HISTOMORPHOLOGIC CHARACTERISTICS OF NEWLY FORMED CAVITY OF A HIP JOINT IN DISLOCATION IN EXPERIMENT

UDC 616.728.2–006–092:616.001.6–001.6
Received 24.04.2012

© **I.Y. Ezhov,** D.Med.Sc., Associate Professor, the Department of Surgery, the Faculty of Doctors' Advanced Training[1];
Head of the Department of Traumatology and Orthopedics[2];
Y.I. Bushuev, PhD, Senior Research Worker, the Pathomorphology Department[3];
Y.I. Ezhov, D.Med.Sc., Professor[3]

[1]Nizhny Novgorod State Medical Academy, Minin and Pozharsky Square, 10/1, Nizhny Novgorod, Russian Federation, 603005;
[2]Privolgzhsky District Medical Center of Federal Medico-Biologic Agency of Russia, Nizhne-Volzhskaya naberezhnaya St., 2, Nizhny Novgorod, Russian Federation, 603005;
[3]Nizhny Novgorod Research Institute of Traumatology and Orthopedics, Ministry of Health of the Russian Federation, Verkhne-Volzhskaya naberezhnaya St., 18, Nizhny Novgorod, Russian Federation, 603155

The aim of the investigation was to study in experiment the head of femur dislocation, which is a variety of transchondral damages, and the process of chondro- and osteogenesis in articular surface formation to create optimal conditions for their reparation and new formation.

Materials and Methods. The experiment was carried out on 20 reproductive chinchilla rabbits. The head of femur was dislocated in experiment after joint capsule transaction, and exposed to dosing impact and force effect in the area of its upper pole. A blow was stricken by the device looking like an impact machine. The blow energy was regulated by changing load weight and the pendulum height. The animals were removed from the experiment 3, 7, 14, 30 days and 3 months after the injury.

Results. For the initial few days in the dislocation area there were found fibrin effusions, hemorrhage, periosteal edema, and granulation tissue. In 2 weeks in fibrous tissue there were determined focal clusters of chondroblasts. By the end of the first month, near the head of femur, connective tissue was underlaid by newly formed fibrous cartilage with the areas of young hyaline cartilage forming a free margin. In 3 months a submarginal zone was formed of hyaline cartilage with ordered cytoarchitectonics of chondrocytes. Different-sized margins of the newly formed hyaline cartilage with the foci of complete osteogenesis in the wall of forming cavity (in the form of osseous tissue of sponge structure with the blood-forming bone marrow in interjoist) were observed in close connection with periosteum of acetabular roof.

Conclusion. A joint cavity forms on the basis of the mechanisms of pluripotent development of cambial cell elements towards chondro- and osteogenesis. Its successful formation can be accompanied by the mass of well blood-supplied muscles surrounding the dislocated head, periosteum of acetabular roof, as well as the capability of active movements the head of femur dislocated into supra-acetabular area in the absence of axial bearing on the operated extremity during the whole postoperative period. Thus, an articular cartlage has significant potential for recovery, and the obtained results enable to help lay down optimal conditions for such a recovery.

Key words: articular cartilage; cartilaginous injury; hip joint injury; hip dislocation.

The cartilage and subchondral bone are primarily affected in mechanical trauma of the hip. Even in the absence of clinically and radiologically revealed damage the integrity of trabecular bone is often violated. In this regard, the probability of various complications in the long term after the injury is a feature of the hip joint transchondral lesion. In the experiment [1] on 24 rabbits, while their hip joints being injured the head of femur (I series) and greater trochanter were affected with shock force (II series) of the femur, it is shown that reparations of damaged cartilage in the experiment was of purely abortive character and did not lead to the replacement of hyaline cartilage tissue defects.

The aim of the investigation was to study in experiment the head of femur dislocation, which is a variety of transchondral damages, and the process of chondro- and osteogenesis in articular surface formation to create optimal conditions for their reparation and new formation.

Materials and Methods. The work is based on the study of the morphological changes of cartilage and bone, occuring in the simulation of hip dislocation. The experiment was carried out on 20 reproductive chinchilla rabbits. In the experiment, after dissecting the joint capsule the femoral bone head was luxated, was affected with dozed shock force influence in its upper pole that to the greatest extent, in our opinion, corresponds to the clinic of injury got in a road traffic of the high damage [2]. The blow was delivered by the device representing copper, the impact energy was regulated by varying the load and lifting the pendulum. The animals were taken from the experiment on 3, 7, 14, 30 days and 3 months after injury. The research was performed according to the ethical principles established by the European Convention for the protection of vertebrata used for experimental and other scientific purposes (adopted in Strasbourg, Mar, 18, 1986, and confirmed in Strasbourg Jun, 15, 2006).

