Biomimetic Hydrogel-Scaffold for Tendon and Ligament Repair

Lucas Chan, Luke Gailloux, Matt Levasseur, Edison Luke

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Abstract

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Introduction

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Hydrogel Structure and Composition

Hydrogels are 3D crosslinked polymer structures containing hydrohpilic functional groups, allowing them to absorb large quantities of water. Because of this, they are flexible and soft, and resemble many natural tissues (Ho et al., 2022). Recent advances in hydrogel technology have led to the development of implantable and injectable hydrogels with potential applications in drug delivery. By adjusting polymer composition, key properties such as swelling-deswelling rate, stiffness, and degradability can be fine-tuned to meet specific use case requirements. As biomedical applications of hydrogels continue to expand, their use in tendon and ligament repair presents a promising opportunity.

Hydrogel cross-linked chains can be formed using natural, synthetic, or semi-synthetic polymers. Natural polymers such as cellulose, chitosan, and collagen are inherently biocompatible and bioactive, but come at the cost of weak stability and poor mechanical strength. Being derived from natural sources, these hydrogels are generally safe to use in clinical applications, but have shown to be allergens in rare cases (Ho et al., 2022).

On the other hand, synthetic hydrogels are made of man-made polymers like polyvinyl alcohol (PVA), polyethylene glycol (PVG), or polyacrylamide (PAAM). Few of these synthetic materials have been shown to be biocompatible, but they offer superior mechanical strength and stability (Ho et al., 2022).

To achieve both the biocompatibility offered by natural hydrogels and the strength and mechanical properties offered by their synthetic counterparts, a common approach is to develop a hybrid, or semi-synthetic hydrogel chain. Hybrid hydrogels can either be made by chemically modifying natural polymers or by blending natural and synthetic components.

Biocompatibility

The Janus Tough Adhesive has shown to exhibit high biocompatibility during testing, despite it containing the synthetic polymer polyacrylamide. To evaluate their performance and impact on natural tissues, Freedman et al. (2022) experimentally tested injured and healthy rats, and applied the JTA to the patellar tendon. For three weeks, potential swelling of the tendon and degredation of the gel were assessed by high frequency ultrasound. When a tendon becomes injured, its echogenicity—the amount of sound it reflects—decreases, because its collagen fibres become more disorganised and less densely packed (Hodgson et al., 2012). Researchers also found that injured tendons without application of the JTA had larger cross-section areas, indicating increased swelling as shown in Figure 1 below. A decrease in inflammation in the affected tendon therefore suggests that the JTA was effective and well-tolerated by the body.

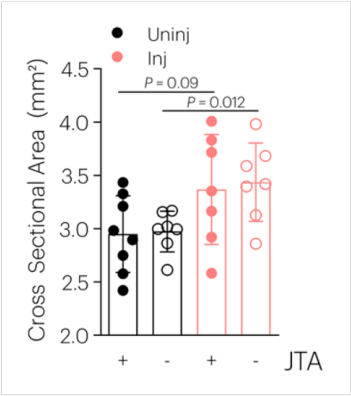

Figure 1: *Patellar tendon cross-sectional area (mm^2) after 3 weeks of treatment [Adapted from Freedman et al., 2022]*

Furthermore, in the patellar tendon, the JTA was found to have improved tendon relaxation (Figure 2), without impacting natural properties such as elastic mechanics, dynamic modulus, or linear modulus.

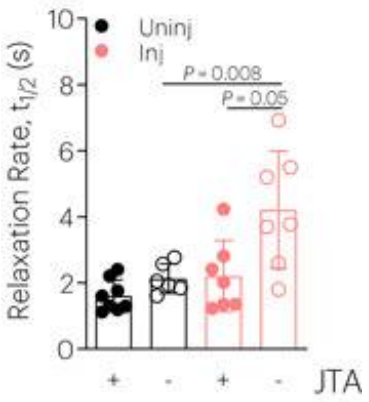

Figure 2: *Patellar tendon relaxation rate [Adapted from Freedman et al., 2022]*