MECHANICAL CHARACTERIZATION OF A TRIPHASIC MEW PCL SCAFFOLD MIMICKING ARTICULAR CARTILAGE ARCHITECTURE

Alessio Amicone (1) & Matthias X. T. Santschi (1), Stephen J. Ferguson (1)

1. *ETH Zurich, Institute for Biomechanics, Zurich, Switzerland*

Introduction

Due to its distinct structure and composition, articular cartilage is a soft tissue that offers a significant amount of dynamic load-bearing capacity while minimizing friction. Due to its avascular nature, however, cartilage is difficult to heal once damaged [1]. Several approaches have been investigated, but their homogeneous designs likely limit their viability. The absence of a native tissue-like structure and organization within such scaffolds may be the cause of regenerated tissue's tendency towards poor mechanical characteristics [2]. Future treatment options depend on the creation of viable articular cartilage transplants with the necessary biochemical and biomechanical characteristics as well as zone-specific organization. Melt-electrowriting (MEW) allows the manufacturing of polymeric fibrous constructions in a precise manner with a high degree of flexibility in terms of fiber orientation, spacing, and dimension [3]. The aim of this study was to use MEW to fabricate multi-scale triphasic scaffolds by varying both fiber size and orientation to mimic articular cartilage's zone-specific organization and properties.

Methods

Sample preparation. Medical grade poly (Ɛ-caprolactone) (PCL) (Mw = 70 kDa) was used to produce all structures on a custom-built MEW device, based on parameter sets established before [4]. Three groups were created for comparison. For the base-grid, a 0°-90° pattern was manufactured for 20 layers. For the mid-phase, a 0°-45°-90°-135° pattern was selected at a higher collector translation speed, to increase the mechanical stretch and thus decrease fibre diameter, for a total of 20 layers. For the triphasic constructs, both the base-grid and the mid-phase were combined and completed with a surface nanomesh, for which the feed rate was reduced by a factor of 10.

Structural analysis. All samples (n=3 per group) were imaged using a scanning electron microscope (SEM, SU5000, Hitachi, Japan). Fibre diameters were assessed using ImageJ (V. 1.51).

Mechanical properties. Scaffolds from all groups (n =3) were cut into rectangular shapes (4.0 cm x 1.5 cm) for testing, and a uniaxial tensile test was performed under quasi-static conditions (0.1 mm/s) until a strain of 150% was reached using an Instron E10000 testing machine (Instron, Massachusetts, USA).

Results

SEM imaging revealed fibre diameters of 19.8µm, 5.5µm and 640nm for the base-grid, mid-phase and the nanomesh respectively.

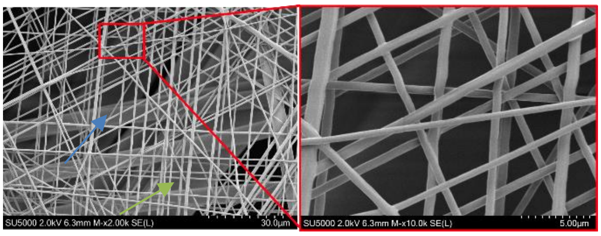

Figure 1: SEM image of the triphasic constructs with the nanomesh on top (red box), melt electrowritten on a fine microfibre mid-phase (blue arrow) and a microfibre grid (green arrow).

Young's Moduli were found to be 4.5±0.72, 3.2±0.48 and 3.8±0.18 MPa for base-grid alone, mid-phase alone and the triphasic construct. The ultimate tensile strengths were found to be 0.38±0.03, 0.27±0.05 and 0.39±0.01 MPa, respectively.

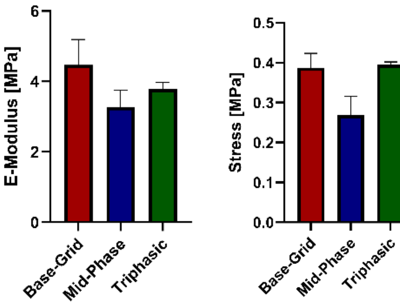

Figure 2: E-Moduli (left) and Ultimate Tensile Strength (right) for the base-grid only, mid-phase only and the triphasic construct.

Discussion and Conclusion

In this study, multiscale triphasic constructs have been successfully manufactured, resembling the zonal architecture of cartilage. Tensile tests revealed Young's moduli in the range reported for native articular cartilage, with the base grid providing critical mechanical support. Triphasic constructs therefore represent promising candidates for further evaluation by compressive testing, tribological assessments and in vitro cell studies.

References

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