For contacts: Ezhov igor Yurievich, phone: +7 910-137-15-95; e-mail: iezhov70@gmail.com

For histological examination acetabulum and proximal femur greater trochanter, neck and its head were excised en bloc. The material was fixed in 10% neutral formalin and subjected to decalcification by the method of Wilson. Celloidine sections were stained with hematoxylin and eosin.

Results. Since the first days after the injury various defects or usuras penetrating into the middle and deep layers were found in the cartilage. Sometimes the articular cartilage on the small area was completely absent, so that the subchondral bone plate appeared to be naked.

In addition to the near-edge necrosis in the areas of mechanical destruction the articular cartilage of the head had necrotic changes in the places that had no apparent connection to its destruction. These necrosis were of focal nature and were located either on the surface or at the bottom of the middle zone with the transition to the deep one. In the peripheral parts of the base of the head cartilage it was often subjected to full-thickness necrosis — up to the subchondral bone plate.

On the surface of necrotic cartilage, and sometimes in the adjacentto the head areas of the neck and the greater trochanter, bedding fibrin was found having the form of lump-like compact structures, filamentous or coarser of mesh fibrinous strands, or massive clusters of fibrin, sometimes combined with fresh hemorrhages.

In the bone marrow of the head and the greater trochanter occurred pictures of focal hyperemia, they acquired diffuse-focal charater and were accompanied by focal hemorrhages more rare. The clinical pictures of focal excessive blood supply were also observed in the periosteum, sometimes swollen, sometimes hyalinized in places being prone to cystic degeneration or focal lipidization that combined with rare subperiosteal hemorrhage, or more pronounced in extravasates paraarticular tissues. Spongy bone head and trochanter were exposed to very explicit rarefaction and bone marrow showed a marked tendency to transform to the bone marrow fat eventually. In some cases, there was a replacement of myeloid bone marrow with osteogenic tissue or it was affected with fibrosation.

Repair processes in the articular cartilage of the femoral head was found in the near-edge areas of necrosis, there was also noted an insignificant picture of chondrocyte hypertrophy, hondrocyte aggregation being increased by a number of chondrocytes in cartilaginous capsule and grouping of aggregations next to necrosis. Filling of a mechanical defect of cartilage with these abortive chondrocyte proliferates was not observed.

New forming processes of cartilage were also observed, also outside the connection to the articular cartilage of the head. So, 2 weeks after the dislocation in of one of the animals fibrous tissue, developing around the site of the femoral neck at the basis of the head, the hyaline cartilage cells enclaves were found , grouped in small foci, separated by fibrous connective tissue. Some of these chondrocytes were necrotic foci. In other animal 1 month after dislocation in a poorly and irregularly vascularized dense scar that developed in the area of the greater trochanter, quite large chondrocytes surrounded by a well-developed matrix were located. Along with this the enclaves of fibrous cartilage character passing along the periphery into the structure of hyaline cartilage. One of the animals after three months of observation dislocated femoral head was partially bricked up in the spikes, synechias and commissures formed between it and the likeness of the scar capsule surrounding the head. Thus in some parts of the free edge of the articular cartilage of the head along with fresh fibrinous deposits found in bedded mature tissue, and in one of the commissures there were located chondrocytes nidus, forming cartilage- hyaline by nature.

In addition to changes occurring in experimental hip dislocation in the proximal femur, and especially in the head, the processes in the acetabulum and head area dislocation have also been studied.

In the first 7 days from the time of dislocation in the acetabulum cavity observed a very slight fibrin stratum at the edges, and sometimes fibrin mesh stratum or the more compact stratums of fibrin in the rest of its parts. Sometimes a flap of a damaged joint capsule wrapped to the cavity, the capsule sometimes being swollen, irregularly fulfilling in some areas slightly imbibited blood was covered with a thin fibrous layer. Bone tissue of acetabulum bone bed remained intact. In its bone marrow spaces contained erythroblastic normal myeloid bone marrow, sometimes with the presence of over-blooded small fresh hemorrhages.

By the end of the 2nd week from the time of dislocation the acetabulum is filled with maturing connective tissue (Fig. 1). The free edge of the acetabulum articular cartilage of the animals was covered with young erythroblastic granulation tissue with fibrinous deposits in the form of delicate filamentary structures or the more compact clumps of fibrin.

