Original Article

NEW ULTRASTRUCTURAL INVESTIGATIONS OF THE CENTRAL ZONE OF THE MENISCI IN THE KNEE JOINT

Nikolay K.Vidinov,
Manol A. Kalniev,
Kalin N.Vidinov[1],
Theodora M. Papadopoulou[2]

Department of Anatomy and Histology,
Medical Faculty,
Medical University,
Sofia, Bulgaria
[1]Department of Endocrine Surgery,
University Specializing Hospital for Active Treatment of Endocrinology,
Sofia, Bulgaria
[2]Department of Orthopedics Diana Princess of Wales Hospital
Grimsby, UK

Corresponding Author:
Manol Anastasov Kalniev
Department of Anatomy and Histology,
1, G.Sofiiski, str.
Sofia, 1431
Bulgaria
e-mail: manol_kalniev@yahoo.com

Summary
On the basis of our investigations of the morphology of the menisci we adopted 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). These zones are the most visible in the most wide part of the cross sectioned meniscus. We pay a special attention to the CZ, because this zone is little investigated. The CZ is situated in the inmost part of the meniscus and it is surrounded by the PZ, the TSZ and the TPZ. The CZ is built on rare situated large, blistered chondroblasts with oval form. They have large, light nucleus and cytoplasm with few organelles. The intercellular space is filled with fine collagen fibers which were type II and proteoglycan complexes. They are more in the interterritorial matrix than the territorial matrix. There are matrix vesicles in the matrix of the CZ without clear marks of calcification. These vesicles are single or in some sectors filled considerable part of the intercellular space.

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

Introduction
The menisci are different depending on the type of cells and the intercellular matrix. According to Sick H. et al. [1] the menisci are built on the following zones: a sliding zone (upper and lower), a pressure zone (in the middle), and a tense zone (in the periphery). Later on Wladimirov B. and Welisarov A. [2] added a parameniscal zone which is situated most peripherally in the meniscus. These zones have the heterogeneous structure especially as far as the elements of the intercellular matrix are concerned. The sliding zone is built on a fibrocartilage; the pressure zone is built on a hyaline cartilage. The tense zone has a fibrous connective tissue [3] and the parameniscal zone has a loose connective tissue [2]. This structure is formed in connection with the mechanical functions of the meniscus. The viscoelastic properties of the meniscus and the interaction between the macromolecules of its tissue (collagen, proteoglycans) and water define the mechanical functions of the meniscus [4, 5, 6]. In present time there are contradictory investigations about cytoarchitectonics of the collagen and the proteoglycans in the different zones of the meniscus. Some authors [5, 7, 8, 9] 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.

The transmission electron microscopy shows, that on the surface of the meniscus there is a covering amorphous layer [10]. 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 been yet.

Materials and Methods

The materials of the investigation were menisci of the knee joint of 30 Wistar rats of both sexes, aged between 60 and 120 days, weighing about 200 g each. The fixation was carried out by glutaraldehyde and formalin. The samples were investigated by routine light microscopy after staining by Mason, Azan, hematoxylin-eosin (HE), alcian blue and Van Gieson. A routine transmission electron microscopy (TEM) was used.

Results

We accepted 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) (Figure 1). The SSZ and the CZ are more metabolic than the others. We pay special attention to the CZ, because this zone is little investigated.

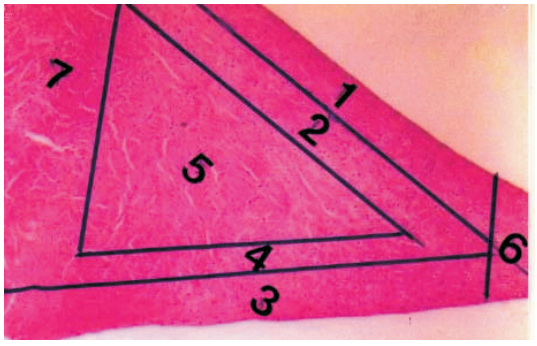

Figure 1. A division of the meniscus: 1. A Superficial Sliding Zone (SSZ). 2. A Transitional Sliding Zone (TSZ). 3. A Superficial Pressure Zone (SPZ). 4. A Transitional Pressure Zone (TPZ). 5. A Central Zone (CZ). 6. A Zone of Fusion (ZF). 7. A Parameniscal Zone (PZ). Staining by HE; X 250

The CZ is situated in the central part of the meniscus. The TSZ and the TPZ is situated above and below the CZ. The CZ is bordered on laterally with the PZ. The CZ was built on rare situated large, light, blistered cells. These cells were chondroblasts with middle size about 20µm. They had oval form. The chondroblasts had cytoplasm with few organelles (mainly separated cisterns GER and units of Golgi apparatus).The large, light nucleus was situated in the centre of the cells in the CZ. The intercellular space was filled with collagen fibers which were type II. They formed a fine network in difference from the above situated SSZ. The collagen fibers in the SSZ were type I and formed thick bundles. The proteoglycan complexes were more in the interterritorial matrix than the territorial matrix (Figure 2).

There were matrix vesicles in the matrix of the CZ without clear marks of calcification. These vesicles were single or in some sectors filled considerable part of the intercellular space (Figure 3).

The investigation for fibronectin showed that small granules of the reactionary product were situated mainly in the territorial matrix of the CZ.

