Can a Polycarbonate-Urethane Meniscal Implant Protect Articular Cartilage? Histopathological Results in a Sheep Model

INTRODUCTION

The menisci play an important role in the knee joint biomechanics [1]. Clinical studies have shown that the loss of the meniscus leads to degenerative arthritis attributed to the changes in load distribution and the loss of proprioception [2]. Clearly, there is a substantial need to protect the articular cartilage by either repairing or replacing the menisci. There are many difficulties dealing with both fresh frozen or cryopreserved allograft menisci and the complexities of meniscal repair may contribute to uneven distribution of load, instability and recurrence of degenerative damage. There is a need for the development of an artificial meniscus that is available at the time of surgery in several sizes that can accommodate most patients.

A novel Polycarbonate-Urethane (PCU) meniscus implant with fibers (Fig. #1) has been developed to comply with these requirements. PCU, an elastic yet tough material with a high resistance to tear is an attractive material for this application since it offers excellent mechanical and tribological properties, comparable to those of natural cartilage [3]. Though explored in other biomedical applications against metal bearing surfaces, no data exists on the performance of PCU against articular cartilage under load. We hypothesized that an artificial PCU meniscus could provide a protective effect on the underlying cartilage subject to joint loading. Therefore, the aim of this study was to elucidate whether a PCU meniscal implant is able to provide adequate protection to delay the occurrence degenerative changes in the post-meniscectomized knee.

METHODS

This animal study was approved by the Institutional Animal Care and Use Committee of the Technion (#10-6-11-06). Seven skeletally mature “Asaph” (Ostries X Avass) ewes (1-2 yrs, 60-80 Kg) were allocated for the research. The sheep underwent a full meniscectomy of the medial meniscus of their left knee, and were implanted with a PCU meniscus substitute. The implant was inserted in the joint and secured to the tibia by H&E staining. The contralateral knee served as control.

RESULTS

In general, the sheep tolerated the operations well. Most stood upright immediately after the operation and weight loaded their operated hind limbs. Periodic physical examination of the sheep indicated that the implant was well tolerated by the animals, who displayed a full ROM, no weight loss and no signs of distress. The PCU implant was durable and remained well-secured throughout the 9 month trial period. Gross and microscopic examinations of the explanted PCU implant’s surfaces did not reveal any changes in their structural or material properties. The PCU did not appear to exert any negative effect on cartilage and the degree of inflammatory cellular infiltration was minimal and primarily associated with the presence of inert foreign matter. The main pathological changes seen at 6 and 9 months post implantation were similar to those observed at 3 months post-implantation. Macroscopically, cartilage in direct contact with the implant was preserved well and did not show significant degeneration (Fig. 2a). This finding was best observed in the medial femur condyle and the central portion of the medial tibialis plateau staining, which as a rule was either within normal limits or showed minimal degeneration (Fig. 2b, region of interest, arrows). Evidence of remodeling was observed by the presence of minimal to mild irregularity with or without discoloration of the medial rim of the femoral condyle and the medial tibialis plateau. These sites were located next to small osteophytes in these areas (Fig. 2c, region of interest, arrows). These osteophytes tended to be larger at 6 months post-operation than at 3 months. In most sheep, there was moderate soft tissue fibrosis, considered consistent with that expected following surgical intervention.

DISCUSSION

PCU as an articulating material offers clear advantages over metal and hydrogel materials that have previously been explored as meniscal bearings against articular cartilage. Specifically, rigid metal implants lack the compliance and shock absorbance a polymer implant can offer, whereas hydrogels generally lack the long-term tolerance to loading and thus fail mechanically. PCU combines compliance with endurance to long-term fatigue, as confirmed here. PCU did not exert any adverse effects in the joint and our results show that primary PCU meniscus transplantation may protect, but not completely prevent articular cartilage degenerative changes in the medial compartment of the knee. Minimal changes associated with joint remodeling occurred within the first 3 months and remained akin throughout the 9 months study duration and on the whole, was preserved well. Contradistinctly, it has been shown recently that a total medial meniscectomy in a sheep model leads to extensive destruction of articular cartilage on the medial tibial and femoral condyles within ~3.5 months [4]. Based on the current preliminary results, we believe that a PCU meniscus implant could counter the occurrence of major degenerative cartilage changes following meniscectomy.

REFERENCES


Figure #1: Polycarbonate-Urethane meniscal implant (left) and in-situ implant in an exposed sheep cadaver joint (right)

Figure #2: Macroscopic comparison between tibial plateau cartilage in both limbs, 9 months post-operation (a), a representative H&E staining of cartilage under the PCU implant (b), and of the contralateral cartilage under the intact natural meniscus (c)