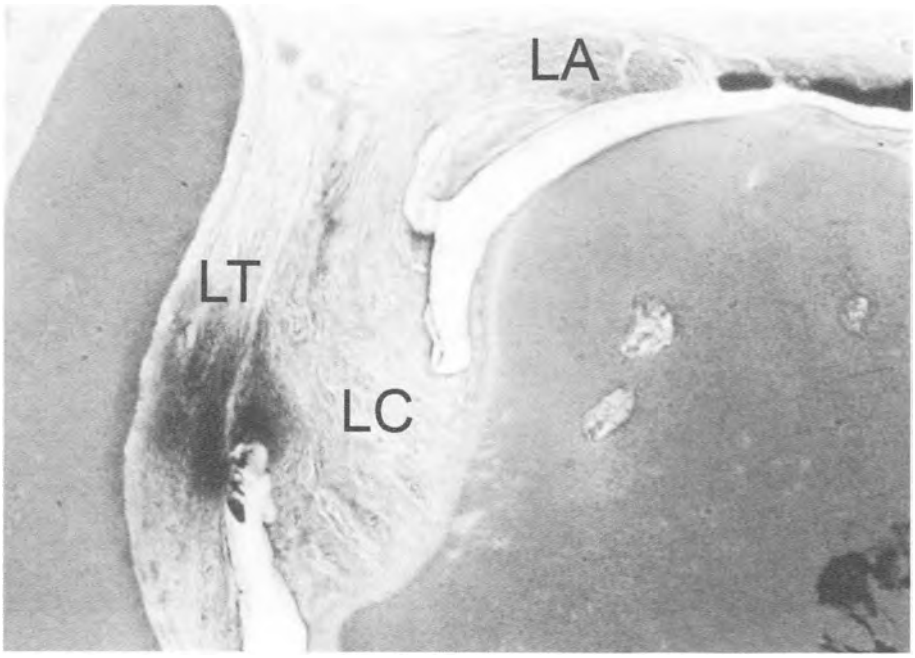

Fig. 6. Lig. transversum acetabuli (LT), lig. capitis femoris (LC) and labrum acetabulare (LA) of a 5 months old human fetus

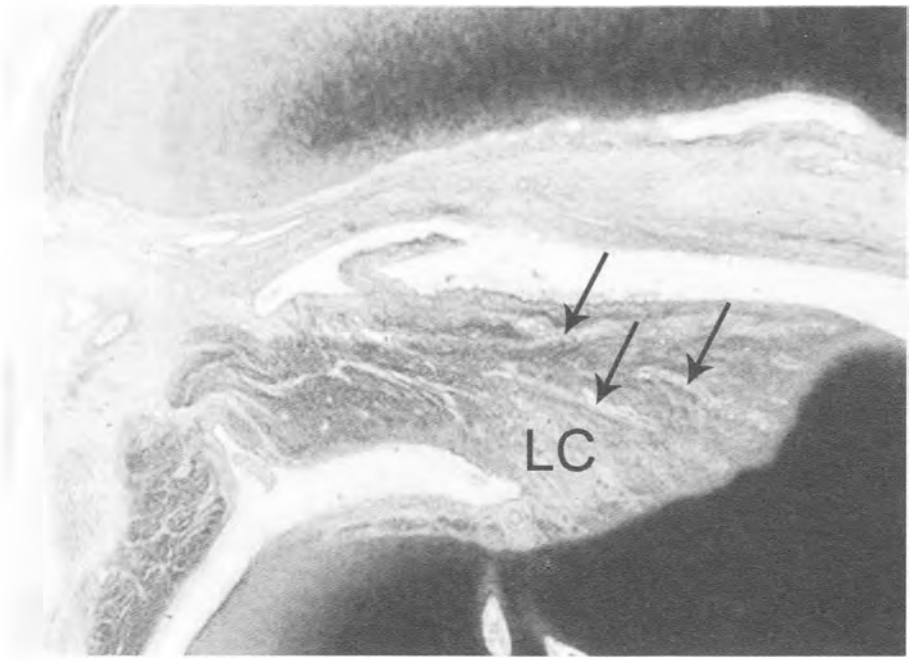

Fig. 7. Lig. capitis femoris (LC) of a 5 months old human fetus with vascular canals (arrows)

