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IMPROVING THE MECHANICAL PROPERTIES OF BIOMATERIALS FOR SOFT-TISSUE REPLACEMENT APPLICATIONS

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In the design and engineering of implantable medical devices, such as soft-tissue replacements, choice of materials is limited to the small subset of materials which are generally accepted as biocompatible. Mechanically demanding applications such as ligament and tendon replacement require materials with sufficient strength and stiffness as well as resistance to long-term detrimental effects such as fatigue and permanent elongation. The tensile strength of the ligaments and tendons derives from parallel, axially aligned collagen fiber bundles. These bundles have a distinctive periodic crimped structure, resulting in a unique non-linear stiffness, characterized by a low modulus toe regime at lower levels of strain and a higher modulus linear regime at greater levels of strain. Furthermore, these bundles are suspended in a ground substance consisting of a hydrophilic proteoglycan matrix and water which accounts for the observed viscoelastic response. Taking a biomimetic approach, we hypothesize that mechanical design inputs for a ligament or tendon replacement device can be satisfied by a construct made of biocompatible, hydrophilic, polymer fiber yarns organized in a periodic textile structure and possibly embedded in a hydrogel matrix. Biocompatible hydrogels in the untreated state have insufficient strength and stiffness to bear tensile loads in vivo and consequently are inadequate for ligament and tendon replacement. Thermal and mechanical treatments such as annealing, freeze-thaw cycling, pre-stretching, and coating of constructs under tension have been explored and have demonstrated promise as techniques by which both the immediate and long-term mechanical properties of prospective materials can be improved to the level required for tensile load bearing soft-tissue replacement. A biocompatible material with improved tensile properties could be applied to a ligament or tendon prosthetic replacement medical device which could provide an adequate alternative to circumvent the drawbacks associated with currently available techniques such as autografts and allografts.