Increasing Porosity of Electrospun Scaffolds with NaCl

Lee D. Wright[1], T. Andric[1], J. W. Freeman[1]

1. Virginia Tech-Wake Forest School of Biomedical Engineering and Sciences
Virginia Polytechnic Institute and State University, Blacksburg, VA 24061

Statement of Purpose: Electrospinning is unique because it is capable of producing small fibers (diameters ranging from several nanometers to several microns) in a nonwoven mat, which is similar to the architecture of the extracellular matrix (ECM) within tissues (Liao, S. Biomed Mater. 2006:1:R45-R53). One of the limiting factors for electrospinning to be successful is cell infiltration into the scaffold. Electrospinning is hampered by an inability to effectively control the three dimensional pore structure and pore size (Karageorgiou, V. Biomaterials. 2005:26:5474-5491). Pore sizes for electrospun scaffolds are typically only several times larger than the diameter of the fibers, significantly less than needed for cell infiltration. Therefore, we have created a new technique to increase pore sizes within electrospun scaffolds. The technique incorporates salt (NaCl) during the electrospinning process. The salt size could be controlled to attain optimal pore volumes within an electrospun scaffold.

Methods: Poly(D,L-lactide) (PDLA) was electrospun at a concentration of 22% w/v in a 3:1 ratio of tetrahydrofuran and dimethylformamide (DMF) and poly(L-lactide) (PLLA) 7% w/v in a 3:1 ratio of methylene chloride and DMF, respectively, onto a rotating mandrel. A hollow mandrel filled with salt was placed above the collection mandrel. The hollow mandrel was designed to release NaCl every rotation onto the collection mandrel.

Electrospun PDLA mats (2D "scaffolds"), with and without NaCl, were then soaked in deionized water to leach NaCl and then mechanically tested in tension on an Instron 5689. The samples were tested at 37°C in phosphate buffer solution (PBS). In addition MC3T3-E1 cells were cultured on PLLA mats and viewed by scanning electron microscopy.

Results: Scanning electron micrographs of the scaffolds after salt leaching show voids left within the mats and ECM produced by cells, Figures 1 and 2 respectively.

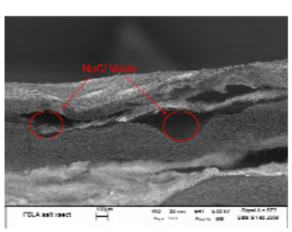

Figure 1: SEM image of electrospun mat with NaCl voids (previous study)

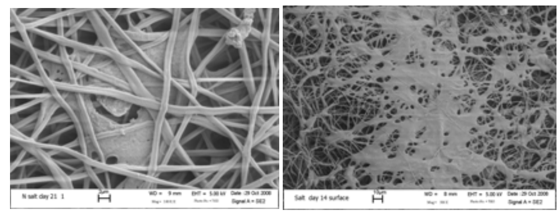

Figure 2: SEM image of ECM within electrospun mats.

After mechanical testing it was found that the addition of these pores created a difference in the mechanical properties of porous and non porous mats. The average of the moduli of the mats with and without NaCl are 3.412±0.700 MPa and 1.628±0.743 MPa respectively while the yield stresses are 549.03±105.16 kPa and 299.26±135.87 kPa respectively, Figure 3.

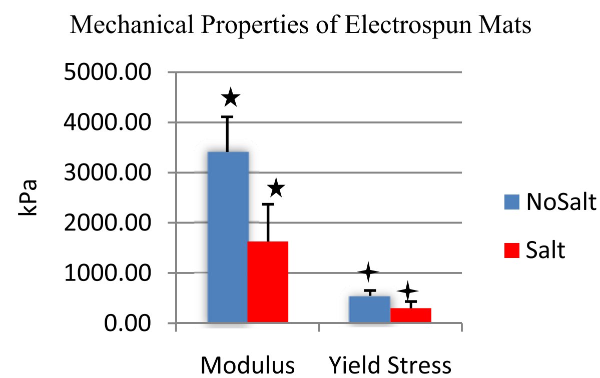

Figure 3: Mechanical properties of electrospun mats including and not including NaCl

Conclusions: In this study, NaCl crystals were used to increase the pore size of electrospun mats of polylactide. The NaCl was incorporated within the mat during electrospinning and leached out with deionized water. The micrograph in Figure 1 displays the voids (pores), averaging 300 µm in diameter, that are left after the NaCl is leached. Significant differences in the elastic modulus and the yield stress were measured between samples that did and did not have NaCl embedded. The elastic modulus and the yield stress are both reduced when NaCl is incorporated during electrospinning. The reduced mechanical properties are due to the presence of voids in the matrix and could impact the scaffold's function depending on the mechanical requirements of the tissue.
Osteoblast like cells deposited ECM into electrospun scaffolds, showing both cell viability and appropriate function of cells within the electrospun mats.