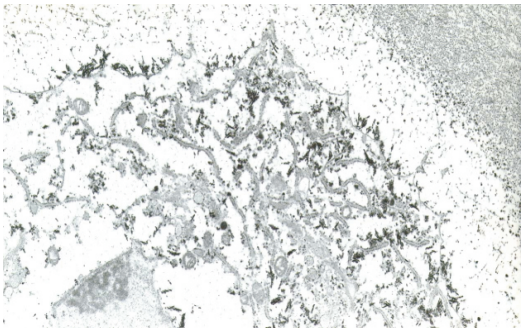

Figure 2. A part of large, light, blistered cell of the CZ. A larger concentration of proteoglycans in the interterritorial matrix than the territorial matrix (in the right side). TEM; X 12000

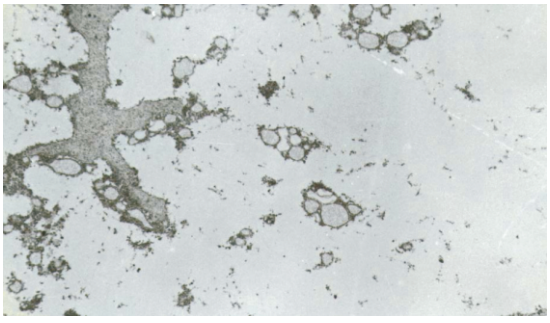

Figure 3. A considerable part of the intercellular space with clusters of matrix vesicles without clear marks of calcification. TEM; X 30000

Discussion

The meniscus is a structure with a heterogeneous morphology. The meniscus has a very important role in the transmission of the loading from the femur to the tibia. The structure of the meniscus is depending on the various functional demands from the different zones. The SSZ has ultrastructural characterization that looks likes the tangential layer of the articular

cartilage [11]. It is known that the SSZ is metabolically most actively in response to the increased functional requirements. The electron microscopic investigation showed that the collagen fibers in the CZ are type II collagen. It is obvious that the CZ is not responsible for the function of the sliding. The presence of the matrix vesicles in the matrix of the CZ drew us to a conclusion that as far as the CZ is concerned it manifests reinforced processes of degeneration and calcification. The matrix vesicles are signs to the initial process of degeneration or they are products of the above mentioned process. The processes of degeneration and calcification are the most marked especially in some pathological conditions as ruptures of the cruciate and the collateral ligaments of the knee [12, 13]. The processes of degeneration and calcification in the CZ are observed likewise after immobilization of the knee. These pathological conditions are common and the immobilization is one of the most used methods in the treatment of the disease of the locomotory system.

Because of the above mentioned the further investigation of the ultrastructural organization of the CZ ought to be done. It is clear that the menisci have an important role 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.

Conclusions

The meniscus has a heterogeneous structure. The structure of the meniscus is depending on the various functional demands from the different zones. It is known that the SSZ is metabolically most actively in response to the increased functional requirements. The electron microscopic investigation showed that the collagen fibers in the CZ are type II collagen. It is clear that that the CZ is not responsible for the function of the sliding. The presence of the matrix vesicles in the matrix of the CZ drew us to conclusion that as far as the CZ is concerned it manifests reinforced processes of degeneration and calcification.

References

1. Sick H, Ring P, Ribat Koritke Ch. Compt Rend Ass Anat. 1969;143(78):1565.
2. Wladimirov B, Welisarov A. Anat Anz. 1974;135(4):327.
3. Kalniev M, Vidinov N. Ultrastructural investigation of the menisci of the knee joints in rats. In: 11 th Congress of Anatomists, Histologists and Embryologists. Sofia: 1993.
4. Hellio Le Graverand MP, Ou Y, Schield Yee T, Barclay L, Hart D, Natsume T et al. The cells of the rabbit meniscus: their arrangement, interrelationship, morphological variations and cytoarchitecture. J Anat. 2001;198(Pt 5):525-35.
5. Myers ER, Zhu W, Mow VC. Viscoelastic properties of articular cartilage and meniscus. In: Nimni ME, ed. Collagen: chemistry, biology and biotechnology, vol. II. Boca Raton, FL: CRC Press; 1988. p. 268-288.
6. Proctor CS, Schmidt M, Whipple RR, Kelly MA, Mow VC. Material properties of normal medical bovine meniscus. J Orthop Res. 1989;7(6):771-82.
7. Gillard GS, Reilly HC, Bell-Booth PG, Flint MH. The influence of mechanical forces on the glycosaminoglycan content of the rabbit flexor digitorum profundus tendon. Connect Tissue Res. 1979;7(1): 37-46.
8. Mow VC, Halmes MH, Lai WM. Fluid transport and mechanical properties of articular cartilage: a review. J Biomech 1984;17(5):377-94.
9. Vogel KG, Paulsson M, Heinegard D. Specific inhibition of type I and type II collagen fibrogenesis by the small proteoglycan of tendon. Biomech J. 1984;223(3): 587-97.
10. Ghadially FN, Lalonde JM, Wedge JH. Ultrastructure of normal and torn menisci of the human knee joint. J Anat 1983;136(4):773-91.
11. Vidinov N. Development of the Articular Cartilage. Ultrastructural and Histochemical Investigation [dissertation]. Sofia: Medical University; 1981.
12. Cipolla M, Scola A, Gianni E, Puddu G. Different patterns of meniscal tears in acute anterior cruciate ligament (ACL) ruptures and in chronic ACL-deficient knees. Classification, staging and timing of treatment. Knee Surg Sports Traumatol Arthrosc. 1995;3(3):130-134.
13. Roos H, Adalberth T, Dahlberg L, Lohmander LS. Osteoarthritis of the knee after injury to the anterior cruciate ligament or meniscus: the influence of time and age. Osteoarthritis Cartilage. 1995;3(4):261-7.