Electrospinning for Neural Applications

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Electrospinning is a fabrication technique used to produce nano- or micro- diameter fibers to generate biocompatible, biodegradable scaffolds for tissue engineering applications. Electrospun fiber scaffolds are advantageous for neural regeneration because they mimic the structure of the nervous system extracellular matrix and provide contact guidance for regenerating axons. Glia are non-neuronal regulatory cells that maintain homeostasis in the healthy nervous system and regulate regeneration in the injured nervous system. Electrospun fiber scaffolds offer a wide range of characteristics, such as fiber alignment, diameter, surface nanotopography, and surface chemistry that can be engineered to achieve a desired glial cell response to injury. Further, electrospun fibers can be loaded with drugs, nucleic acids, or proteins to provide local, sustained release of such therapeutics to alter glial cell phenotype to better support regeneration.

Electrospinning Neural Regeneration

1. Introduction

Electrospinning is a versatile technique used to generate biocompatible, biodegradable scaffolds for tissue engineering applications. Electrospun polymer fibers are frequently used in regenerative medicine, drug delivery, and in vitro modeling for a variety of biomedical applications, including wound healing, bone regeneration, and nervous system regeneration [1][2][3][4][5][6].

2. Electrospinning

Electrospinning is a fabrication technique used to produce nanometer or micrometer diameter fibers using an electric voltage drop to draw a thin polymer jet from a metal needle and deposit fibers onto a grounded collector [7][8]. The solvent used to dissolve the polymer evaporates as the jet rapidly elongates and whips through the air [9]. The whipping results in the random collection of thin polymer fibers on the collector, usually a metal plate. However, the orientation of the fibers can be controlled by collecting the fibers on a rotating mandrel [10][11] (Figure 1A), an oscillating collection plate [12], or between two parallel plates [13][14]. Studies using electrospun fibers as scaffolds for peripheral nerve or spinal cord regeneration have shown that an aligned fiber arrangement is critical for directionally guiding neuronal regeneration through the injury site, as the aligned fibers mimic the aligned topography of the uninjured anatomy in peripheral nerves and the white matter tracts found in the spinal cord [15][16][17][18][19][20][21][22].

Figure 1. Electrospinning apparatus configurations and examples of electrospun fiber features that affect glial cell behavior. (**A**) Electrospinning apparatus configuration for generating randomly oriented fibers on a flat plate (left) and aligned fibers on a rotating mandrel (right). Electrospinning apparatus parameters and the materials used for electrospinning can be tuned to alter fiber (**B**) nanotopography, (**C**) conductivity, (**D**) functionalization, or (**E**) drug-loading to engineer a desired cell response.

The process of electrospinning is versatile in that several parameters can be adjusted to produce fibers with desired properties. Fiber diameter can range from tens of nanometers to tens of micrometers and is modified by altering the concentration of the polymer solution, the dielectric constant and vapor pressure of the solvent, the polymer solution flow rate, and the distance between the needle tip and the collector [17][23]. The nanotopography on the surface of each individual fiber can also vary from smooth to pits, divots, pores, or grooves by incorporating a nonsolvent into the electrospinning solution or varying the humidity of the electrospinning environment [24][25][26] (Figure 1B). Electrospun fiber diameter, alignment, density, and surface nanotopography have all been shown to affect neuronal and glial behavior][24][27][28][29]. Additionally, the unique properties of various materials used to generate electrospun fibers, such as biocompatibility, degradation rate, and conductivity (Figure 1C), can affect cell adhesion, migration, and phenotype [30][31][32]. Fibers can also be further functionalized by incorporating drugs or surface coatings to produce a desirable effect for a given application [1][6][23][33] (Figure 1D,E)

3. Conclusions

Electrospun fiber scaffolds mimic the native ECM in the nervous system and provide contact guidance for regenerating neurons. The major glia in the PNS and CNS are affected by several electrospun fiber characteristics both in vitro and in vivo. The complex pathophysiology of nervous system injury requires therapies that target multiple aspects of the repair and regeneration process for various durations. Electrospun fiber scaffolds offer a wide range of design parameters that can be tailored to achieve this; fiber diameter, alignment, density, biocompatibility, surface nanotopography, and surface chemistry can be tuned to elicit a desired cell response. Further, electrospun fibers can be loaded with drugs, nucleic acids, and growth factors to provide the local and sustained release of therapeutics to alter the glial cell phenotype and create a regenerative environment.

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