

Unveiling the 3D vascular architecture of the meniscus

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Introduction

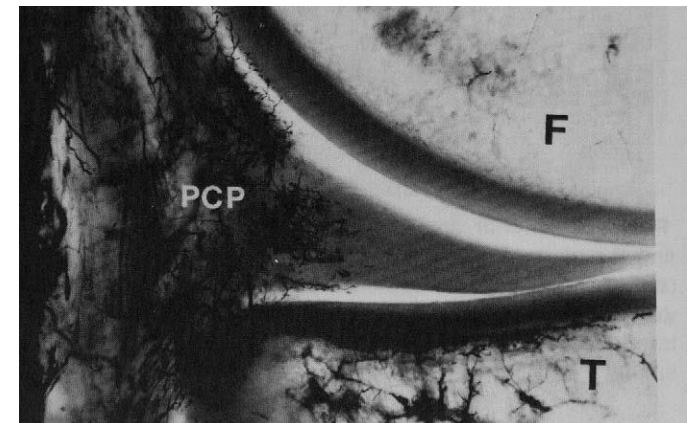
The meniscus is a fibrocartilaginous tissue located between the femur and the tibia. Its principal roles are load transmission, increase in joint stability, shock absorption, and maintenance of lubrication and nutrition of the knee joint.

Meniscus injuries are among the most common lesions in orthopedics and the vascular supply is crucial to the self-healing potential of the tissue. Indeed, only tears in the outer vascularized region are capable of repair. However, so far the microvasculature architecture of the tissue was determined only using 2D imaging techniques [1].

Aim: create an *in-silico* 3D anatomical model of the microvasculature of the meniscus in physiological and pathological conditions

Three work packages are defined:

1. 3D microvasculature of healthy meniscal tissues
2. 3D microvasculature of pathological meniscal tissues
3. Preclinical *in-vivo* study on the revascularization of allografts



Cross histological section of the medial compartment of the knee. Blood vessels are present in the peripheral portion of the medial meniscus [1].

The 3D vascular network of the meniscus is investigated through the use of **X-ray Computed Tomography**

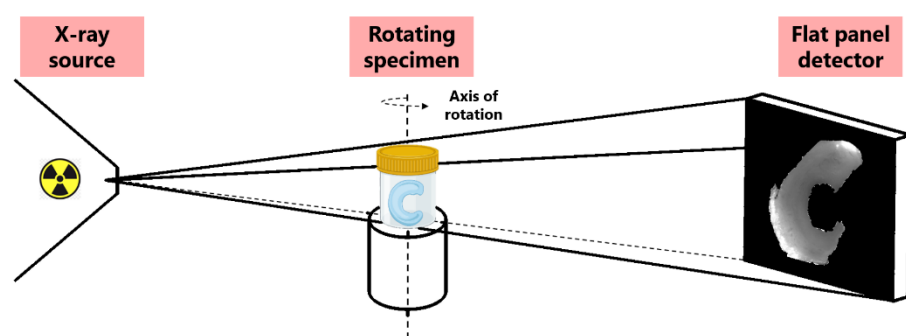
Methods

Sheep samples

- Micro-CT analysis of the entire knee joint
- Immersion of lateral and medial meniscus in iodine contrast agent solution
- Micro-CT analysis of contrasted menisci

Human samples

- Perfusion of the femoral artery with the polymerizing contrast agent μ Angiofil
- Micro-CT analysis of the entire knee joint and contrasted menisci

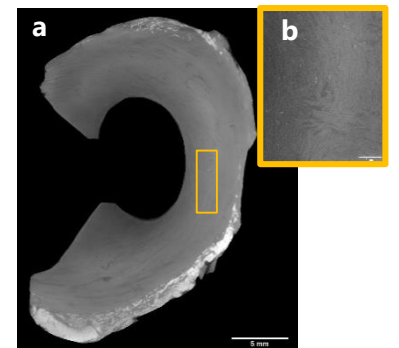


Scheme of X-ray Computed Tomography (CT) scanning geometry

Micro-CT sections were reconstructed using the XAct software and visualized with both Fiji ImageJ and Avizo.

Results

- Setup of a soft tissue contrast protocol: 24 days of immersion in Lugol's solution and 5 days of washing in dH_2O
- Qualitative analysis of the CT datasets and 3D volume-rendering of the meniscus



Transverse-sectional micro-CT image of a contrasted sheep medial meniscus showing a "negative" imaging of the vessels and the collagen fiber organization (Vx size a. 19.5 μm , b. 4.5 μm).



Sagittal micro-CT section of a perfused human leg showing a "positive" imaging of the vessels (Vx size 75 μm). The arrow indicates the femoral artery.

- Efficient perfusion of the polymerizing contrast agent
- Qualitative analysis of the CT datasets and 3D volume-rendering of the meniscus

Conclusions

3D assessment of the microvascular anatomy of the meniscus

Allows to quantify the degree of vascular penetration from the periphery

Development of new patient-specific clinical programs

Outlook

- ❑ **Quantitative analysis** of the CT datasets obtaining information on vessels diameters, ramification angles and branch lengths
- ❑ Analysis of **pathological samples** obtained from surgical procedures (Meniscectomy or Total Knee Replacement)
- ❑ Confirmation of micro-CT results with **histological analysis**

[1] Arnoczky SP, Warren RF. Microvasculature of the human meniscus. *Am J Sports Med.* 1982;10(2):90-95