Using 3D Electrospun Nanofibrous Scaffolds to Repair Tendons

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We propose 3D electrospun nanofibrous scaffolds, which replicate the tendon tissue ultrastructure, as an innovative tendon repair device.

INTRODUCTION

Biomaterial scaffolds offer an alternative intervention for the repair of damaged tendons, where suitable donor tissue is scarce.

Using electrospinning we have fabricated 3D poly(ε-caprolactone) nanofibrous scaffolds, which mimic the hierarchical structure of tendons.

SCAFFOLD FABRICATION & PROPERTIES

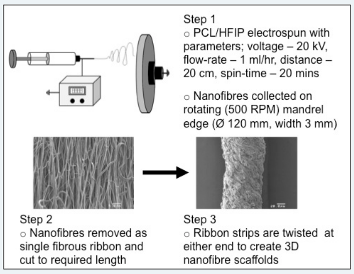

Fig. 1: Methodology for producing 3D electrospun poly(ε-caprolactone) (PCL) fibre scaffolds from a 10 %w/v solution of PCL dissolved in hexafluoro-2-propanol (HFIP).

Mechanical Property	3D Nanofibrous Scaffold
Young's Modulus (MPa)	68.14 ± 23.66
Tensile Strength (MPa)	41.54 ± 13.61

Table 1: Tensile properties of 3D scaffolds, strained to failure using Instron 1122, 5 N load cell and 5 mm/min cross-head speed (n=5).

IN VITRO CHARACTERISATION

Equine superficial digital flexor tenocytes were seeded (50,000 cm^{-2}) on ethanol sterilised and media-treated scaffolds, and cultured up to 14 days.

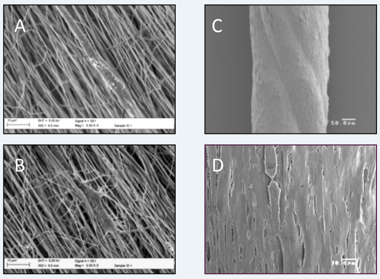

Fig. 2: Scanning electron micrographs of 3D fibre scaffolds with seeded tenocytes adhering and elongating parallel to underlying fibre direction after 24 hours (a,b).
Following 14 days culture, the entire scaffold surface is covered by proliferating cells that are orientated parallel to the scaffolds' longitudinal axes (c,d).

IN VIVO ASSESSMENT

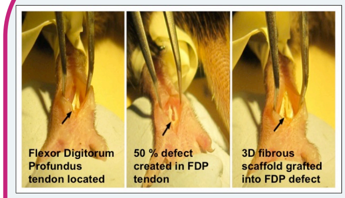

Fig. 3: Surgical procedure for creating a purpose-made defect in the flexor digitorum profundus (FPD) tendon of a mouse. 3D scaffold inserted into defect and held in place by surrounding tissues. Excised tissue was used as autograft tissue in the opposing FPD tendon.

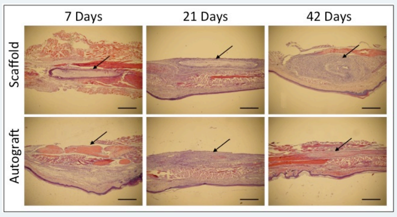

Fig. 4: H&E staining highlighting a dense population of inflammatory cells surrounding the PCL scaffold, with some infiltration. By 42 days, the scaffold appears to have degraded. Arrows indicate position of graft. Scale bar = 50 μm.

Discussion

Controlled orientation and manipulation of fibres has allowed 3D scaffolds, which mimic the tendon ultrastructure to be fabricated. 3D nanofibrous scaffolds yielded tensile strengths comparable to human Achilles tendons[1] (36.5 MPa - not tested to rupture). 3D scaffolds were biocompatible and conferred contact guidance to seeded tenocytes. Scaffolds were successfully implanted *in vivo,* however, a marked inflammatory reaction was observed. Cells were visible within the scaffold core, suggesting infiltration. Following 42 days implantation, the scaffolds appeared to have degraded, which was unexpected for this slow degrading polymer[2].

3D electrospun nanofibrous scaffolds mimic tendon tissue, confer cell contact guidance, are relatively strong and are biocompatible *in vivo.*

[1] Magnusson *et al*. (2003) *Acta Physiol Scand*, 177(2):185-195.
[2] Bosworth and Downes. (2010) *Polym Degrad Stabil*, 95(12):2269-2276.