School of Biomedical Engineering, Science and Health Systems

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Tissue Engineering Technologies for Cardiac and Neuronal Applications: Intelligent Scaffolds Made by Electrospinning, Lyophilization, and Critical Point Drying

Mengyan Li, Anat Perets, Peter I. Lelkes

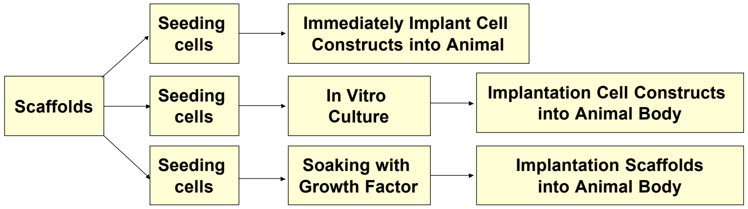
School Of Biomedical Engineering, Science and Health Systems, Drexel University

Abstract: Tissue engineering is a rapidly growing area that aims to create, repair and/or replace tissues and organs by using combinations of cells, biomaterials, and/or biologically active molecules. Tissue engineering strategies promise to advance current therapies for numerous clinical applications, such as repair of spinal cord injury, or of irreversible myocardial damage, heart failure, and significantly improve the quality of life for millions of patients. Amongst the most challenging goals in the field of neuronal and also of cardiovascular tissue engineering is the creation of engineered functional task-specific tissue constructs. In this study, we summarized the tissue engineering scaffolds that could be used to grow functional tissue constructs for several clinical applications.

Introduction

The goal of tissue engineering is to repair or replace the damaged organ or tissues by delivering functional cells, supporting scaffolds, growth promoting, and signal molecules or DNA encoding these molecules to areas in need. It applies the principles of engineering and the life sciences in an effort to reach a fundamental understanding of structure-function relationships in normal and pathological tissues and to develop biological substitutes that can grow and remodel to restore, maintain, or improve tissue and organ function.

Strategies for Application of Tissue Engineered Scaffolds



Scaffolds

Seeding cells → Immediately Implant Cell Constructs into Animal

Seeding cells → In Vitro Culture → Implantation Cell Constructs into Animal Body

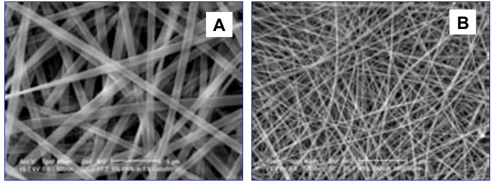
Seeding cells → Soaking with Growth Factor → Implantation Scaffolds into Animal Body

Technologies for Fabrication of Scaffolds

The ideal scaffolds for tissue engineering must provide the necessary mechanical and structural support to allow the tissue engineered construct to be assimilated into the host surroundings. The scaffolds presently being investigated in animal research promote some cellular ingrowth, but overall have many host integration issue limits and are not as effective as organ replacement. Therefore novel scaffolds and approaches need to be developed.

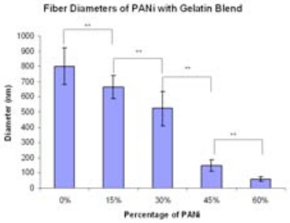
- Electrospinning: It is a process for the production of polymer filaments using an electrostatic force. In this process, a polymer solution was introduced into the electrical field. The polymer filaments were formed, from the solution, between two electrodes bearing electrical charges of opposite polarity. One of the electrodes was placed into the solution and the other onto a collector. Once ejected out of a metal spinnerette with a small hole, the charged solution jets evaporated to become fibers which were collected on the collector.
- Lyophilization: It is a process by which material is rapidly frozen and dehydrated under high vacuum, which is also called freeze-drying. It is a method to dry frozen biomaterial solution under vacuum preserving biological and chemical properties.
- Critical Point Drying: CPD is a method used for carbon dioxide drying of delicate biomaterials, without damaging the natural structure by surface tension that occurs when changing from the liquid to the gaseous phase.

Co-electrospun Fibrous Scaffolds from Synthetic and Natural Polymers

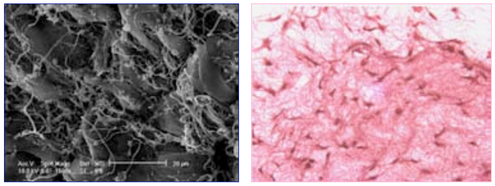


Electrospun gelatin (A) and PANi-gelatin (B) fibrous scaffolds.

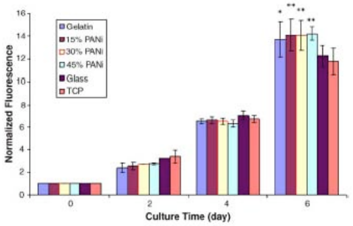
Maximum Fiber size: 802.8 ± 120.7 nm. Minimum Fiber Size : 61.2 ± 13.1 nm



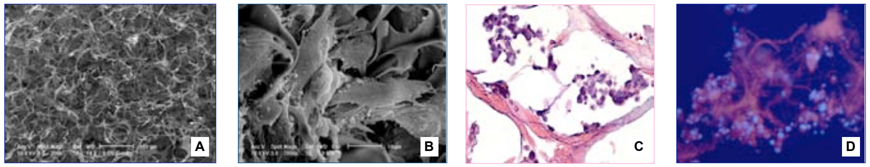
Cell Morphology and Proliferation on Electrospun Fibers



SEM and H&E staining of cells in electrospun fibrous scaffolds.



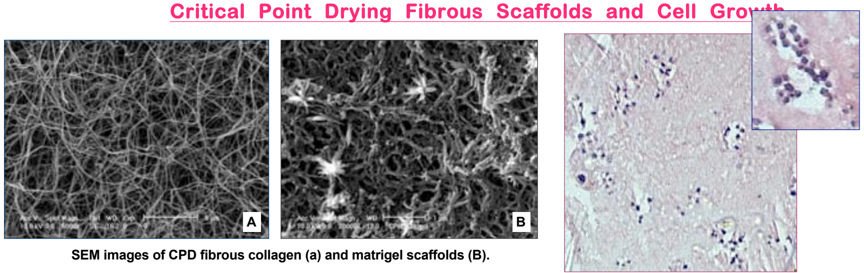
Cells Growth in Lyophilized Porous Scaffolds



SEM images of porous lyophilized scaffolds (A) and cells grew into the pores (B).

H&E and BBZ staining of cells in the porous scaffolds (C,D).

Critical Point Drying Fibrous Scaffolds and Cell Growth



SEM images of CPD fibrous collagen (a) and matrigel scaffolds (B).

H&E staining of cells cultured in CPD scaffold (C).

Conclusion

Interactions between cells and engineered ECM are crucial for modulating or redirecting cell functions in an *in vitro* environment. Biocompatibility of tissue engineered scaffolds is of primary concern since it affects cell attachment, proliferation, and further growth. In our search for novel “intelligent” biomaterials for cardiac and neuronal tissue engineering, we have further explored the use of synthetic and natural polymers to generate three-dimensional fibrous and porous scaffolds, which could be used for future transplantation in clinical applications.