Institute of Experimental Morphology and Anthropology with Museum
Bulgarian Anatomical Society

Acta morphologica et anthropologica, 13
Sofia • 2008

Ultrastructural Features of the Different Zones of the Menisci

M. Kalniev, N. Vidinov, K. Vidinov

Department of Anatomy and Histology. Medical University, Sofia

The aim of our study was to present in detail that the meniscus is a heterogeneous, whose structure is depending on the different functional demands from the different zones. The investigations were performed upon menisci of the knee joints of Wistar rats. A light microscopy and transmission electronic microscopic observation were used. We made a new division of the zones of the meniscus: 1. A Superficial sliding zone (SSZ). 2. A Transitional sliding zone (TSZ). 3. A Superficial pressure zone (SPZ). 4. A Transitional pressure zone (TPZ). 5. A Central zone (CZ). 6. A Zone of fusion (ZF). 7. A Parameniscal zone (PZ). We pay attention to the SSZ and the CZ because these zones were more energetic than the others.

Key words: meniscus, proteoglycans, collagen, chondroblasts, fibroblasts.

Introduction

The menisci are different depending on the type of cells and the intercellular matrix. The menisci are built on following zones: a sliding zone (upper and lower), a pressure zone (in the middle), a tense zone (in the periphery) [8] and a parameniscal zone [11]. These zones have heterogeneous structure especially as far as the intercellular matrix is concerned. The pressure zone is built on a hyaline cartilage; the sliding zone is built on a fibrocartilage. The tense zone has a fibrous connective tissue [4]. This structure is formed in connection with the mechanical functions of the meniscus. These functions depend on the meniscus' viscoelastic properties and the interaction between the macromolecules of the tissue (collagen, proteoglycans) and water [6, 7, 3]. There are contradictory investigations about cytoarchitectonics, the collagen and the proteoglycans in the different zones of the meniscus. Some authors claim, the regions that are subjected to tense forces are fibrous and contain fibroblasts. The regions subjected to pressure forces are more "hyalinizates" and contain chondroblasts [2, 5, 6, 10].

Transmission electron microscopy shows, that on the surface of the meniscus there is an amorphous layer covering it [1]. The question of the precise division of the meniscus is not completely resolved. A full ultrastructural characterization of the cells in the different zones of the normal meniscus has not done.

Material and Methods

The materials of the investigation were menisci of the knee joints of 20 Wistar rats. The fixation was carried out by glutaraldehyde and formalin. The samples were investigated by routine light microscopy after staining in Mason, Azan, alcian blue, hematoxylin-eosin and microscopy and Van Gieson. Routine transmission electron microscopy was used.

Results

We made a new division of the zones of the meniscus: 1. A Superficial sliding zone (SSZ). 2. A Transitional sliding zone (TSZ). 3. A Superficial pressure zone (SPZ). 4. A Transitional pressure zone (TPZ). 5. A Central zone (CZ). 6. A Zone of fusion (ZF). 7. A Parameniscal zone (PZ). We pay attention to the SSZ and the CZ, because these zones were more energetic than the others.

The light microscopic examination of the meniscus showed, that SSZ was narrowly stripe, which lateral passed to the PZ, medial to the ZF, downwards to the TSZ. The articulations surface above the zone is completely smoothly. The relief of the SSZ depends of the prolongated bodies of the cells of the superficial layer and the bundles of thick collagen fibers situated between them. The cells from this zone were fibroblasts. They were prolonged and were situated parallel to the articulation surface. These cells had developed granular endoplasmic reticulum, which sometimes was approximately 2/3 of the cells' volume. At the same time they had developed Golgi complex and lysosomes (Fig. 1). The lysosomes of the chondroblasts of the articular cartilage were observed comparatively rarely. The examination with Safranin O showed comparatively few proteoglycan complexes situated uniformly in the intercellular matrix. The CZ was built on rare situated large, light, blistered cells. These

