FIBER REINFORCED HYDROGELS AS A SYNTHETIC MENISCUS REPLACEMENT

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The meniscus is a semi-lunar fibrocartilage disc present in the knee that is important primarily for weight bearing and shock absorption.[1-3] Injuries in the meniscus occur frequently and over time lead to degeneration of the knee joint.[4] Most injuries occur in the inner two-thirds of the meniscus, which is avascular and generally not surgically repairable. Initially, the meniscus was regarded as an unnecessary appendage and was completely removed at the first sign of injury. In the past few decades, however, total meniscectomy has been shown to lead to severe joint degeneration. Partial meniscectomy is currently the most common treatment for a meniscal injury; however, degradation of the joint still occurs. Allograft transplantation has been used to replace injured menisci and is capable of alleviating pain and swelling; however, the long-term results of this procedure are still unknown. Availability, donor matching, and the possibility of transferring diseases limit allograft transplantation in its use as well.[1,3]

Current research is attempting to regenerate the meniscus using tissue-engineering concepts and to evaluate the use of autografts and allografts as a replacement meniscus. Tissue-engineered scaffolds show promise; although, poor initial mechanical properties limit the use of these scaffolds as complete meniscal replacements. Autografts and allografts are primarily ill suited to replace the meniscus due to size mismatches between the donor tissue and the original tissue. Limited research has been performed on the development of a synthetic meniscus. The selection of the biomaterials to use for the implant has shown to be a significant issue.[1]

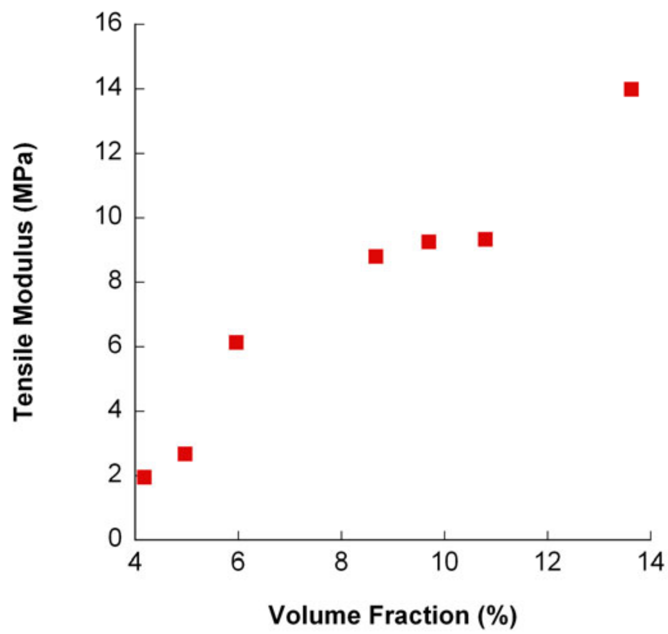

Figure 1 Tensile modulus of polypropylene reinforced hydrogels as a function of fiber volume fraction

Fiber reinforced hydrogels have been selected as a possible biomaterial capable of withstanding the forces present in the knee during loading. Several different fiber types including polypropylene and ultra high molecular weight polyethylene (UHMWPE) have been chosen for reinforcement. Preliminary work synthesizing and characterizing these composites has shown significant increases in tensile modulus by incorporation of polypropylene fibers within the hydrogel matrix. Figure 1 shows a tensile modulus of approximately 14 MPa at a polypropylene fiber volume fraction of 14% compared to the hydrogel tensile modulus of 0.3 MPa.

Environmental scanning electron microscopy (ESEM) was used to look at the interface between the fiber and hydrogel. As shown in Figure 2, circular voids are present around the polypropylene fibers. These voids are believed to be a result of poor adhesion between the fiber and hydrogel matrix.

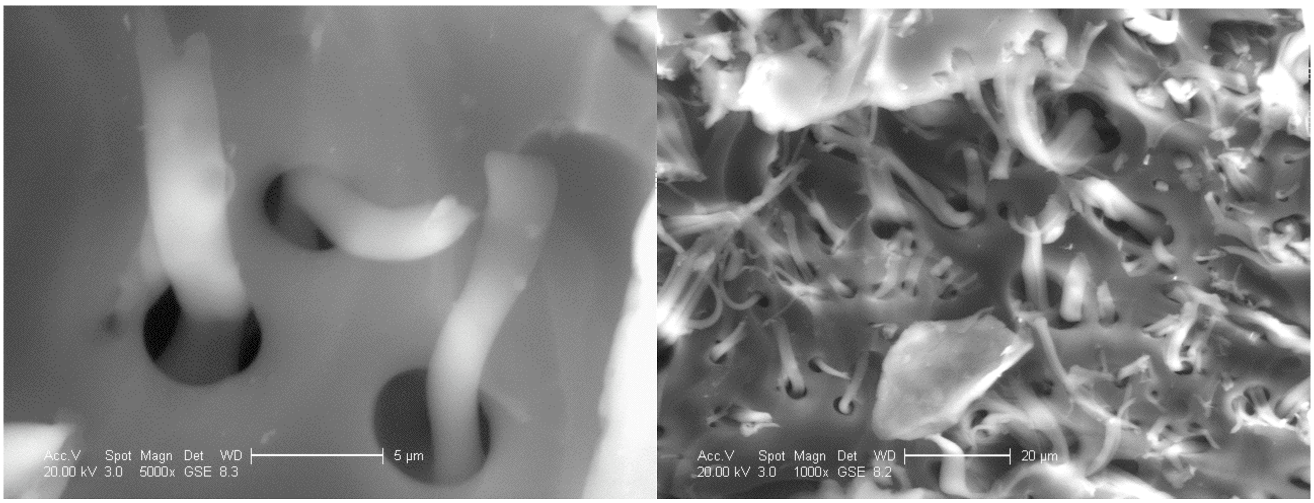

Figure 2 ESEM images of polypropylene reinforced hydrogel composites

Additional research was performed on composites synthesized using UHMWPE fibers; however, all of the samples tested in tension experienced interlaminar failure in between 5% and 15% strain. The tensile modulus before failure was approximately 20.8 MPa at a fiber volume fraction of 10%.

Polypropylene reinforced hydrogels successfully satisfy the loading conditions of the meniscus in areas that experience minimal loading, such as at the surface and radially. UHMWPE reinforced hydrogels show promise for the areas of the meniscus that experience increased loads, such as circumferentially. However, continued research needs to examine the impact of fiber orientation and interfacial strength in order to minimize the occurrence of failure.

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