Changes in the acetabulum after 1 month from the time of dislocation presented ambigious. Apart from the fact that changes in the articular cartilage cannot be detected, there is atrophy of cartilage lining. Sometimes the free edge of the articular cartilage is partially covered by a thin layer of mature fibrous connective tissue. In one of the animals an outer layer and a part of the middle layer of the articular

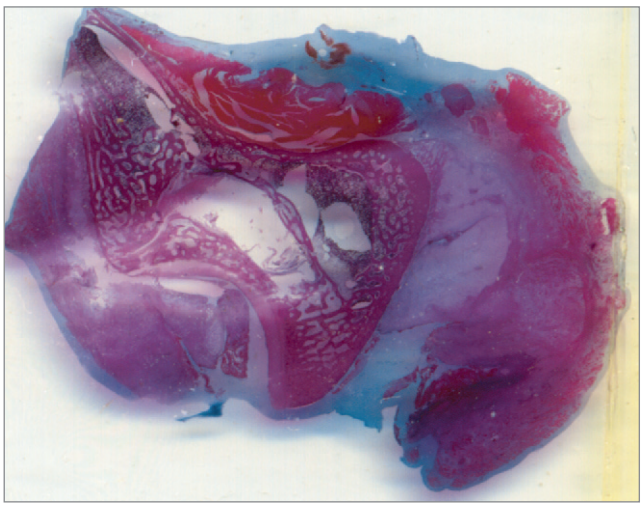

Fig. 1. Two weeks after the dislocation: the cavity is filled with granulation tissue with fibrinous deposits; the area of head dislocation. Scanning. Hematoxylin-eosin staining

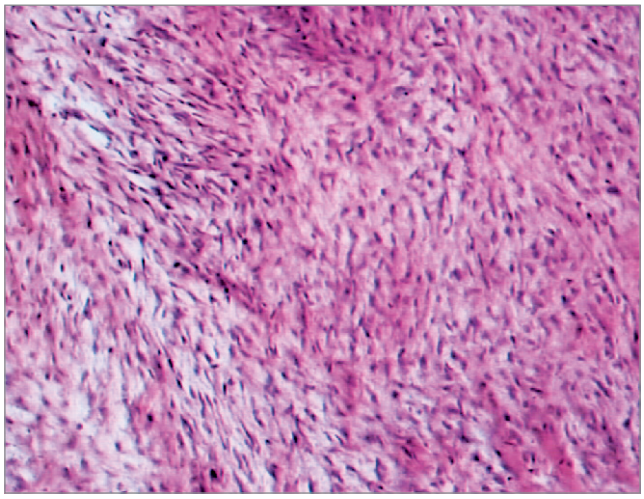

Fig. 2. Two weeks after dislocating: erythroblastic loose edematous granulation tissue with signs of maturation it up to fibrosis in the area of deployment. Ocular ×10, lense ×40; hematoxylin-eosin staining

cartilage appeared to be necrotic cavities with the pattern of focal chondrocyte proliferation in paranecrotic zone and, in the other sections, the free edge of the cartilage has been lined with a wide layer of young connective tissue. The acetabulum bone bed tissue remained unchanged. In some cases, the tendency to fibrosis of the bone marrow and a slight tendency to rarefaction of the bone bed was observed.

By the end of three months from the moment of dislocation of the articular cartilage of the acetabulum either remained unchanged or showed lesions of purely superficial necrosis with reactive proliferation of chondrocytes in the paranecrotic area and fragmentation of small areas of necrotic cartilage. In other cases, directly at the edges of the acetabulum or in its entirety we observed erythroblastic young connective tissue or completed in its development cicatrice with the symptoms of poor vascularization. Acetabulum bone bed within the period was under marked rarefaction and bone marrow in the interjoist spaces of porous substance — fibrosis.

In one of the animals in the area of the head dislocation 7 days after injury were observed the pattern of new focal necrosis of periosteum acetabulum roof with the presence of necrotizing fibrinous stratums and neighboring unaltered areas. In another case, 2 weeks after the injury in the area of the head dislocation next to the roof of the acetabulum significant areas of loose edematous erythroblastic granulation tissue with the symptoms of its more or less marked maturation, up to the fibrosing of peripheral regions of this connective tissue mass were found (Fig. 2). The dissociated bundles of muscle fibers or individual fibers with varying degrees of severity of atrophic changes were collocated.

In one case, after 2 weeks in the areas of direct contact of such a connective tissue mass with the femoral head (Fig. 3). Proliferation of connective tissue erythroblastic structures with a tendency to mutually parallel orientation took place. There are isolated chondrotsyte (Fig. 4) or small focal accumulations in this inner layer surrounding the head, part of chondrocytes, at that it turns out to be the subject to necrobiotic changes and necrosis (Fig. 5).

The changes in the area of the dislocation of the femoral head revealed 1 month after are of considerable interest the time of dislocation. In one of the animals there were bands and areas of fibrous, dense connective tissue scaring in some places with imbedded in it dissociated muscle fiber bundles with distinct phenomena of dystrophy and atrophic changes. On the periphery of the mass near the roof of the acetabulum there was located a focal point of the newly formed bone tissue with a tendency to the formation of porous structures and swollen irregularly filled with the blood fibrosing bone marrow.

