Airbrushing polymer fibers for tissue engineering applications: Impact of a device design on fiber quality X. Palmer¹, W.Tutak²

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Statement of Purpose: Submicron, synthetic polymer fibers have great appeal to tissue engineering because of their bio-mimetic morphology, ability to tune fiber degradation and mechanical properties, as well as, their ability to deliver biomolecules. Currently, fibrous scaffolds are electro-spun but the technique requires electrical current, lacks portability, and is relatively slow [1]. Polymer airbrushing, on the other hand, can potentially overcome these limitations. Airbrushed fibers are deposited at high rates, directly on live tissue [2], form 3D biomimetic scaffolds with improved cell penetration rates [3], and can be deposited in various chemical and structural configurations. Reproducible, high quality fiber synthesis is important to control cell response and tissue regeneration. However, currently little is known how various airbrush designs affect fiber synthesis, quality and reproducibility. In our work, we set out to investigate two brush designs and analyze their impact on fiber mat quality. A commercial gravity fed brush with internal mixing (CA) and a custom built syringe pump operated with external air-blast atomization brush (CBA) were compared. Methods: The CA method delivered on average 12.03 mg/s of fibers for a 4 % polymer solution at 25 PSI of air gas. For the CBA method, a 4% polymer solution (flow = 35 ml/h at 25 PSI) produced nanofibers at a rate of 11.17 mg/s. The polymer deposition rates at 4%, for both designs, were deemed comparable. Therefore, 4 and 8 % concentrations were chosen to make a comparison between the designs. All of the polymer nanofiber specimens were collected on aluminum films or polyester mesh 15-20 cm away from the tip of the nozzle. A single mat was deposited for each tested condition. After deposition, random pieces of the nanofiber mats were analyzed using SEM (S-4700-II FE-SEM, Hitachi) at magnifications of 200x (imaged area: 0.263 mm²) and 1500x (imaged area: 0.0046 mm², for fiber diameter). All calculated values (except fiber diameter) are reported as an average over the random sample area (3.15 mm^2) . Polymer fiber diameters were measured based on n>15 for each imaged area. The micrograph images were analyzed with ImageJ software (NIH). Statistical analysis was carried out using one-way ANOVA with a Tukey extension test applied to data with a normal distribution Significance level profile. 0.05). (p Results/Disscussion: When considering fiber synthesis and importance of factors as such as :(1) material reproducibility (smaller number and size of beads) and (2) control of fiber synthesis (polymer feed rate at low gas pressures), the tested brushes seem to have comparable performance but only at lower polymer concentrations. That is particularly important for CA deposition for which we found comparatively good fiber quality at tested parameters. However, at higher polymer concentrations (8 % PCL), fiber quality drastically deteriorated. Therefore, results from CBA deposition are more promising since the

higher polymer concentration and deposition rates lowered overall size of beads. Observed weak trends suggest that CBA deposition could be more reproducible and efficient if applied at higher PCL polymer concentrations. Resulting polymer solution viscosity was calculated at: 100 and 8000 IJ, and therefore required energy for the solution break up was same for both tested devices. Although the fiber formation efficacy is defined by polymer solution characteristics our results suggest that brush design is also very important. Material processing parameters such as: polymer-gas mixing mechanism, solution feed rate or nozzle design (solution



appear to impact fiber formation and quality. Conclusions: Results from this study indicate that (1) CBA appeared to be more effective in breaking up the PCL/chloroform solution and delivering better quality fibers (smaller bead size) than CA at set pressures and concentrations (2) for both CA and CBA bead number was unaffected by pressure, polymer concentration, deposition rate or device type (3) solutions with lower polymer concentration broke up easier, formed less beads and smaller diameter fibers for both devices (4) higher pressures were more effective at breaking up PCL in concentrated polymer solutions to deliver smaller fibers in CBA than in CA. This study suggests that proper brush design has an effect on polymer fiber synthesis, efficacy and final fiber quality. References: [1] Tutak, W. et al. Biomaterials 34.10 (2013): 2389-2398. [2] Behrens, A. et al. ACS Macro Letters 3.3 (2014): 249-254. [3] Hoffman, K. et al. Tissue Engineering Part C: Methods (2014).