REPLACEMENT OF THE KNEE MENISCUS BY BIODEGRADABLE POROUS POLYMER PROSTHESES. A STUDY IN DOGS


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Introduction
In case of heavily damaged meniscus, nowadays, (sub-total meniscectomy is standard procedure, although it has been proved that this might lead to degeneration of the articular cartilage[1]. Our research is aimed to develop a meniscus prosthesis based on biodegradable porous polymers with optimal initial mechanical and biological properties. The question is if new tissue will grow into such porous polymer scaffold, and if the new tissue will express a meniscus phenotype, i.e. presence of fibrochondrocytes that synthesize proteoglycans and collagen types I and II in their extracellular matrix. Aim of this study is to evaluate the tissue ingrowth from the capsule/synovium into a newly developed prosthesis (1), the metaplasia of the ingrown tissue into fibro-cartilaginous tissue (2), the stiffness of the prosthesis-tissue construct (3) and the consequences of the replacement for the articular cartilage (4).

Materials and methods
Porous polymer prostheses were composed of biodegradable Estane. Pores were made by mixing the polymer solvent solution with NaCl crystals. After polymerization the salt was washed out and interconnectivity of the pores was determined on scanning electron pictures. (74% porosity, pore size: 155-355 microns) The compression modulus of the foam was 260 kPa. We performed lateral total meniscectomy in 24 knees of Beagle dogs. In 12 knees the meniscus was replaced by a prosthesis and attached peripherally in the capsule/synovium and on the tibial plateau by leading sutures through two drill holes in the tibia (Fig. 1a,b) and the meniscal prosthesis (c).

The prosthesis was attached to the capsule (d). 12 meniscectomized knees were left empty and served as controls. Follow up periods were three and six months. The ingrowth of tissue from the capsule into the prosthesis and the foreign body reaction were evaluated. Differentiation of this tissue into meniscus-like tissue was determined by evaluating the production of meniscus-like extracellular matrix; the degree of Toluidine blue staining (proteoglycan formation) and labeling with collagen type I and II antibodies (immunohistolocalization) was determined. Furthermore, the stiffness of the polymer tissue construct was determined before implantation and after explantation and compared with the stiffness of native meniscal tissue. Finally, the consequences of the two treatments for the femoral and tibial articular cartilage were evaluated.

Results
After two weeks, all dogs showed a normal gait. Already at three months after surgery, all implants were intensively integrated with the surrounding capsule and were completely filled with fibrovascular tissue, with abundant collagen type I antibody labeling in the extracellular matrix. No proteoglycan and collagen type II staining was observed. After six months, peripheral tissue remained fibrovascular with positive collagen type I staining (Fig.2a). In the inner rim of the prosthesis, however, vascularity was less and typical round cartilage-like cells were visible and their matrix showed positive staining of proteoglycans (Fig.2b) and collagen type II. The stiffness of the prosthesis-tissue construct increased in the six months after implantation and slope of the compression stress curve (stiffness) resembled that of the native meniscus at higher but physiologic stress levels. Microscopically, both groups showed articular cartilage degeneration (Fig.3). In all implant cases only few macrophages and giant cells were seen.

Discussion
Regeneration of a new meniscus seemed to be possible by in vivo tissue engineering. The optimal properties of these polymer prostheses resulted in a fast ingrowth of fibrovascular tissue into the prosthesis and in a location specific phenotypic differentiation of this tissue. The distribution of these different phenotypes in the prosthesis approached that of the native meniscus. Only a very mild foreign body reaction was observed in and around the polymer. The compression modulus of the prosthesis-tissue construct approached that of the native meniscus at higher but physiological stress levels. In this short-term study, cartilage degeneration could not be prevented. However, the authors speculate that in the long term, when the prosthesis is completely infiltrated and surrounded with tissue, the gliding characteristics of the construct will improve. This might end the progression of the degeneration. Nevertheless, in the development of a prosthesis for total replacement of the heavily damaged meniscus, the results of this experiment are very promising.

References
1. King Clin Orthop (1990) 252;4-7

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