Review Article

ISSN (0): 2455-5274; ISSN (P): 2617-5207

Histological Structure of Meniscus

Sivasakthi M[1], Yogesh Ashok Sontakke[2], Aravindhan K[3]

[1]Junior Resident, Department of Anatomy, Jawaharlal institute of Postgraduate Medical Education and Research (JIPMER), [2]Associate Professor, Department of Anatomy, Jawaharlal institute of Postgraduate Medical Education and Research (JIPMER), [3]Professor, Department of Anatomy, Jawaharlal institute of Postgraduate Medical Education and Research (JIPMER) (An Institution of National Importance under the Ministry of Health & Family Welfare, Govt. of India), Pondicherry, 605006 India.

Abstract

Meniscal damage is a common cause of joint injury, which can lead to the development of post-traumatic osteoarthritis, a prevalent form of osteoarthritis among the younger population Therefore, understanding the structural knowledge of the Meniscus will help in reproduce the native meniscus. Objectives: To improve the histological knowledge of meniscus and to understand the valuation of histology of meniscus attachment to the bone. Ultrastructure of meniscus observed from proximal to distal attachments showed the more complicated and complex arrangement of collagen bundles with interspersed cells in between. Ultrastructure of meniscus also should be borne in mind before preparing meniscal grafts. It has complex histological structure. It is essential to consider the details of the histological structure in meniscus reconstruction surgeries to restore its full functionality. This review may be useful as a reference to investigate the mechanical properties of meniscus.

Keywords: Meniscus, Histology, Ultrastructure, Light Microscopy, Discoid Meniscus.

Corresponding Author: Dr. Yogesh Ashok Sontakke, Associate Professor, Department of Anatomy, Jawaharlal institute of Postgraduate Medical Education and Research (JIPMER).

Received: September 2019
Accepted: September 2019

Introduction

Knee joint is the largest of all synovial joint in the body. It is a compound joint includes two condylar joints between femur and tibia, being partly divided by menisci. Meniscus is a fibrocartilaginous structure that preserves articular cartilage integrity in the knee and contribute to a healthy knee joint. Meniscus has two components, medial and lateral menisci. Each is a glossy white complex tissue comprised of cells, specialized extracellular molecules and region-specific innervation and vascularization. Both menisci are critical component of a healthy knee joint.[1] The meniscus appears smooth upon gross inspection. Though both menisci are roughly wedge-shaped and semi-lunar, lateral menisci display greater variety in size, shape, thickness and mobility than medial menisci. Lateral menisci also cover a larger surface area of the tibial plateau in comparison to medial menisci.[1]

Meniscus of knee has a specific microstructure. Most of the content is water, approximately 70% and the remaining 30% is organic residue. Organic matter is mostly collagen and the non-collagenous proteins. Collagen type I is predominant in normal meniscus in regard to articular cartilage were collagen type II is predominant. Collagen type II, III, V, VI are also present in smaller concentration. Besides collagen it also contains different cells, elastin fibers and proteoglycans. Functionally, meniscus is a essential component in the knee joint, responsible for stability, load transmission and lubrication. To enable efficient transmission of the complex tensile, compressive and shear stresses, the extracellular matrix of meniscus possesses a unique, hierarchically structured framework that is both heterogeneous and anisotropic at multiple length scales.[2] At the macroscale, the outer and middle zones mainly sustain circumferential tensile hoop stresses to provide joint stability.

Meniscal damage is a common cause of joint injury, which can lead to the development of post-traumatic osteoarthritis, a prevalent form of osteoarthritis among the younger population. Unfortunately, similar to articular cartilage, the meniscus has a limited self-healing capability, especially in the avascular, proteoglycan-rich inner zone. To repair damaged meniscus and recover normal joint function, it is necessary not only to replicate the whole tissue morphology of the native meniscus, but also to restore its matrix structural heterogeneity at the microstructure level, which is critical for the tissue to perform its specialized tissue level properties. Hence, knowledge about the histology of meniscus plays a major in role in the repair and restoration native meniscus. This study paves a path in understanding the histology of knee meniscus.[2]

Subjects and Methods

Search engine:
PubMed, Google search

Inclusion and exclusion criteria:

Articles were searched in PubMed and Google search as meniscus and histology, Meniscus and light microscopy and ultrastructure. Articles in the English language were included and articles in other language were excluded. Articles involving human studies and animal studies were included.

Review

The present review article on histology of meniscus were discussed under the following headings: light microscopy of meniscus, structure of meniscus that includes collagen, elastin fiber, meniscal cells, adhesion glycoprotein and finally about the histopathology of discoid meniscus.

