Incorporation of Biochemical Stimuli by Surface Coating Fiber Based Scaffolds for Tissue Engineering a Tendon-Bone Junction

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Statement of Purpose: A musculoskeletal interface, such as a tendon bone junction, is a complex tissue site, which connects two tissues with widely different mechanical properties. The interface therefore transfers stress from soft flexible tendon tissue to hard mineralized bone, and in doing so, it plays an important role in generating movement and maintaining the stability of joints. Such an interface is prone to injury since it connects two very dissimilar types of tissues.
Many studies have successfully engineered tendon and bone tissues separately, but this has not led to the reattachment of torn or severed interfacial tissues clinically. Hence it is one of the most immediate challenges in the field of tissue engineering and regenerative medicine. The ultimate goal of this study was to develop a biodegradable biphasic scaffold for tendon-bone junction regeneration using textile technologies and surface treatments. In order to achieve this goal, the first step was to develop a tubular scaffold and incorporate biochemical stimuli by means of a surface coating to improve the biocompatibility and cell adhesion and proliferation.

Methods: A novel grooved (4DG) fiber, a trilobal shaped fiber and a traditional round fiber made from poly(lactic acid) (PLA) were included in this study. The polymer containing 98% L isomer and 2% D isomer was supplied by Nature Works LLC (Minnetonka, MN) and was spun and drawn into multifilament yarns at Hills Inc. (Melbourne, FL, USA). The yarns were developed into different scaffold structures through braiding on a Steeger braiding machine and by circular knitting on a Lamb single feed 12 needle weft knitting machine (Fig 1).

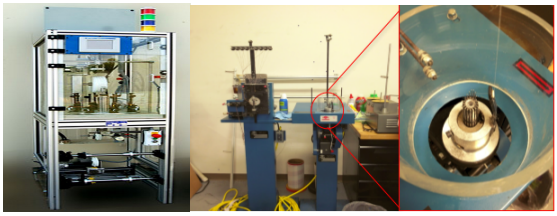

Fig 1. a) Steeger braiding machine, b) Lamb single feed 12 needle circular weft knitting machine

The scaffolds were then coated with type I collagen using genipin as a spacer molecule following radio frequency plasma treatment for surface activation after immersing in a 1M maleic acid prior to the plasma treatment (Fig 2).

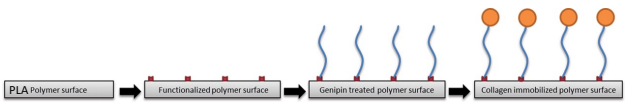

Fig 2. Schematic diagram of collagen immobilization [1]

Results: The linear density of the yarn with round and trilobal shaped fibers was 300 denier with 72 filaments per ply, and the linear density of the 4DG yarn was 500 denier with 62 filaments per ply. SEM images of the three fiber cross-sections are shown in Fig 3.

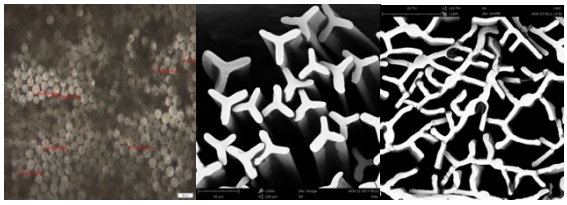

Fig 3. SEM images of yarns with a) round, b) trilobal and c) 4DG fiber cross-sections

The yarns were used to fabricate the following 6 different scaffolds:

Sample	Fibers	Inner layer	Outer layer
SC1	Round	Braided inner layer	Braided outer layer
SC2	Round	Weft knitted structure	Braided outer layer
SC3	4DG	Braided inner layer	Braided outer layer
SC4	4DG	Weft knitted structure	Braided outer layer
SC5	Trilobal	Braided inner layer	Braided outer layer
SC6	Trilobal	Weft knitted structure	Braided outer layer

The surface chemistry of the scaffolds will be analyzed using Fourier transform infrared (FTIR) spectroscopy, contact angle measurements, x-ray photoelectron spectroscopy (XPS) and time of flight secondary ion mass spectrometry (TOF-SIMS) to determine the uniformity and efficiency of the collagen coating process. The attachment and proliferation of mesenchymal stem cells will be determined on all 6 different types of scaffolds.

Conclusions: The collagen coated PLA tubular structure will mimic the natural tendon tissue both mechanically and biologically. The incorporation of a collagen coating will promote bioactivation and improve biocompatibility. Further, the different cross-sectional shapes of the fibers such as the trilobal and 4DG will increase the porosity of the scaffolds due to the high surface area of the fibers, which in turn will provide guidance for cell attachment and migration.

References:

[1] Tambe, Nisarg, et al. *Journal of Biomedical Materials Research Part B: Applied Biomaterials* 103.6 (2015): 1188-1197.
[2] Tellado, Sonia Font, et al. *Advanced Drug Delivery Reviews* 94 (2015): 126-140.
[3] Apostolakos, John, et al. *Muscles, Ligaments and Tendons Journal* 4.3 (2014): 333.