Introduction: Meniscal pathology is a common and costly problem worldwide. Avascular meniscal tears do not typically heal due to lack of blood supply and cell and tissue ingrowth. Various methods for augmenting the blood supply to avascular defects during the critical healing period have been attempted in animal models and clinical patients. However, limited success has been realized. Success appears to be limited by the ability to maintain the vascular channel during healing, the technical aspects of the procedure, or both. A device that allowed for consistent arthroscopic placement prior to, or as part of, repair, which maintained a vascular channel to the tear during healing would have important clinical ramifications. The purpose of this study was to evaluate the effects of the BioDuct™ Meniscal Repair Device (Bioduct LLC) on creation and maintenance of a vascular channel from the synovium to a surgically created longitudinal avascular meniscal tear in dogs.

Methods: All procedures were approved by the University ACUC. Healthy, adult dogs (n=10 dogs, 20 defects) weighing 17.05-21.2 kg were anesthetized and a medial approach to the knee via osteotomy of the origin of the medial collateral ligament was performed. Two 5-mm longitudinal tears were created in the avascular portion of the medial meniscus of each dog: one anterior and one posterior. Trephination to the meniscal rim was performed for each tear (Fig. 1). Based on random assignment, a BioDuct™ Meniscal Repair Device (MRD) was placed into the trephination site to the level of the tear, either anterior or posterior (Fig. 2). The remaining site received no implant. Each tear was then repaired with one horizontal mattress suture of 5-0 nylon (Fig. 3). The medial collateral ligament was reattached using a 2.7 mm screw.

Non-weight-bearing slings (2 weeks) followed by splints (2 weeks) were placed on the limbs after surgery. The dogs were restricted to kennels, and were allowed to use the limbs ad libitum after week 4. Lameness scoring was performed every 4 weeks after surgery. The dogs were euthanatized 12 weeks after surgery. Both knees were assessed for gross pathology, articular cartilage damage by India ink staining, and appearance of the meniscal defects. The operated menisci were harvested and processed for histologic examination (n=8) or biomechanical testing (n=12). Histologic sections were subjectively evaluated for the presence and character of visible channels extending from the periphery to the tears, and the presence and character of tissue within the tear. Biomechanical evaluation involved testing each tear for load to failure by applying linear traction in a radial direction at a displacement rate of 3.5 mm/sec (strain rate >100%/sec). Data were statistically analyzed for significant differences with p <0.05.

Results: All dogs survived and no surgical complications were noted. Mild to moderate lameness was noted in 2 dogs at 4 weeks after surgery (mean ± SD lameness = 1.00 ± 1.7), with all resolving by 12 weeks after surgery (mean ± SD lameness = 0.0 ± 0.0). No articular cartilage damage was present in any dog. Grossly, the meniscal tears ranged in appearance from readily recognizable to non-apparent. Histologically, evidence for retention of the BioDuct™ implant was noted in 4 of 5 sites. In these sites, fibrovascular tissue was noted to be present extending from the synovial-meniscal junction to the tear, in association with the implant. This fibrovascular tissue was present within the lumen of the implant. The fibrovascular tissue was composed of a dense population of spindlyloid cells, associated homogeneous extracellular matrix, and small blood vessels. BioDuct™ MRD was associated with complete or partial healing in all avascular defects in this model. This was not seen in implants treated by trephination alone. The trephination defect was visible in 3 of 3 defects examined histologically, but was not associated with any fibrovascular tissue or blood vessels. There was no histologic evidence of healing in any of the trephination sites. (Fig. 4)

Discussion: BioDuct™ MRD could be implanted into menisci and maintain position and integrity for 12 weeks. BioDuct™ MRD was associated with complete or partial healing in all but one of the avascular defects in this model. This healing was not seen in meniscal defects treated by trephination alone. The finding is consistent with historical data from animal model studies as well as clinical cases. Therefore, the fact that BioDuct™ MRD resulted in at least partial healing in all but one of the defects in this study and complete healing in 80% of avascular defects examined histologically has important scientific impact and clinical relevance. The clinical relevance is supported by the fact that the meniscal healing associated with BioDuct MRD in this study was functional in terms of limb function, chondroprotection, and BioDuct-treated defect strength compared to normals and trephine-treated defects. A load to failure value of 52% of normal, intact meniscus at 3 months post-surgery is considered very high and physiologically functional (Cook JL, et al. AJSM, 2006). Based on these data and the ability to apply this to arthroscopic delivery in human knees (Cook JL, unpublished data 2006), this novel biodegradable implant, BioDuct™ MRD, has tremendous potential for treatment of avascular (white-white) and poorly vascularized (red-white) meniscal tears, for which it can be successfully implanted from the tear site to the vascular meniscal rim-synovial junction, the tears can be surgical repaired, and patient compliance to appropriate postoperative rehabilitation can be ensured.

*Funded by BioDuct LLC

IN VIVO EVALUATION OF A SYNTHETIC CONDUIT FOR AUGMENTATION OF AVASCULAR MENISCAL HEALING AND REGENERATION IN A DOG MODEL

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Fig.4. Histologic appearance of A) BioDuct™ MRD- and B) trephine-treated avascular meniscal tears 12 weeks after surgery

For the biomechanical testing portion of the study, the mode of failure for all treated specimens was failure at the defect site. Normal, unoperated menisci all failed at mid-substance of the tissue between the grips. Gross slippage of meniscal tissue in the grips was not seen. Three of five (60%) trephine-treated meniscal specimens had zero strength; whereas, only 1 of 7 (14%) BioDuct-treated specimens had zero strength. Mean (±SE) load to failure for the normal, unoperated meniscal tissue specimens was 43.2 ± 19.3N. Mean (±SE) load to failure for the defects treated with the BioDuct was 22.3 ± 8.4N, which was 52% of what was measured for intact, normal meniscus. Mean (±SE) load to failure for the defects treated with trephination was 0.6 ± 0.3N, which was 1% of intact, normal meniscus. Load to failure for normal menisci was significantly (p<0.017) higher than BioDuct- and trephine-treated menisci. Load to failure for BioDuct-treated menisci was significantly (p=0.05) higher than trephine-treated menisci. (One-way ANOVA with all pairwise post-hoc test)