Introduction: Meniscal injuries account for a significant number of orthopaedic surgeries performed each year. Currently, meniscectomy is the most common form of treatment for meniscal injury. While meniscectomy provides pain relief and return to function, the loss of meniscal tissue results in long-term dysfunction and secondary osteoarthritis. Meniscal allografts and xenografts can be used in an attempt to replace damaged meniscal tissue. However, currently available materials and techniques do not allow for complete regeneration of functional meniscal tissue. Porcine small intestinal submucosa (SIS) has been used with success to enhance meniscal regeneration. (1,2)

Therefore, the purpose of this study was to determine the long-term (6 months) effects of replacement of vascular, posterior meniscal defects with SIS grafts in promoting meniscal regeneration and protecting articular cartilage.

Methods: All procedures were approved by the University ACUC. Healthy, adult, conditioned dogs (n=24) weighing 23.4-35.5 kg were anesthetized and a medial approach to one randomly assigned knee via osteotomy of the origin of the medial collateral ligament was performed. A standardized, subtotal meniscectomy was created in the posterior portion of the medial meniscus using a cutting template. The meniscectomy extended to the vascular portion of the meniscus (Fig. 1).

The dogs were randomly assigned to one of 2 different treatment groups:
- SIS (n=13) – SIS scaffold sutured into the defect (Fig. 2)
- Control (n=11) – defect was left empty (meniscectomy)

Non-weight-bearing slings (3 weeks) followed by splints (3 weeks) were placed on the limbs after surgery. The dogs were restricted to kennels. Lameness scoring was performed every 4 weeks postoperatively. The dogs were killed 3 months (n=12) or 6 months (n=12) after surgery. Both knees were assessed for gross pathology, articular cartilage damage by India ink staining, and amount and character of tissue in the meniscal defects. The operated menisci were harvested and processed for histologic examination and biomechanical testing. Histologic assessment of the menisci included subjective evaluation of the anterior, central, and posterior aspects of the defect. Assessment was based on tissue amount in the defect, tissue type in the defect, and new tissue integration to remaining meniscus. 2mm diameter explants from regenerated tissue and tissue at the same site on contralateral medial meniscus were tested under unconstrained stress relaxation (step-wise strain 5%, 10%, 15%, 20%) and stress-strain curves were obtained based on equilibrium stress values. Tissue modulus was calculated from the slope of the linear region of the stress-strain plot. Explants from the anterior horn of each meniscus were also tested to determine changes due to favoring of the operated limb. Statistical analyses were performed.

Results: All dogs survived and no complications were noted. Control dogs were significantly (p<0.05) more lame than SIS dogs 3 and 6 months after surgery. SIS treated menisci had significantly (p=0.026) more tissue regeneration than Controls determined by area measurements at 3 and 6 months. SIS grafted joints had significantly (p=0.029) less articular cartilage damage than Controls. Meniscal defects treated with SIS were more consistent in terms of amount, type, and integration of new tissue compared to Controls (Fig. 3).

Discussion: SIS scaffolds placed in posterior, vascular meniscal defects resulted in production of meniscal-like replacement tissue. The meniscal replacement tissue in SIS grafted meniscal defects has always been consistently superior to meniscectomy in terms of amount, type and integration of new tissue, chondroprotection, and limb function in both the short and long term. While the biomechanical properties of this new tissue are still inferior to those of native meniscus 6 months after grafting, the properties appear sufficient to provide chondroprotection and appropriate limb function. It is likely that the material properties of the replacement tissue will improve when allowed more time for remodelling. Our previous work indicates that SIS likely provides a scaffold that can hold and protect a blood clot resulting in tissue regeneration through tissue conduction (1,2). SIS may also stimulate mitogenesis and matrix synthesis in resident cell populations.(3)

Therefore, a source of blood for clot formation via hemarthrosis from open arthroscopy, hemorrhage from meniscal vessels, or induction of hemorrhage via trephination of meniscus or subchondral bone appears to be necessary for successful SIS-enhanced meniscal regeneration. Current research is focused on optimizing the SIS implants, the surgical technique, and methods for improving the healing time, consistency, and functionality of the regenerative tissue.


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