Use of a Tibial Tunnel Technique to Optimize Outcome for Treatment of Meniscal Defects Using Small Intestinal Submucosa Grafts in a Dog Model

Introduction: Meniscal pathology is a common and costly problem worldwide. Current treatment options do not comprehensively address the need for restoration of long-term meniscal function. Therefore, strategies aimed at regeneration of damaged or missing meniscal tissue are needed. Porcine small intestinal submucosa (SIS) has been used with success to enhance meniscal regeneration. (1,2) Data suggest that SIS-induced regeneration of meniscal-like tissue is optimized when initial fixation of the SIS scaffold is stable, the SIS scaffold has direct access to a rich blood supply and source of cells, hemorrhosis for fibrin clot formation on the scaffold is ensured, and the SIS scaffold and regenerative tissue are protected during the initial postoperative period (6 weeks). (1,3) While success in treating posterior meniscal defects in a dog model has been realized using SIS scaffolds, optimizing the aforementioned criteria may further enhance meniscal tissue regeneration using SIS scaffolds. Therefore, the purpose of this study was to determine the temporal effects of a clinically-relevant tibial tunnel technique aimed at optimizing SIS scaffold fixation and access to blood and cells on meniscal tissue regeneration and chondroprotection following partial medial meniscectomy in the vascular zone of the posterior horn in dogs.

Methods: All procedures were approved by the University ACUC. Healthy, adult, conditioned dogs (n=22) weighing 22.0-29.1 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 and the anterior and posterior margins of the defect were tapered to mimic the clinical situation. (Fig. 1). For the tibial tunnel (TT) fixation technique, a bone tunnel (2 mm diameter) was drilled from the medial aspect of the proximal tibia to exit at the insertion of the medial posterior meniscotibial ligament.

The dogs were randomly assigned to one of the following groups:
- **SIS** (n=4) − SIS scaffold sutured into the defect
- **SIS-TT** (n=8) − SIS scaffold pulled into tibial tunnel with suture then attached to medial tibial peristeum, scaffold sutured into defect. (Fig. 2)
- **Control** (n=3) − defect left empty (meniscectomy)
- **Control-TT** (n=7) − Tibial tunnel created, defect 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 euthanatized 3 months (n=14) or 6 months (n=8, SIS-TT and Control-TT only) 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. Statistical analyses (one-way ANOVA with post-hoc tests) were performed with significance set at p<0.05.

Results: All dogs survived and no complications were noted. Dogs in the meniscectomy group(s) were significantly (p=0.002) more lame than dogs in the SIS-treated group(s) 3 and 6 months after surgery. SIS treated menisci had significantly (p<0.03) more tissue regeneration than Controls determined by total surface area measurements at 3 and 6 months. SIS-treated joints had significantly (p<0.01) 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). The tibial tunnel could be identified in histologic sections from TT groups and contained dense fibrous tissue, fibrocartilage, and/or bone 12 weeks after surgery. No significant differences in measured outcome variables were noted between SIS and SIS-TT groups or between Control and Control-TT groups.

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 was consistently superior to meniscectomy in terms of amount, type and integration of new tissue, chondroprotection, and limb function. No objective advantages associated with the tibial tunnel technique were noted with respect to new tissue amount, chondroprotection, or limb function in comparison to sutured SIS scaffolds. However, subjective advantages seemed apparent with respect to initial stability of the SIS implant and intimate association of the implant with vascularized meniscus (i.e., posterior horn and meniscotibial ligament). In addition, the tibial tunnel technique may augment meniscal tissue healing and regeneration associated with SIS implants in arthroscopically treated meniscal defects in the human knee by providing access to bleeding and cells from the bone tunnel. No untoward effects related to the use of this technique were noted. Further research investigating the use and importance of the tibial tunnel technique with respect to technical, biomechanical, and biological factors is warranted.


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