In another animal in a mass of dense connective tissue free edge with a smooth surface was contoured, lined with well-rounded cells with well-staining small nuclears of cellular elements like, of the fibroblast-fibrocyte series (Fig. 6). This substance is underlaid, and in some areas, is substituted with vast newly formed hyaline type of cartilage

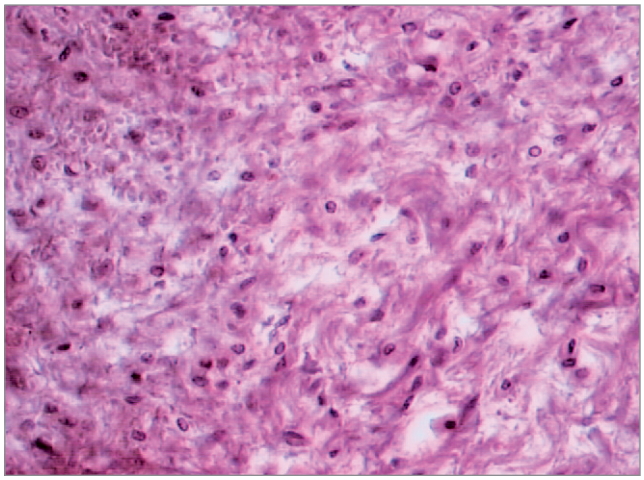

Fig. 3. Two weeks after the dislocation: a connective array in the head. Ocular ×10, lense ×40; hematoxylin-eosin staining

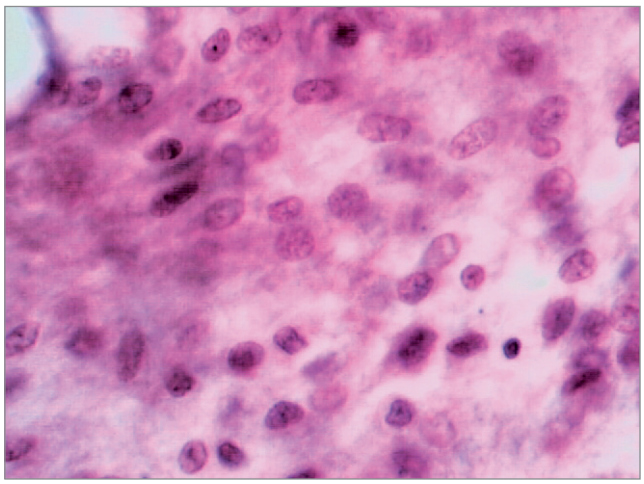

Fig. 4. Two weeks after the dislocation: a fibrous connective tissue isolated chondroblasts. Ocular ×10, lense ×40; hematoxylin-eosin staining

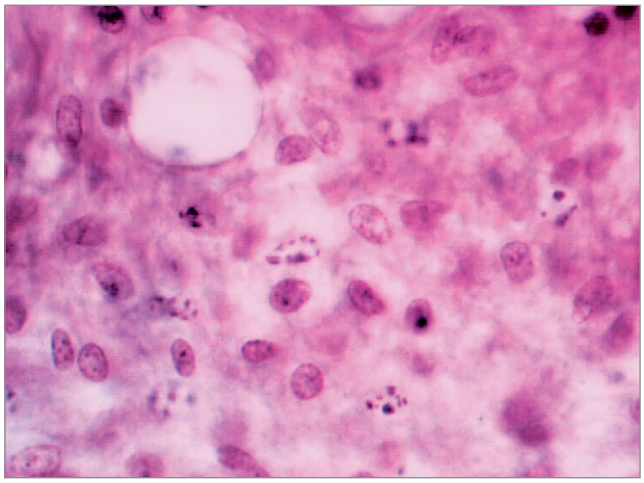

Fig. 5. Two weeks after the dislocation: a part of chondrocytes exposed necrobiotic changes and necrosis. Ocular ×10, lense ×40; hematoxylin-eosin staining

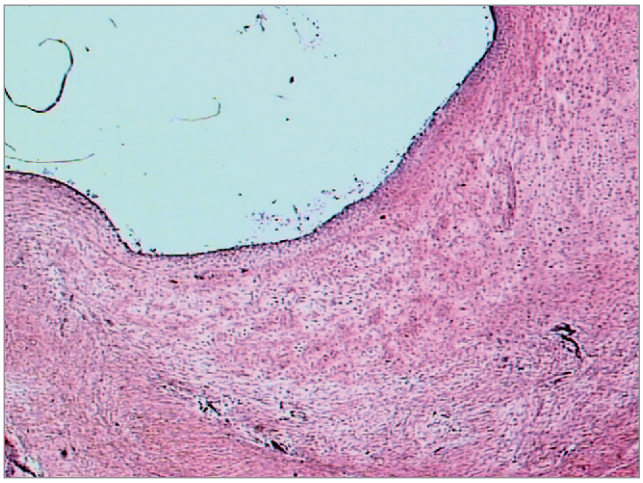

Fig. 6. One month after the dislocation: the newly formed free edge with a smooth surface lined with rounded cells fibroblast-fibrocyte series. Ocular ×10, lense ×40; hematoxylin-eosin staining

