Effects of Rastering Velocity on Electrospun Polyeurthane Structure and Mechanical Properties

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Statement of Purpose: Interest in electrospinning of polymeric nano-microfibers for tissue engineering application has rapidly grown during the last decade. In spite of this technique flexibility and the possibility to form various fiber assemblies more studies are necessary to elucidate and control the complex mechanics of the fabrication process. This work explores the effects of the rastering velocities on the mechanical response and on the micro-structural organization of electrospun polyurethane scaffolds.

Methods: Poly (ester urethane) urea (PEUU) was synthesized and electrospun using a protocol described in [2]. Scaffolds were fabricated using a tangential velocity of 8 cm/s and three different rastering velocities: 0.3 cm/s (slow rastering velocity group), 3 cm/s (medium rastering velocity group), 30 cm/s (high rastering velocity group). Three groups were tested adopting the biaxial testing procedure previously described [3]. In addition to the mechanical testing, the scaffolds microstructure was analyzed using scanning electron microscopy (SEM) images and a custom made software. The SEM images (n=3 randomly selected for each scaffold group from 3 different batches) were processed with a semi-automatic algorithm developed in MATLAB (The MathWorks). Fibers were manually detected by an operator. A modified Delanauy network was then generated starting from the detected fiber overlap coordinates. Pixel grey intensity variation over the directions perpendicular to each fiber enables the diameter to be estimated. The following micro architectural descriptors were extracted from the generated network: (1) fiber overlap spatial density, (2) connectivity distribution, (3) fiber angle distribution and (4) fiber diameter.

Results: The mechanical testing proves that there is no significant difference between the scaffold groups over the longitudinal axis which is the direction parallel to both the rasterer motion and to the mandrel rotating axis (Fig. 1). In contrast, the circumferential axis exhibits pronounced stiffening upon increasing the rastering speed from 0.3 cm/s (slow rastering velocity). The image analysis corroborates these findings, the 0.3 cm/s (slow group) has a fiber overlaps density significantly larger than the other groups (one way ANOVA, p values 0.017 and 0.007 for the slow-medium and slow-fast groups respectively) (mean ± std errors Fig 2). Orientation index for the fiber angle distribution plots showed a moderate reduction from the slow to the fast rastered scaffolds (mean ± std errors: 0.60 ± 0.08, 0.56 ± 0.03, 0.53±0.02 data not shown). Interestingly as the rastering velocity increases the fiber overlap spatial density decreases. Furthermore whereas the connectivity of the three groups remains constant the fiber diameter increases with the rastering velocity (fiber diameter for the three groups 0.3 cm/s 0.66 ±0.05 μm, 3 cm/s 1.17±0.2 μm, 30 cm/s 1.34 ± 0.3 μm).

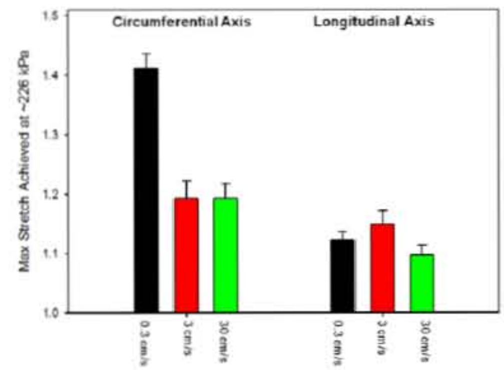

Figure 1. Max stretch from the equi-biaxial test

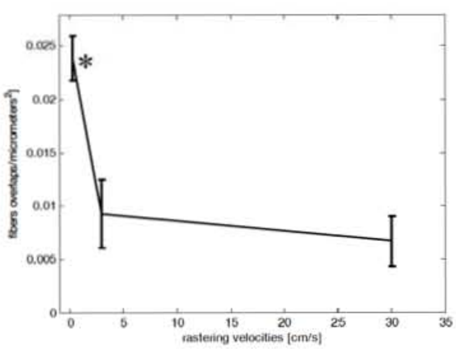

Figure 2. Fiber overlap density from the image analysis

Conclusions: These results suggest that anisotropy can be induced in electrospun scaffolds at a low mandrel tangential velocity by the reduction of the rastering velocity. For a constant value of rastering velocity overlaps spatial density decreases as the mandrel tangential velocity is raised [4]. Whereas the mandrel velocity controls the fiber angle distribution [2] the rastering velocity seems to have a direct control over the fiber overlap density. Anisotropic scaffolds can be potentially produced with a desired fiber overlap density and fiber alignment modulating the ratio between the mandrel tangential velocity and the rastering velocity. Controlling both alignment and fiber overlap density has fundamental implications on the possibility to tailor the scaffold mechanical behavior to a specific native tissue mechanical response.

References:

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