Fabrication and characterization of electrospun membranes and hydrogels for Tissue Engineering application

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Scaffolds for Tissue engineering (TE)

Concept

Nowadays, the regeneration capacity of auto/allografts has produced interest in exploring alternative approaches for tissue engineering (TE). The main purpose of TE is to replace or regenerate damaged tissues or organs. TE refers to the combination of scaffolds, cells, and growth factors into functional artificial tissues. A scaffold is a 3D porous structure that emulate the extracellular matrix (ECM) and can provide cell adhesion, proliferation and differentiation. For this purpose, TE needs a scaffolds with required properties such as biocompatibility, good mechanical properties, bioactivity, biodegradability into nontoxic byproducts, and interconnected porous structure. Scaffold fabrication methods including electrospinning (ES) process, compact hydrogel and 3D bioprinter. ES allows to obtain electrospun membranes with a fibrous pattern that mimics ECM. 3D bioprinter allows to print a material loaded with cells (bioink) and obtain a cell-laden porous structure. Natural based hydrogels mimic biological tissue for its water content and biocompatibility.

Scientific approach

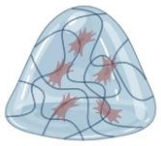
This research project is proposed to fabricate different types of scaffolds for tendon, chondral and bone regeneration, neural application, breast cancer environment, and kinetic release of essential oils for bronchial mucosa. ES process is optimized with the aim of producing fibrous patterns from synthetic polymers such as polylactic acid (PLA) or polyvinyl fluoride (PVDF). To obtain a scaffold for chondral regeneration, the membrane is loaded with magnetic nanoparticles. Instead, to obtain a scaffold for tendon regeneration, the membrane is loaded with an antifibrotic drug. Also, natural based hydrogel such as alginate, chitosan is loaded with hydroxyapatite for bone regeneration or natural polymer is loaded with carbon nanotubes for neural application is fabricated. The bioprinter process is investigated to obtain a bioink for a cell-laden hydrogel porous structure. Morphological (SEM), mechanical (uniaxial compression, cyclic and tensile test), rheological (frequency and amplitude sweep test), water contact angle and FTIR spectroscopy characterizations is carried out. Finally, biomolecule release and in vitro cell culture behavior is investigated. Following the optimization of the scaffolds, the project will investigate both static and dynamic cell culture. The aim of this last task will compare these two different culture approaches on the same scaffold, thereby elucidating the benefits of dynamic culture systems in promoting enhanced cellular activities.

Research objectives

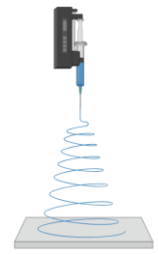
The aim of this PhD project is to fabricate and characterize scaffolds for different TE applications. Specifically, the project focus on the fabrication of composite and functionalized electrospun membranes, compact and printed hydrogels. Biological test is also carried out in static cell culture in a multiwell plate. To study the effect of a dynamic culture scaffold will be integrated into a poly methyl methacrylate (PMMA) microfluidic device.

Scaffold fabrication

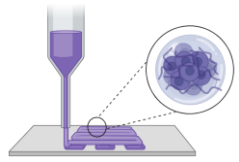
Hydrogel



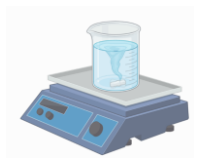
Electrospinning



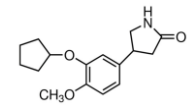
Bioprinter

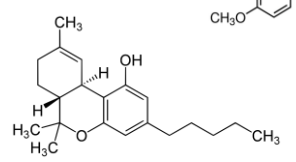


Scaffold functionalization



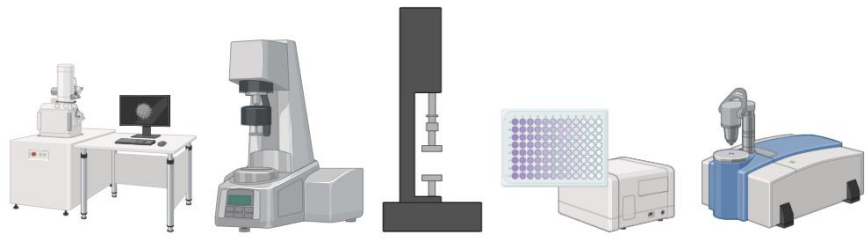
- Physical – chemical surface treatment;
- Natural polymers coating to modify biocompatibility and mechanical properties;
- Essential oil or drug incapsulated into electrospun membrane to study the effect of the kinetic release.





Scaffold characterization

- Mechanical, rheological, SEM, water contact angle (WCA) characterization;
- UV-vis and FTIR spectroscopy



Dynamic and static cell culture

The objective of this study is to evaluate the effect of dynamic cell culture compared to static cell culture, using scaffolds (electrospun membranes and hydrogels) integrated into a microfluidic device.