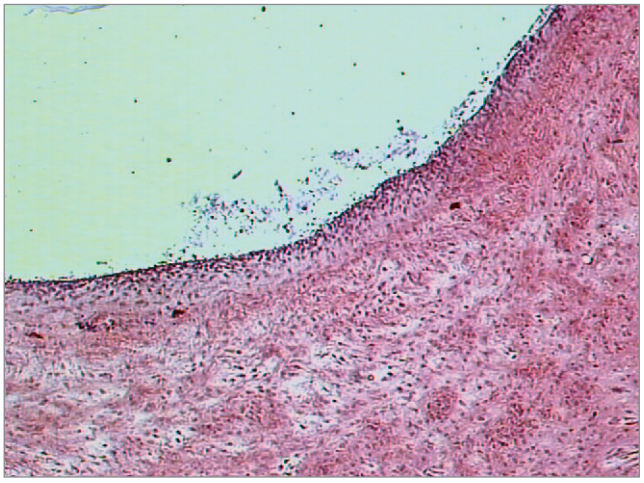

Fig. 7. One month after dislocating: newly forming fibrocartilage. Ocular ×10, lense ×40; hematoxylin-eosin staining

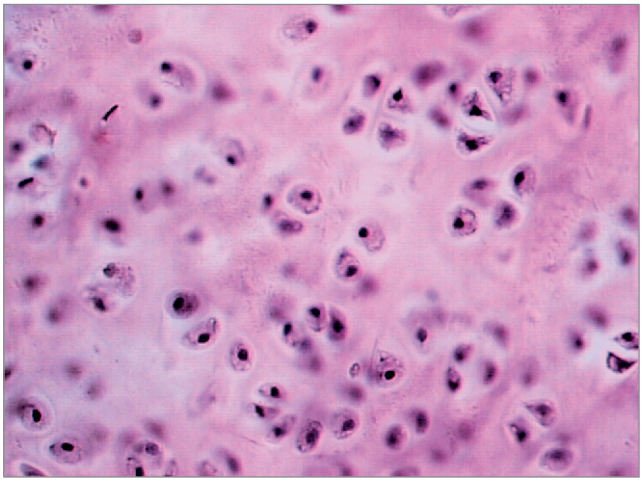

Fig. 8. One month after dislocating: free loose arrangement chondrocytes of the young newly formed hyaline cartilage. Ocular ×10, lense ×40; hematoxylin-eosin staining

(Fig. 7). In these areas there were some focal points of the newly formed hyaline cartilage with friable (Fig. 8) or a more dense arrangement of mono-morphic large small nuclear chondrocytes (Fig. 9).

In one of the sections of this cartilage proliferate located focal points of newly forming spongy bone with the signs of enchondral and trabecular bone structures ossification. This bone was compactized and had full-blooded fat bone marrow interjoist spaces. All of this is surrounded by atrophing muscle tissue and was separated from it by well-formed capsule of mature fibrous connective tissue. Along with the signs of cartilage formation in the area of head dislocation near the roof of the acetabulum there were found combined signs of fibrous and young hyaline cartilage with focal endostosis.

To a large extent these signs seem to be similar to zone changes of dislocation of the femoral head in the other two animals of this period of observation. In these cases, even more clearly defined the free edge of the newly formed coxal cavity, built of fibrous connective tissue developed

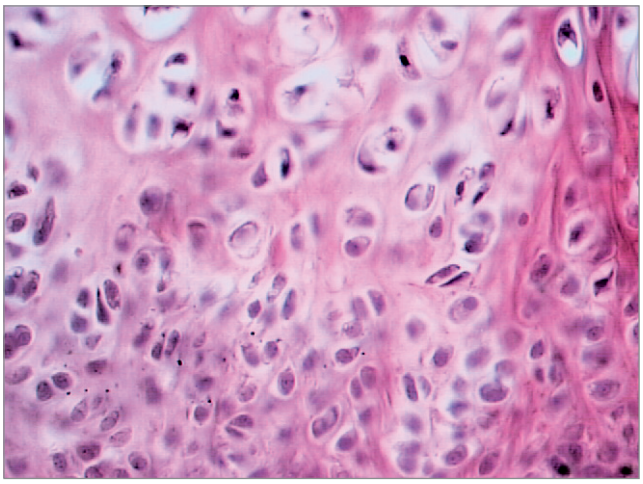

Fig. 9. One month after the dislocation: an intimate arrangement chondrocytes of monomorphic small nuclear of young newly formed hyaline cartilage. Ocular ×10, lense ×40; hematoxylin-eosin staining

as its narrow or broader layer with a well-ordered, mutually parallel arrangement of collagen fibers and fibrocyte cellular elements. This fibrous connective tissue underlaid newly forming cartilage tissue, built according to the type of transition fibrous hyaline cartilage with a disordered arrangement of chondrocytes with small well-stained nuclei having well-rounded or polygonal shape. In some places such as cartilage forming a free edge of the cavity that is formed around the dislocated head (Fig. 10). Sometimes there are niduses or massive fields of proliferating or, vary continiously maturing hyaline cartilage, sometimes with signs of endostosis up to the formation of primitive bone trabeculae or more mature bone tissue of spongy structure with integral or integrated beams.