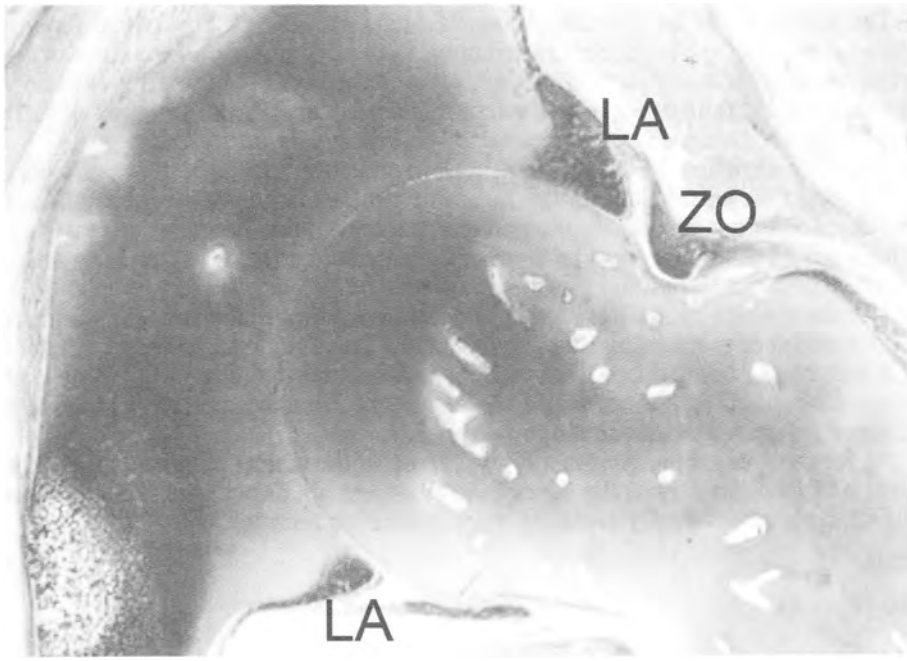

Fig. 8. Zona orbicularis (ZO) and labrum acetabulare (LA) of a 5 months old human fetus

(caudal labrum) whose collagen fibers penetrate the embryonic cartilage. The ring is abundantly vascularized during all the stages of development. Its upper portion (cranial labrum) is much more prominent and covers the femoral head (Fig. 5).

The internal joint structures differentiate in parallel with the articulating surfaces, and at first look like mesenchymal condensations. With advancing time, the amount of collagen fibers in them gradually increases. The lig. transversum acetabuli and the lig. capitis femoris are formed together with the caudal labrum (Fig. 6). The lig. capitis femoris occurs in the intermediate zone of the joint and retains its location between the skeletal anlagen. Between the collagen bundles making it up, numerous vascular canals are present (Fig. 7).

The joint capsule, the zona orbicularis and the extra articular ligaments appear as accumulations of collagen fibers (Fig.8).

Discussion

The study corroborates the data of other authors (Gray and Gardner, 1950) about absence of essential differences in the main stages of the development of the hip and other joints. An important stage of the formation of the skeletal elements is the occurence of chondroblasts, that produce precursors of the extracellular matrix.

The hip joint structures originate from the joint intermediate zone. Together with the chondrification of the skeletal anlagen, differentiation of the synovial membrane takes place. It includes differentiation of functionally different synovial fibroblasts and synovial macrophages that provide the homeostasis of the joint (Wassilev, 1981).

The formation of the chondrogeneous skeletal anlage of the proximal femur gets ahead of the one of the hipbone. Contributing to the congruency of the joint is the acetabular labrum. Its upper portion predominates in the course of the differentiation and undertakes a part of the pressure of the femoral head. The internal structure of this portion is the one of an abundantly vascularised connective tissue complex.

The differentiation of the lig. transversum acetabuli lags behind when compared with the one of the acetabular labrum. As a result of the loading of the joint and because of the absence of a skeletal pad, the collagen content in this ligament increases, and a cartilaginous covering occurs. The latter complements the facies lunata as an articulating surface of the acetabulum.

The importance of the lig. capitis femoris to the hip joint biomechanics and trophics is a matter of great discussion. Given that the articulating surfaces at birth are only in part congruent, the ligament most probably contributes to the stability of the joint. In addition, by containing a lot of blood vessels (as the ultrastructural analysis reveals) it undoubtedly contributes also to the joint trophics.

As for the congenital dysplasia of the hip joint, the results obtained suggest that it is a result of deviations from the normal development not only of the skeletal elements but of all the joint structures including the surrounding muscles.

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