Light microscopy of Menisci

In sectioned material, the surface of normal menisci and uninjured portion of menisci did not appear smooth but slightly irregular, wavy or markedly undulating. However marked roughening and disruption of the surface were frequently seen adjacent to tears. In haematoxylin and eosin-stained sections, the cells were seen to lie in lacunae. That such an appearance is largely an artefact due to cell shrinkage is evidenced by the fact that in plastic embedded material this feature could hardly be discerned. However, in some instances a specialised area of fine textured metachromatic matrix surrounded the cell. This could be designated as the pericellular or territorial matrix. Collagen fibres and bundles of such fibres of the general or interterritorial matrix were more easily visualised in paraffin than in plastic-embedded material.[6]

Structure

The meniscus is highly hydrated with 72% of water and remaining 28% of organic matter mostly of extracellular matrix and cells. Collagen being the major constituents of this organic matter then followed by other components such as glycosaminoglycans, adhesion glycoprotein and elastin. The proportion varies according to age, injuries and other pathological conditions.

Collagen

Though collagen is the major fibrillar component of the meniscus, different collagen types exists in varying quantities in each region of the meniscus. In the red zone collagen type I is predominant at approximately 80% composition by dry weight with other variant collagen like type II, III, IV, VI, XVIII also present in this zone. In the white zone, collagen makes up 70% of the tissue by dry weight of that 60% is collagen type II and 40% of collagen type I1.

Meniscus tissue is similar to ligament tissue in terms of collagen organization, with collagen primary oriented in the circumferential directions in all regions of the meniscus and along the direction of loading in ligaments.[3] The load experienced by these two tissues are also similar, as tension is generated in both tissues along the axis of collagen orientation. Some of the radially or circumferentially arranged fibers change direction to become perpendicular. Bullough et al., proposed that the orientation of fibers is such that to withstand the tension and the radially exposed fibers probably acts as tie to resist longitudinal splitting of meniscus. He found that there is little variation in the strength of tissues which are perpendicularly oriented compared with those in which the fibers are parallel to the tensile axis.[8]

Elastin fibers

Besides collagen, another fibrillar component is Elastin which is a combination of mature and immature elastin fibers that has been found in very low concentration. Elastic fibres have two components, a central amorphous core of low electron-density in which focal densities are seen and a peripheral zone of electron-dense filaments about 11 nm in diameter. Further, studies on consecutive stages of elastogenesis in various sites have shown that the filamentous component appears first and that the amorphous component (elastin) is deposited amongst the filaments, ultimately forming quite a large lucent or medium-density core.[6] Collections of electron-dense filaments, acceptable as pre-elastic fibrils, were noted by Silva (1969) in the intra-articular disc of the temporomandibular joint of the guinea-pig, but mature or maturing elastic fibres, with characteristic lucent core indicating the deposition of elastin, are not found. In the rabbit menisci (Ghadially et al. 1978), innumerable small fibrils, composed of electron-dense filaments acceptable as pre-elastic fibrils,were present as were a few larger fibrils composed of such filaments.[7] However, fully mature elastic fibres were not found although occasional young elastic fibres with a small lucent core surrounded by numerous electron-dense filaments were present. In human menisci, the situation is somewhat different in that quite a few relatively large mature elastic fibres (i.e. fibres containing more elastin than electron-dense filaments) and many smaller elastic fibres are present, but here also a few electron-dense fibrils seem to persist. It is likely that in the menisci (as in the skin), not all such electron-dense fibrils are destined to serve as scaffolding for elastin deposition and conversion into elastic fibres, but more detailed studies of menisci from various age groups are needed before a firm conclusion can be reached.[6]

Adhesion glycoprotein

Proteoglycans are heavily glycosylated molecules that constitute a major component of the meniscus extra cellular matrix. These molecules have a core protein which is decorated with glycosaminoglycans. The main glycosaminoglycan found in the normal human meniscal tissue are chondroitin sulphate, dermatan sulphate and keratan sulphate. Aggrecan is the major large proteoglycan of the meniscus while biglycan and decorin are the main small proteoglycans.[5] Tankka et al., studied the effect of proteoglycan synthesis and found that the meniscal cells particularly cells from the inner 2/3 possess quite a high ability to synthesize proteoglycan and he also demonstrated there is a decrease in synthesis of proteoglycan in a time dependent manner. He also studied the effect of Transforming growth factor β on proteoglycan synthesis by fibrochondrocytes and articular chondrocytes and found that Transforming growth factor β in a dose dependent manner stimulate proteoglycan synthesis and the findings are in par with the previous studies which helps in the meniscal repair.[5]

Meniscus cells

During early development, all meniscus cells have the same cellular morphology in terms of both size and shape with no regional variations. The cells of meniscus are classified according to their shape and the presence or absence of territorial matrix as fibroblasts, chondrocytes or intermediate cells exhibiting characteristics of both were identified.