By the end of three months in the area of the head dislocation in the vicinity of the acetabular roof and close engagement with a sub-marginal-zone of newly formed acetabulum is more enriched with fibrous cartilage, replacing, in turn, the maturing cartilage of hyaline nature. In some cases, the entire thickness of it is built of hyaline cartilage with an ordered cytoarchitectonic of compactly located monomorphic moderately, mature enough chondrocytes (Fig. 11) with inclusions of maturing or mature trabecular bone sponge substance (Fig. 12), sometimes being similar to the subchondral bone plate (Fig. 13).

Free edge of the forming cavity by the end of the experiment is uneven in its structure. It is built of erythroblastic fibrous connective tissue acquiring similarity to a fibrous or hyaline cartilage. Sometimes this kind of cell formations in the form of a very broad layer inlay the well-formed hyaline cartilage with a chaotic and loosely arranged chondrocytes, in other cases, the entire thickness of the cavity forming cartilage — hyaline nature with partly chaotic arrangement of different-sized chondrocytes. Certain parts of the free edge of the forming cavities are sometimes presented quite equal

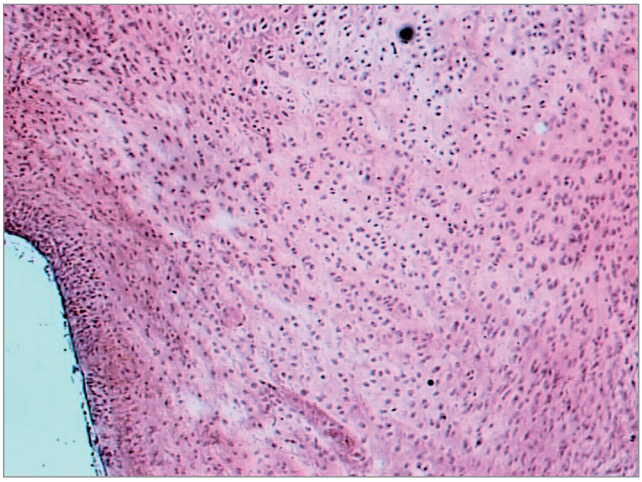

Fig. 10. One month after dislocating: cartilage, forming a free edge of the newly-formed cavities. Ocular ×10, lense ×40; hematoxylin-eosin staining

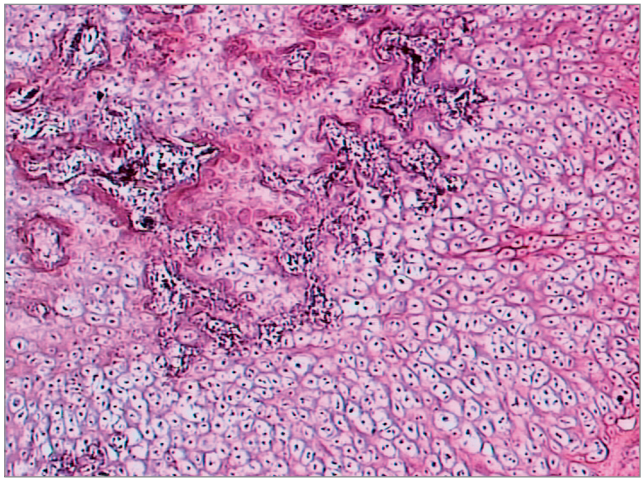

Fig. 12. Three months after the dislocation: the inclusions of maturing cancellous newly formed bone. Ocular ×10, lense ×40; hematoxylin-eosin staining

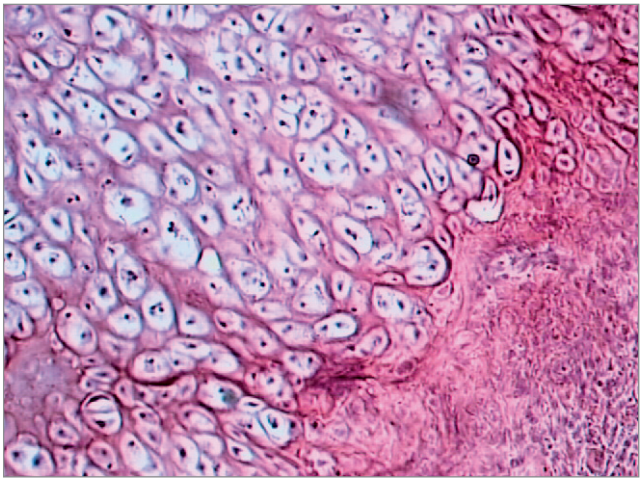

Fig. 11. Three months after dislocating: fibrous cartilage is replaced by the newly-formed hyaline cartilage with the ordered cytoarchitectonics of compactly located monomorphic chondrocytes. Ocular ×10, lense ×40; hematoxylin-eosin staining

