Highly moldable 3D nanofibrous elastomeric scaffolds with enhanced mechanical properties.

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Statement of Purpose: In the present presentation, development of three-dimensional, macroporous and elastomeric electrospun biodegradable scaffolds is discussed. The presented system was developed to overcome the limitations of the conventional electrospun scaffolds including i) limited shapes (two-dimensional sheet-like shapes) and ii) restricted cellular infiltration. In our previous study, by the core/sheath electrospinning technique with the polystyrene (PS) and the poly (ε-caprolactone) (PCL) followed by selective leaching technique, three-dimensional, macroporous and highly moldable nanofibrous structure was fabricated. Though the scaffolds showed outstanding flexibility and moldability, the mechanical strength of the scaffolds needed to be enhanced. In the presentation, two strategies to enhance mechanical strength of the highly moldable 3D electrospun scaffolds were introduced. Employing poly(glycerol-co-sebacate) (PGS), the three-dimensional and macroporous scaffolds with elastomeric properties could be fabricated. To increase the tensile strength, self-polymerizable additives including polydopamine or carbon nano tubes (CNTs) were added.

Methods: 3D PGS scaffolds were fabricated co-axial electrospinning followed by PGS crosslinking and selective leaching. PS solution was utilized as a sheath solution and PCL/PGS blend solution was chosen as a core solution. To crosslink PGS after electrospinning, the scaffolds were incubated for 24 hours in a vacuum oven (120 °C). After crosslinking PS in the sheath of the fibers were selectively leached out from the scaffolds using selective leaching technique as described in our previous study[1]. To fabricate additive-incorporating scaffolds, PCL/additive blend solution was employed as a core solution instead of PCL solution.

Results: Even after the vigorous leaching and washing steps, the nanofibrous structures in the scaffolds were not compromised. As described in the our previous study, a centimeter-scale scaffold with the additives (polydopamine or CNTs) could be fabricated within 10 minutes which is a significant reduced fabrication time. Furthermore, the scaffolds could be shaped into a variety of desirable shapes with manual shaping, molding and rolling with the thin wires. Interestingly, the nanofibrous structures in the scaffolds including the fibers at the outer surface of the scaffolds were intact without structural deformation likely due to its flexibility. Tensile test results show that the flexibility of the developed scaffolds were significantly higher than the conventional electrospun scaffolds. The elongation-at-break of the moldable 3D fibers without scaffolds is about 2000% and much higher compared to that of the conventional electrospun scaffolds (600%).

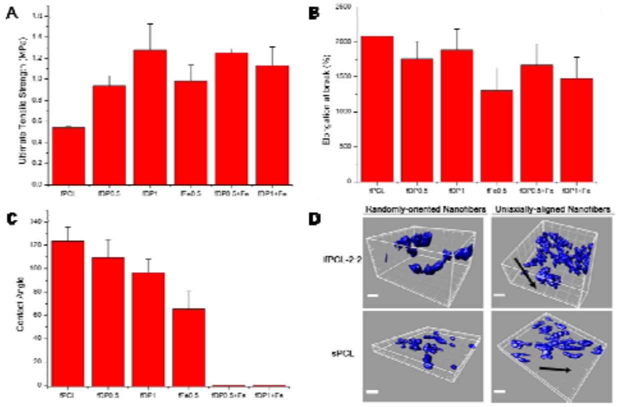

Figure 1. Mechanical properties (ultimate tensile strength (A), elongation-at-break (B) and contact angles (C)) and cellular behavior (D) on the scaffolds.

Incorporating the additives, ultimate tensile strength of the scaffolds and Young's modulus were 2- or 3- folds increased without a significant decrease of elongation-at-break. Interestingly, the additives were not removed from the scaffolds after vigorous leaching step whilst PS in the sheath was completely removed from the scaffolds. Furthermore, the cells seeded on the scaffolds showed three-dimensional infiltration into the scaffolds and increased cellular viability compared to the two-dimensional culture.

Conclusions: In conclusion, we have developed 3D electrospun biodegradable scaffolds with high flexibility and moldability by co-axially electrospinning PS and PCL/additives followed by selectively leaching the polystyrene out of the scaffolds. The resulting process generated highly fluffy PCL/additives composite structures within 10 minutes, which is relatively very short time compared with conventional electrospinning. Due to the 'clay'-like properties of highly moldable scaffolds, the scaffolds could be formed into any desired shape without compromising the micro- and macroscopic structural integrity. Scaffolds with the additives were mechanically enhanced and their tensile strength increased 3-folds. Importantly, cells cultured in the highly moldable fibrous scaffolds both *in vitro* and *in vivo* three-dimensionally expanded and infiltrated throughout the scaffolds, all of which can be regarded as significant improvements compared with conventional 2D electrospinning. Microfibrous and biodegradable scaffolds with any desirable three-dimensional shapes with tunable mechanical strengths have great potential to contribute to tissue engineering and regenerative medicine.

References:

1. Lee S. ACS Appl Mater Interfaces. 2014; 6:1082−1091