**THE MECHANICAL MAPPING OF THE MENISCUS**

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**Introduction:** Although the meniscus has been reported as an important structure for knee kinematics and prevention of the degenerative joint disease, the mechanical characteristics of the meniscus have not yet been well investigated. An information on the mechanical architecture of the meniscus is essential to understand the function and mechanisms of meniscal tear. The load transmission is one of the important functions of the meniscus. The compression force on the wedge-shaped meniscus extrudes the meniscal body radially and outward. This radial extrusion of the meniscal body stretches the collagen bundles in circumferential direction between the anterior and posterior ligamentous attachments. This circumferential stress (hoop stress) has been considered as a major stress inside the meniscal body.

In the present study, we analyzed the intrinsic mechanical properties under hoop stress at entire coronal section of meniscal body. The mechanical characteristic of the meniscus was assessed by comparing the mechanical properties among different anatomical locations.

**Materials and Methods:** Six fresh-frozen porcine stifle joints were dissected, and both the medial and lateral menisci were harvested. A 15 mm thick radial section was cut from the middle segment of each meniscal body. The sections of 1 mm thickness from periphery to center were prepared using the specially designed slicer. Then each section was cut horizontally into a shape of rectangular parallelepiped with a long axis aligned to circumferential direction of the meniscus (Fig. 1). Totally, 501 test specimen were prepared. The cross sectional area was measured at the middle point of each specimen using a micrometer. The stress-strain curve of each specimen was obtained from constant rate uniaxial tensile test using a mechanical testing machine (Autograph; Shimazu, Kyoto, Japan). The tensile modulus was calculated using a least-squares regression of the linear portion of the stress-strain curve.

The radial cross sectional area of the meniscal body was divided into 4 zones from periphery to center and designated as red-red (RR), red-white (RW), white-white (WW) and free edge (FE). Each zone was subdivided into femoral, middle and tibial portions except the free edge zone. Thus, all specimens were divided into 10 areas. Regional differences in modulus were analyzed for either the medial or lateral meniscus using one-way factorial ANOVA among 4 zones, 3 portions and 10 areas. Moduli at the identical area were compared between the medial and lateral menisci using unpaired t-test. The level of significance was p<0.05.

**Results:** The average cross sectional area of the specimens was 0.86 mm². Modulus at the RR zone was found to be significantly higher than that in other zones in both the medial and lateral menisci. On the other hand, modulus at the femoral portion was higher than other portions only in the lateral meniscus. The medial meniscus had significantly higher modulus than the lateral meniscus except FE zone and the femoral portion (Fig.2).

Obvious regional variation in modulus was seen in the lateral meniscus. The mean moduli at 10 different areas of the lateral meniscus were graphically shown in the gray scale (Fig. 3). The areas with the lower modulus were found to locate at the middle portions of RW and WW zones and the tibial portion of RW zone. There were statistically significant differences in modulus between these areas and surrounding areas at both femoral and peripheral sides. Dual lines in figure 3 expressed the boundaries where significant differences were detected. In contrast, in the medial meniscus, the regional difference could be seen only between RR and RW zones. With comparison between the medial and lateral menisci at each identical area, the lateral meniscus had less modulus except areas in the femoral portion and at the FE zone.

**Discussion:** We found the regional variation in modulus in the porcine meniscus. The areas with higher modulus correspond to the histological location where the dense circumferential collagen bundles are observed. On the other hand, the areas with lower modulus lie at the location radial tie fibers exist. This suggests that the collagen architectures have significant influence on the intrinsic mechanical properties of the meniscus. As the porcine meniscus has similar collagen architectures as seen in the human meniscus, we presume same regional variation in modulus may also exist in human. As the shear stress will concentrate on the boundary where modulus changes greatly, the horizontal boundary of modulus would be a possible reason for the development of horizontal cleavage. In the future, the mechanical mapping as we studied would be necessary to develop the more functional meniscal prosthesis.

![Fig. 1: Preparation of the specimen](image1.png)

![Fig. 2: Tensile modulus at 4 zones and 3 portions (*:p<0.05, **:p<0.001)](image2.png)

![Fig. 3: Graphical presentation of modulus at 10 areas in the lateral meniscus (*)](image3.png)

**References:**