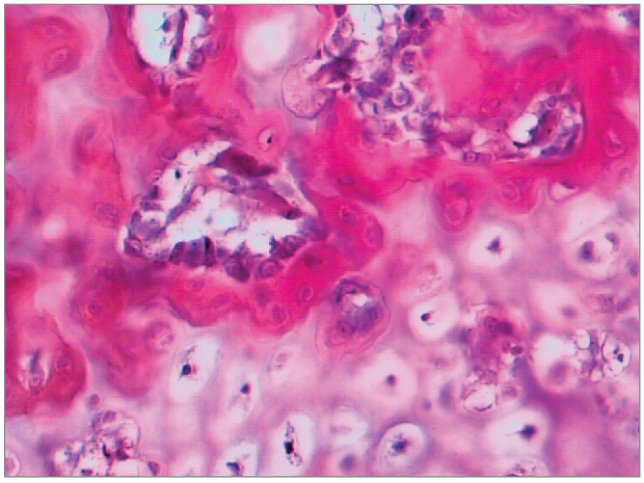

Fig. 13. Three months after the dislocation: the maturing newly formed trabecular bone takes resemblance to the subchondral bone plate. Ocular ×10, lense ×40; hematoxylin-eosin staining

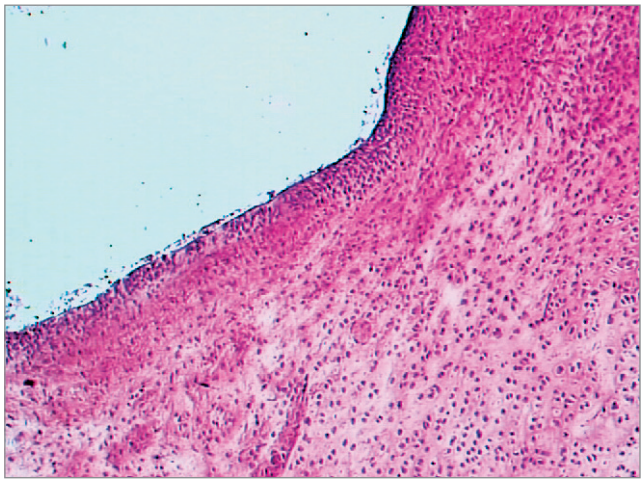

Fig. 14. Three months after dislocating: clearly distinguishable, well circumscribed smooth edge of the newly formed cavity of heterogeneous structure. Ocular ×10, lense ×40; hematoxylin-eosin staining

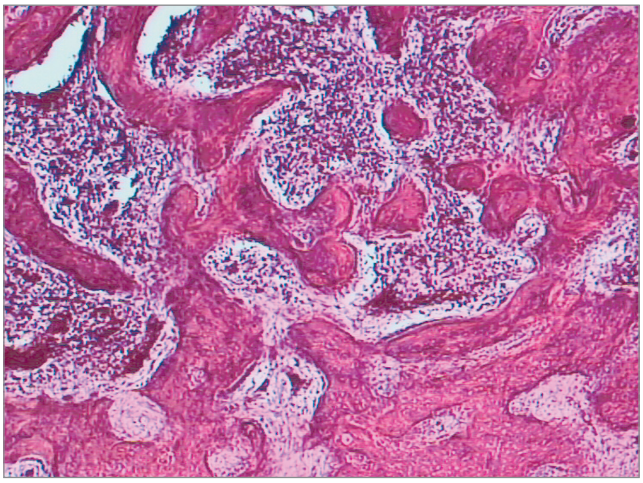

Fig. 15. Three months after dislocating: newly forming bone spongy structure with the presence of hematopoiesis bone marrow next to the periosteum of the acetabular roof. Ocular ×10, lense ×40; hematoxylin-eosin staining

throughout fairly great extent (Fig. 14). It should also be noted that different-sized being often quite large in the middle of the newly formed hyaline cartilage with niduses of completed bone formation in the wall of the forming cavity in the form of bone of spongy structure with the presence of blood-forming bone marrow in header-joist spaces are found in close conjugation with the periosteum of the acetabulum roof (Fig. 15).

Discussion. The assessment of histomorphological pictures of the dislocation of the femur suggests a new formation and very intensive development of fiber, and what is especially important, hyaline cartilage with a tendency to the formation of a new acetabulum. This impression is reinforced by the fact that in the area of cartilage regenerate the spongy bone is quite rapidly developing, usually contiguous to the roof of the acetabulum or on the periphery of the growing fields and arrays of newly formed cartilage tissue near the greater trochanter.