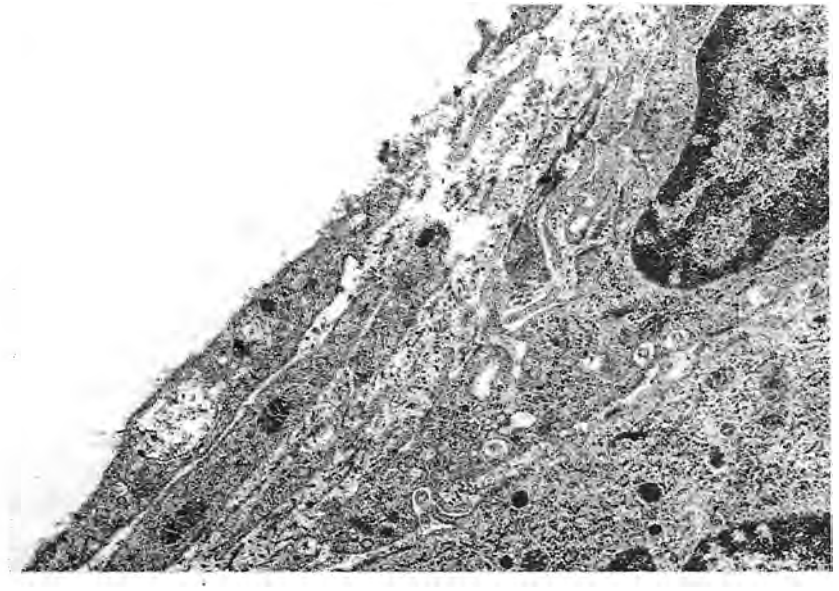

Fig. 1. Cells from the superficial sliding zone. × 10 000

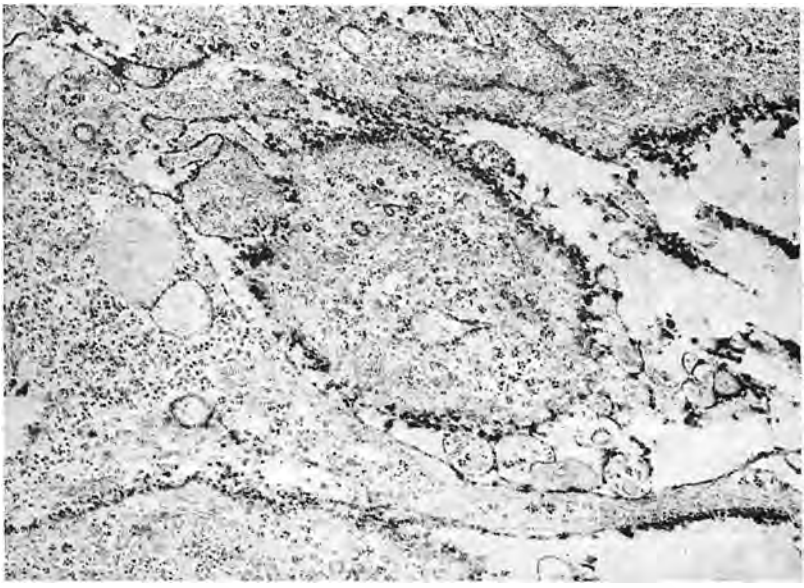

Fig. 2. Cells from the central zone. There is a big concentration of proteoglycans in the territorial matrix. × 10 000

cells had cytoplasm with few organelles (mainly separately cisterns GER). The intercellular space was filled with fine collagen network type II and proteoglycan complexes. They were more in the territorial matrix than the teritorial matrix (Fig. 2). There were matrix vesicles in the matrix of the CZ without clear marks of calcification. These vesicles were single or filled considerable part of the intercellular space.

Discussion

The meniscus is a heterogeneous, whose structure is depending on the different functional demands from the different zones. SSZ has ultrastructural characterization that resembles the tangential layer of the articular cartilage [9]. The fact that the cells are fibroblasts shows us the presence of intensive collagen synthesis, which depends on the considerable tense forces in this zone. The evidence for the above-mentioned is the electron microscopic characterization of the collagen type I. The distribution of the proteoglycan complexes, however, shows for severe friction forces at the same time. The conclusion is that SSZ is metabolic the most actively in response to the increased functional requirements. A CZ manifests reinforced processes of degeneration and calcification. A cause for the above-mentioned is the necessity of opposition to the increased pressure forces at the time of growth.

Further investigation of the ultrastructural organization ought to be done in connection with the important role of the menisci for the biomechanics of the knee joint. It is known that the injuries of the menisci are the most frequent injuries of the soft tissues of the knee.

References

1. Ghadially, F. N., J. M. Labonde, J. H. Wedge. Ultrastructure of normal and torn menisci of the human knee joint. — J. Anat., **136**, 1983, 773-779.
2. Gillard, G. S., H. C. Reilly, P. G. Bell-Booth, M. H. Flint. The influence of mechanical forces on the glycosaminoglycan content of the rabbit flexor digitorum profundus tendon. — Connect. Tissue Res., 7, 1979, 37-46.
3. Helio Le Graverand, M. P., Y. Ou, Y. Schield, L. Barclay, D. Hart, T. Natsume, J. B. Rattner. The cells of the rabbit meniscus: their arrangement, interrelationship, and morphological variations on cytoarchitecture. — J. Anat., **198(Pt 5)**, 2001, 525-535.
4. Kalinev, M., N. Vidinov. Ultrastructural investigation of the menisci of the knee joints in rats. — In: 11th Congress of Anatomists, Histologists and Embryologists. Sofia 1993.
5. Mow, V. C., M. H Halmes, W. M. Lai. Fluid transport and mechanical properties of articular cartilage: a review. — J. Biomech., **17**, 1984, 377-394.
6. Myers, E. R., W. Zhu, V. C. Mow. Viscoelastic properties of articular cartilage and meniscus. — In: Collagen: Chemistry, Biology and Biotechnology, (Ed. M.E. Nimni) vol. II, Boca Raton, FL. CRC Press, 1988, 268-288.
7. Proctor C. S., M. Schmidt, R. R. Whipple, M. A. Kelly, V. C. Mow. Material properties of normal medical bovine meniscus — J. Orthop. Res., 7, 1989, 771-782.
8. Sick, H., P. Ring, Ch. Ribat Koritke. — Compt. Rend. Ass. Anat., **143**, 1969, p. 1565.
9. Vidinov, N. Development of Articular Cartilage. Ultrastructural and Histochemical Investigation. Dissertation, 1981.
10. Vogel, K. G., M. Paulsson, D. Heinegard. Specific inhibition of type I and type II collagen fibrogenesis by the small proteoglycan of tendon. — Biomech. J.,**223**, 1984, 587-597.
11. Wladimirov, B., A. Welisarov. Changes in structure of menisci in various functional states of the knee joint in dogs. — Anat Anz., **135**, 1974, p. 327.