Multiscale model of scaffold for heart valve for in situ tissue engineering

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Introduction
The traditional tissue engineering approach requires the growth of tissue on a scaffold in a bioreactor before implantation (1). An attractive alternative is in situ tissue engineering by designing an instructive electrospun scaffold, able to meet the hemodynamic demand when it is implanted, being sufficiently strong and durable, and able to promote cellular ingrowth, proliferation and differentiation, and in-vivo tissue maturation.

Aim of the project
The aim of the present work is to develop a computational model of electrospun scaffolds based on microstructural parameters (fiber diameter, anisotropy, fibers bonding, void volume fraction). The model aims at being useful to optimize the micro- and macroscopic properties of the electrospun scaffolds.

Materials and methods
The Driessen's constitutive model (2) describes the angular fibers distribution in cardiovascular tissue through a periodic version of the normal probability distribution

\[
\phi_i = A \exp \left( \frac{\cos(2(\gamma_i - \alpha) + 1)}{\beta} \right)
\]

where \(\alpha\) indicates the main fibers angle and \(\beta\) indicates the dispersity of fibers distribution.

A representative volume element (RVE) of electrospun scaffold is built by processing the model through an algorithm that generates a distance-based fiber dispersion based on microstructural parameters (Fig 1).

A continuum layer with relatively low stiffness overlayed to the discrete network represents the neo-tissue that is formed in-situ. Ties between the discrete and the continuum layer mimic the in vivo status (Fig 2). Periodic boundary conditions describing a biaxial deformation are applied to the continuum layer with the aim of performing the complete mechanical characterization of the network (Fig 3).

Figure 2: Model of scaffold RVE with description of microstructural parameters

![Figure 2](https://example.com/figure2.png)

Results
The described model represents a tool for designing a structural model of a scaffold for in situ tissue engineering. The output of a multi-scale analysis of the in-vivo behavior of the scaffold is suitable for addressing the process of spinning of an electrospun scaffold.

Figure 3: Scaffold RVE in the deformed configuration

![Figure 3](https://example.com/figure3.png)

Future work
The coupling of the micro- and macromechanical behavior of the scaffold will be performed to fit the micromodel to the macromechanical behavior of the natural heart valve.

References
(2) Driessen N. Modeling and remodeling of the collagen architecture in cardiovascular tissue. Thesis.