INTRODUCTION: Clinically, total medial meniscectomy in the human knee frequently results in osteoarthritis. Presumably, loss of the cartilage protection by a normal meniscus (i.e., shock absorption and load distribution) cause chronic cartilage overloading that leads to cartilage degeneration. Experimentally, meniscectomy insult has been utilized to replicate OA pathology in animal joints in vivo. One of these cases involves rabbit models of partial meniscectomy. Previous investigators reported that partial medial meniscectomy reproducibly caused relatively mild to moderate degeneration [1], and that partial lateral meniscectomy caused more severe degeneration [2]. To date, these models have been utilized in many studies, particularly to test the efficacy of therapeutic treatments. However, both models necessarily involve a limitation in control of the amount of meniscectomy, which potentially affects reproducibility. Theoretically, consistent with human clinical cases, total meniscectomy should cause higher-grade degeneration, with less outcome variability associated with technical perturbations, than by partial meniscectomy. Messner et al. [3] demonstrated that total medial meniscectomy in their rabbit model caused cartilage degeneration in the medial compartment. However, the degeneration developed over a relatively long time period (13-40 weeks), and the degrees of degeneration were variable from very mild to severe.

In an ongoing project, we are attempting to document the effects of chronic cartilage overloading on acute cartilage injury. The purpose of this study was to identify a surgical insult technique suitable for modeling chronic cartilage overloading in the rabbit knee. The hypothesis was that total medial meniscectomy would reproducibly cause modest cartilage degeneration in the medial compartment in a relatively short term (8 weeks).

METHODS: Five New Zealand White rabbits were subjected to experimental surgery in this IACUC-approved study. For each animal, the medial meniscus of the left knee was totally removed (MM-tomy) using a combined anterior and posterior approach. The surgery was started with the animal placed in the prone position. A medial popliteal longitudinal skin incision was made, and the posteromedial joint capsule was exposed through the intermuscular plane between the semimembranosus and medial gastrocnemius. The gastrocnemius tendon was retracted laterally, with the femoral insertion left intact. The joint capsule was then incised longitudinally to expose the posterior aspect of the medial compartment. First, the posterior horn of the medial meniscus was sharply sectioned from the tibial attachment. Next, the meniscal body was atraumatically released from the medial collateral ligament, using a curved mosquito hemostat. After closing the posterior skin incision, the animal was flipped to the supine position, and an anterior arthrotomy was made through the intermuscular plane between the semimembranosus and medial gastrocnemius. The gastrocnemius tendon was retracted posteriorly, the anterior arthrotomy was made through a parapatellar incision. Then, the anterior horn of the medial meniscus was sharply sectioned from the tibial attachment, and the completely released meniscus was excised as a single piece. The joint capsule and skin were closed in layers. Throughout the surgery, special care was taken to avoid iatrogenic cartilage damage.

Eight weeks later, the experimental joints were sampled and prepared for histo-morphological evaluation. Femoral and tibial surfaces in both medial and lateral compartments (at the primary load bearing region for each surface) were rated individually by means of Mankin score. These results were compared with data archived from a previous study, in which rabbit knee cartilage histology was evaluated 8 weeks after complete anterior cruciate ligament transection (ACLT) or sham control surgery (n = 10, for each). (Note: The surgery for these rabbits also included both anterior and posterior arthrotophomy, identically with this study.)

RESULTS: In the MM-tomy knees, four out of the five joints exhibited distinct cartilage degeneration (Mankin score ≥ 4 points) in the medial compartment, on both the femoral and tibial surface (Figures 1 and 2). This incidence was higher than the stock ACLT knee data (3/10 and 6/10 for the medial femoral and medial tibial surfaces, respectively). Statistically, the average score for the medial femoral surface in these five MM-tomy knees was significantly higher (p = 0.046) compared to the stock control (sham surgery) data. Histological changes in the lateral compartment were minimal (≤ 2 points) in every case (Figure 2).

DISCUSSION: The preliminary results from these rabbits suggest that total medial meniscectomy using our surgical technique creates modest degeneration in the medial compartment, with reasonable reproducibility. The disease development was relatively rapid, compared to the previous total medial meniscectomy model [3]. This may be associated with the unilateral surgery in this study. (Bilateral surgery in the previous model may have led to significant reduction of post-operative animal activity.) The mildly-invasive surgical approach in the present technique (compared to two arthrotomies immediately anterior and posterior to the medial collateral ligament in the previous technique) also may have similarly affected the post-operative conditions. Unfortunately, the present study did not include inflammatory measures to support the notions above. However, the documented difference in histological changes compared to the control data indicates that the post-operative conditions in our experimental setting were distinctly different between with and without meniscectomy. The piloted surgical insult technique appears to be promising for modeling chronic cartilage overloading in the rabbit knee in vivo.

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References:

Figure 1. Cartilage histological images (Safranin-O stained) in the medial compartment in the five MM-tomy knees, and the Mankin score for each surface.

Figure 2. Histological scores for the MM-tomy knees in the present study, compared with the archival data for sham surgery control knees and ACLT knees. Bars indicate standard deviations.