From different studies, it is apparent that the cells in the outer zone have an oval, fusiform shape and are similar in appearance and behavior as fibroblasts. These cells display long cell extensions that facilitate communications with other cells and the extracellular matrix. The matrix surrounding these cells are mainly composed of type I collagen with small percentage of glycoprotein and collagen type III and V.[4]

Cells in the inner portion are round and are embedded in an ECM comprised largely of type II collagen intermingled with a smaller but significant amount of collagen type I and a higher concentration of GAG than in the outer region. This relative abundance of collagen Type II and aggrecan in the inner region is more reminiscent of hyaline articular cartilage. Therefore, the cells in the region are classified as fibrochondrocytes or chondrocyte-like cells.

A third cell population have been reported by Eleftherios et al., over the superficial zone of meniscus. These cells possess a flattened fusiform morphology and are absent of cell extensions. It has been reported that these cells are possibly progenitor cells with therapeutic and regenerating capabilities.

Johannah (2012) studied that meniscus cells were similar in biomechanical properties and cytoskeletal staining to ligament cells although outer meniscus cells proved to be stiffer than inner meniscus cells and also shows more compressibility compared to inner cells. Outer meniscal cells being more fibroblastic and primarily experiencing tensile loads and the inner cells and articular chondrocytes showing more chondrocytic characteristics while experiencing mainly of compressive loads. As cells are primarily filled with water the increased compressibility with strain of outer meniscus and ligament cells may indicate a more permeable cell membrane in these cells allowing more water to escape under higher strains.[4]

Discoid meniscus

Discoid meniscus is a more common finding in children. In discoid meniscus, the central area is completely filled. In some cases, there is a very small aperture in the central part. The outer part that is connected to the joint capsule is much thicker than in normal meniscus. This variation disturbs normal mechanical loading and share stress and are predisposing factor to meniscal tears.

Watanabe's classification, the most common is type I, complete discoid meniscus, which is a much thicker lateral meniscus that covers the whole of the lateral tibial plateau, and is more vulnerable to tear during sports activities than normal meniscus. The next, type II, is incomplete discoid meniscus, which is smaller than type I, varies in size, structure, and shape and does not cover the whole of the lateral compartment. Common to both types are normal peripheral and posterior horn attachments and stability during arthroscopy probing. The least common is type III, the so-called Wrisberg type. The shape of this type is near to normal, not necessarily discoid, but with the absence of the posterior meniscal tibial attachments, including menisco-tibial (coronary) ligament. The only attachment is the ligament of Wrisberg that connects the posterior horn of the lateral meniscus to the lateral surface of the medial femoral condyle. This leads to hypermobility of the posterior horn of the lateral meniscus during knee extension, displacement of the meniscus, and is probably the cause of the snapping.[9]

References

1. Eleftherios PG, Pasha HBS, Athanosiou KA. Biomaterials.2011 Oct;32(30):7411-7431.
2. Qing L, et al. Micromechanical Anisotrophy and Heterogeneity of the Meniscus Extracellular Matrix. Acta Biomater.2017 May;54:356-366.
3. Scott A, et al. Histological Analysis of Human Meniscal Allografts. JBJS.2000;82-A(8):1070-1082.
4. Adams JS, Athanosiou KA. Biomechanics of Meniscus Cells:Regional variation and comparison to Articular chondrocytes and ligament cells. Biomech Model Mechanobiol.2012 Sept;11(7):1047-1056.
5. Tanaka T, Fujii K, Kumagae. Comparison of biochemical characteristics of cultured fibrochondrocytes isolated from the inner and outer regions of human meniscus. Knee surg, Sports Traumatol, Arthrosc.1999;7:75-80.
6. Ghadially FN, Lanlonde A, Wedge JH. Ultrastructure of normal and torn menisci of the humamn knee joint. J.Anat.1983;136(4):773-791.
7. Ghadially FN, Thomas I, Lanlode J. Ultrastructure of rabbit semilunar cartilages. J.Anat.125:499-517.
8. Bullogh PG, Munuera L, Murphy J, Weinstein AM. The strength of the menisci of the knee as its realtes to their fine structure. JBJS.52-B:564-570.
9. Kecojevic' V. Discoid Meniscus-Histology and Pathology. IntechOpen 2018;7:111-120.

How to cite this article: Sivasakthi M, Sontakke YA, Aravindhan K. Histological Structure of Meniscus. Acad. Anat. Int. 2019;5(2):63-5. DOI: dx.doi.org/10.21276/aanat.2019.5.2.17

Source of Support: Nil, **Conflict of Interest:** None declared.