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Commentary

Hydrogel Based on Porous Poly (Vinyl Alcohol) for Knee Meniscus Functional Repair

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COMMENTARY

In terms of load transfer, stress absorption, and general proprioception, the meniscus fibrocartilage plays a critical role in knee joint biomechanics. By developing circumferential (hoop) strains, the menisci primarily transfer forces between the femoral and tibial joint surfaces. The viscoelastic nature of meniscal fibrocartilage is also important for compressive load dissipation: the energy is absorbed by the compression of meniscal collagen fibres and the ejection of joint fluid through the tissue's highly ordered structure. Severe meniscal injuries are common, and because suturing is often impossible, they are treated with partial or total meniscectomy. One way to prevent these issues is to restore meniscal functions with a biostable substitute that can match the meniscus' biomechanical natural features. Total meniscal replacement allografts are an option, but they come with drawbacks in terms of clinical availability, size tenability, and cost. As a result, a synthetic implant with long-term durability, clinical processability, and customizable biomechanical qualities similar to the natural meniscus could be a viable option. The high water content of native fibrocartilage can be approximated using a hydrogel-based substance. Furthermore, submillimeter-scale porosity might be added into the hydrogel's bulk to simulate fluid exudation and pressurisation in natural tissue, as well as tunable viscoelasticity to functionally mimic the meniscus' load dissipation capabilities.

Porosity would also aid in the implant's integration with the surrounding tissue, allowing for cell migration and mechanical anchoring. To create such an implant, we used Poly (Vinyl Alcohol) (PVA), a biocompatible polymer with long-term stability that has been used in a variety of biomedical applications, including as a meniscal implant, according to the literature. In vivo, PVA hydrogel meniscus prosthesis were shown to enhance histology scores in a rabbit meniscectomy model. PVA hydrogels were used in sheep, however they failed miserably due to the hydrogels' inability to tolerate the tensile hoop stresses experienced by the meniscus. Others have sought particle- or fiber-reinforced hydrogels as a result. However, such solutions may have the typical downsides of composite materials, such as inhomogeneous mechanical and biological responses and more complex processing, particularly when manufacturing a porous matrix, as in this case. The goal of this study was to design, develop, and validate a porous PVA hydrogel-based meniscal repair implant that could be a surgical alternative to allograft implantations. Because of its tissue-like mechanical behaviour and biocompatibility, PVA hydrogel is a promising material for biomedical applications, with the potential to replace stiff prosthesis components and function as a synthetic meniscal cartilage-like structure.

PVA hydrogels have a viscoelasticity that is comparable to that of native biological tissue. After a compressive action, the porous structure is able to exudate the internal aqueous fluid phase with a specific time-dependency as a function of its stress-relaxation behaviour confirms that the porous structure is able to exudate the internal aqueous fluid phase with a specific time-dependency as a function of its stress-relaxation behaviour confirms that the porous structure is able to exudate the internal aqueous fluid phase with porosity (relative).

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