It should be said that in a few publications devoted to dislocations, including the hip, or clinical manifestations of coxarthrosis, it is also mentioned the formation of the new cavity and development of cartilage tissue in the area of epy location of the articular head of the femur or stump. The first of the publications available to us belongs to T. Billroth (1879), who wrote about the dislocation of the shoulder: «... in the newly formed glenoid cavity a fairly thick layer of cartilage may develop» [3]. Also the information presented by V.D. Chaklin [4] for the formation of cartilage in the case of arthrosis, arthritis of the hip as a complication of typhoid fever is of interest. If the femoral head is destroyed, the stump of its neck is usually appeared to be covered with cartilage tissue with an irregular bumpy surface, and the new joint bed is lined with chondroid tissue. Finally, in 1993, O.Sh. Buachidze in one of his studies showed that overgrown soft connective tissue gradually becomes rough, thickened, turning in the dense scarring, in 1.5–2 months after acetabulum fracture and after 5–6 months, and is a single, thickened conglomerate along with some of the muscles surronding coxafemoral joint [5].

Unfortunately, we in all publications having beenfound by us there is no results of histologic study and photomicrographs of those formations which are considered by the authors as a newly formed glenoid cavity, that does not make it impossible to compare the seen pictures of the newly-formed cartilage with the character of described changes in the area of deployment of the articular head. Chronic hip dislocation in dogs, but in relation to the pre-existing cavity and the femoral head [6] is described in details.

Thus, the results of the experiment with a dislocated hip in experimental animals indicate that in the context of dislocation being accompanied with the shock applied on the femoral head, its articular cartilage suffers greatly, also the acetabulum is changed, where the phenomenon of articular cartilage atrophy with partial replacement of its connective tissue is developed and there is a reduction of the spongy substance of acetabulum with fibrosis of the bone marrow. New fiber, and then the well-formed hyaline cartilage with enchondral ossification and formation of bone structures such as cancellous bone rapidly develop in the area of head dislocation. A tendency to newly-formed acetabulum presented first as fibrous connective tissue, and then as fibrous and hyaline cartilage is found.

In general, we can agree with the statements that the articular cartilage is significantly potential for its restoration [7], and further tasks can be the research at the contemporary level of the best conditions for this restoration. The described changes can help to formulate these conditions.

Conclusion. A joint cavity forms on the basis of the mechanisms of pluripotent development of cambial cell elements towards chondro- and osteogenesis. Its successful formation can be accompanied by the mass of well blood-supplied muscles surrounding the dislocated head, periosteum of acetabular roof, as well as the capability of active movements the head of femur dislocated into supra-acetabular area in the absence of axial bearing on the operated extremity during the whole postoperative period.

References

1. Bushuev Yu.I., Ezhov Yu.I., Ezhov I.Yu. Gistomorflogicheskaya kharakteristika tkaney tazobedrennogo sustava pri mekhanicheskoy travme [Histomorphologic characteristics of hip joint tissues in mechanical injury]. *Vestnik travmatologii i ortopedii im. N.N. Priorova — Vestnik of Traumatology and Orthopedics named after N.N. Priorov* 1997; 2: 56–59.

2. Yang R.S., Tsuang Y.H., Hang Y.S., Liu T.K. Traumatic dislocation of the hip. *Clin Orthop Relat Res* 1991 Apr; 265: 218–227.

3. Billroth T. *Obshchaya khirurgicheskaya patologiya i terapiya v pyatidesyati lektsiyakh* [General surgical surgery and therapy in fifty lectures]. Saint Petersburg: Izd. knizhnago magazina «Novago vremeni»; 1879; 856 p.

4. Chaklin V.D. *Infektsionnye zabolevaniya kostey, sustavov i khryashchey* [Infectious diseases of bones, joints and cartilages]. Sverdlovsk; 1937.

5. Buachidze O.Sh. *Perelomovyvikhi v tazobedrennom sustave* [Hip joint dislocation-fractures]. Moscow: MONIKI; 1993; 198 p.

6. Chernigov Yu.V., Chirkova A.M., Molokanov V.A., Ilizarova G.A. *Morfologicheskie izmeneniya v tazobedrennom sustave sobaki pri zastarelom vyvikhe bedra* [Morphological changes in dog's hip joint in neglected hip dislocation]. http://vetport.ru/modules.php?name=Pages&pa=showpage&pid=92

7. Yang N.P., Chen H.C., Phan D.V., Yu I.L., Lee Y.H., Chan C.L., Chou P., Renn J.H. Epidemiological survey of orthopedic joint dislocations based on insurance data in Taiwan, 2000–2005. *BMC Musculoskelet Disord* 2011 Nov; 12: 253. doi: 10.1186/1471-2474-12-253.