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INFLOWMATION CHRONICLES
HIGHLIGHTS OF INTERESTING SCIENTIFIC APPLICATIONS

What is Electrospinning?

The electrospinning process uses high voltage to create an electric field between a droplet of polymer solution at the tip of a needle and a collector plate (see Figure 1&2). One electrode of the voltage source is placed into the solution and the other is connected to the collector. This creates an electrostatic force. As the voltage is increased, the electric field intensifies causing a force to build up on the pendant drop of polymer solution at the tip of the needle. This force acts in a direction opposing the surface tension of the drop. The increasing electrostatic force causes the drop to elongate forming a conical shape known as a Taylor cone. When the electrostatic force overcomes the surface tension of the drop, a charged, continuous jet of solution is ejected from the cone. The jet of solution accelerates towards the collector, whipping and bending wildly. As the solution moves away from the needle and toward the collector, the jet rapidly thins and dries as the solvent evaporates. On the surface of the grounded collector, a nonwoven mat of randomly oriented solid nanofibers is deposited. Some important applications for these nanofibers include, but are not limited to, catalytic substrates, photonics, filtration, protective clothing, cell scaffolding, drug delivery and wound healing. Different applications may require the fibers to possess different properties. For instance, one application might require the nanofibers to be hydrophobic or hydrophilic; another may need the fiber to be biodegradable or biocompatible. It will, therefore, be extremely important to completely understand the process by which these fibers are produced.

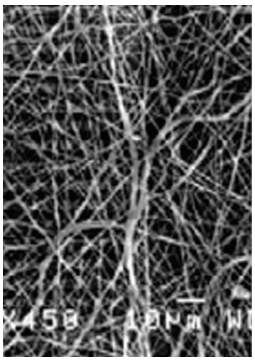


Figure 2: Resulting nanofibers.

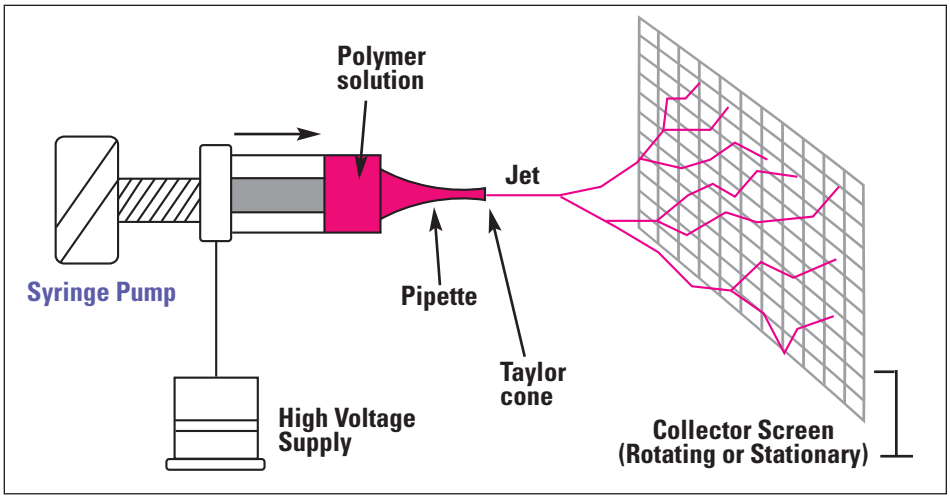
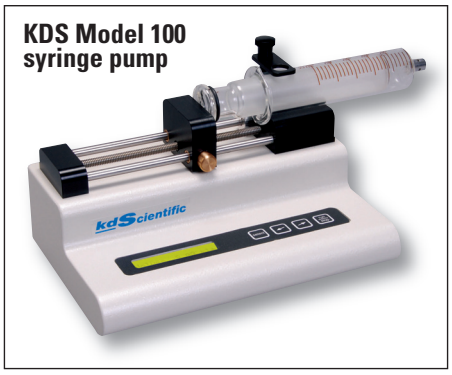


Figure 1: Basic Electrospinning Setup: Experimental setup.

Tailoring Fiber Diameter in Electrospun Poly (e-Caprolactone) Scaffolds for Optimal Cellular Infiltration in Cardiovascular Tissue Engineering

Product highlighted:
KDS Model 100 syringe pump



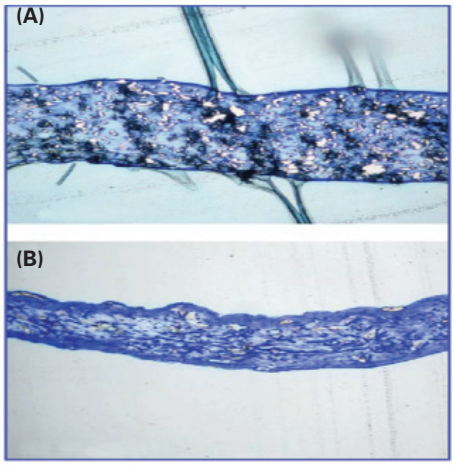
Key features for this application:

- **High precision and accuracy**
- **Smooth flow**

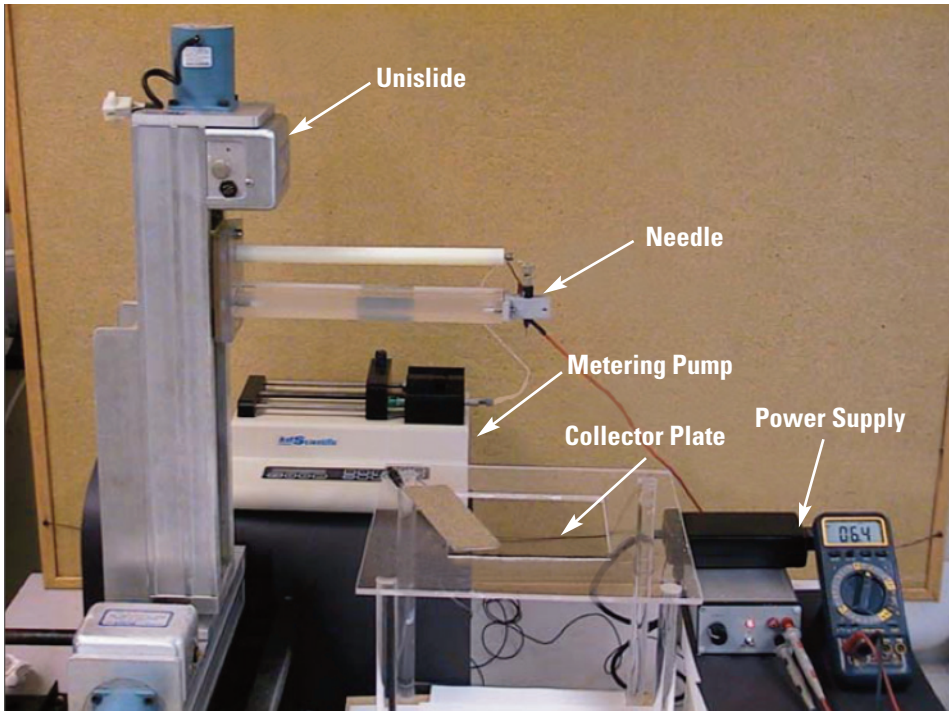
Despite the attractive features of nanofibrous scaffolds for cell attachment in tissue-engineering (TE) applications, impeded cell ingrowth has been reported in electrospun scaffolds. Previous findings have shown that the scaffold can function as a sieve, keeping cells on the scaffold surface, and that cell migration into the scaffold does not occur in time. Because fiber diameter is directly related to the pore size of an electrospun scaffold, the objective of this study was to systematically evaluate how cell delivery can be optimized by tailoring the fiber diameter of electrospun poly(e-caprolactone) (PCL) scaffolds. Five groups of electrospun PCL scaffolds with increasing average fiber diameters (3.4–12.1 mm) were seeded with human venous myofibroblasts. Cell distribution was analyzed after 3 days of culture. Cell penetration increased proportionally with increasing fiber diameter. Unobstructed delivery of cells was observed exclusively in the scaffold with the largest fiber diameter (12.1 mm). This scaffold was subsequently evaluated in a 4-week TE experiment and compared with a poly(glycolic acid)-poly(4-hydroxybutyrate) scaffold, a standard scaffold used successfully in cardiovascular tissue engineering applications. The PCL constructs showed homogeneous tissue formation and sufficient matrix deposition. In conclusion, fiber diameter is a crucial parameter to allow for homogeneous cell delivery in electrospun scaffolds. The optimal electrospun scaffold geometry, however, is not generic and should be adjusted to cell size.

Introduction

Scaffold design in tissue engineering (TE) plays an Important role in modulating tissue growth and development. Various scaffold fabrication techniques, including rapid prototyping, solvent casting, salt leaching, and electrospinning, are used to construct a broad range of scaffold geometries.Using electrospinning, highly porous, nonwoven, three-dimensional fiber structures can be made, of which the fiber diameter can range from nano- to micro-scale. The basis of this technique is to produce thin fibers by electrically charging a polymer solution flowing through a needle. The geometry of the collector determines the gross shape of the fiber mesh; this can be adapted to suit its purpose (e.g., blood vessel or heart valve geometry). The morphology of fibers can be controlled with various parameters in the electrospinning process, such as solution properties (e.g., viscosity, conductivity, polymer molecular weight), controlled variables (e.g., flow rate, electric field strength), and ambient parameters (e.g., temperature, humidity). One advantage of electrospun scaffolds is that their fiber structure, particularly when in nanoscale, is associated with high surface-to-volume ratios, providing a large area for cell attachment. Furthermore, the physical form of the nanofibrillar matrices provides high porosity and high spatial interconnectivity. It was postulated that the use of nanofibrous structures would bear a close resemblance to the dimensions of natural extracellular matrix (ECM).



Histological images of toluidine blue stained slides of poly(e-caprolactone) (PCL) group E (A) and poly glycolic acid coated with poly (4-hydroxybutyrate) (PGA-P4HB) (B). Homogeneous tissue throughout the whole scaffold was observed in the PCL construct, whereas in the PGA-P4HB constuct, the tissue structure was more compact at the edges. Scale bar indicates 1mm.



Vertical Electrospinning Setup

Although this resemblance may apply to the fiber thickness and the porosity of the nanofibrous scaffold, the spatial characteristics of ECM were not attained. In fact, the pore size of the scaffold was smaller with decreasing fiber diameter and can be as small as 100 nm. Such small pore sizes may interfere with cellular infiltration in the scaffold, thus undoing the advantages of nanofibrous scaffolds for use in TE. However, this featuremay be beneficial when the nanofiber mesh is used as a membrane, separating cell types, yet allowing communication through interconnected pores.

Materials and Methods

PCL Electrospinning

The custom-built electrospinning set-up existed of a highvoltage power supply, an infusion pump (Kd Scientific, USA), a 10-mL plastic syringe (Terumo, Belgium), a stainless steel blunt needle (inner diameter 0.6 mm), and a stagnant grounded collector. The syringe was horizontally fixed in the infusion pump. The polymer solution was led through a plastic tube to the needle, which was vertically fixed 15cm above the collector. The polymer solution was electrostatically drawn from the tip of the needle using high voltage between the needle and the collector. Five sheet-like scaffolds (groups A to E) with increasing fiber diameters were produced by varying the spinning parameters: flow rate (Q), the applied voltage (V), and the concentration of the polymer solution. The thickness of all electrospun sheets was approximately 1 mm.

In summary, successful delivery of cells during seeding on an electrospun scaffold strongly depends on the fiber diameter, and hence pore size, of the electrospun mesh. Despite the attractive features of nanofibrous structures for cell attachment, the data presented here encourage a shift from nano- to microfiber meshes for use in TE. Because cell size varies over a broad range, the optimal electrospun scaffold structure is not generic and should be adapted to the dimensions of the cells to be used.

Reference:

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[a] Mary Ann Liebert, Inc.
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