PARAMETRIC STUDY OF MECHANICAL BEHAVIOR OF AUXETIC GEOMETRIES FOR SKIN TISSUE ENGINEERING SCAFFOLDS

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Introduction

Skin is the biggest organ in human body. It is an anisotropic organ composed of three different thickness and composition layers which are not uniform across the body. This particular organ is also very susceptible to large wounds as a consequence of burns that can affect the high healing capacity of the skin, and often require some type of dressing structure that might enhance tissue regeneration. The aim of this work is to study different designs for tissue engineering scaffolds whose mechanical properties can be modified according to the patient's wound needs, which could vary depending on the body location or the patient's age or gender [1]. This property tuning can be achieved by using micro-scale auxetic designs. Auxetic structures are known to expand in multiple directions when stretched, so they could better conform to the wound shape and, in addition, could promote wound healing by providing enhanced mechanical support and facilitating cell migration and infiltration [2], which would improve the mechanical properties of the regenerated tissue.

Methods

A computational parametric study of the auxetic geometries has been conducted via numerical simulations of uniaxial tensile tests based on the finite element method (FEM) using the FEM software Abaqus. For this purpose, a versatile software tool based on Python scripts has been developed to automatize the process of generation, calculation, and subsequent results post-processing of the numerical models.

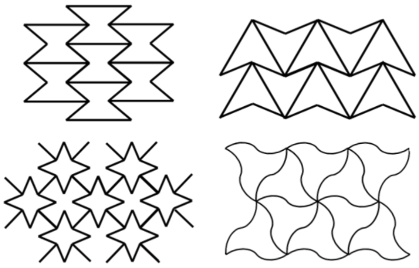

Figure 1: Examples of some auxetic designs.

Auxetic scaffold designs are based on the 2D geometries shown in *Figure 1* and their main parameters, such as rib lengths or angles, are varied among studied ranges of values in order to perform the parametric study without affecting the geometrical integrity of the studied design. Poly ε-caprolactone (PCL) is the material selected to conform the scaffolds, whose mechanical properties are obtained from literature [3], and bidimensional elements have been chosen for meshing the structure.

Results

After running the numerical simulations, mechanical properties of the scaffolds are obtained by taking the forces, displacements and sizes of the scaffolds and calculating their elastic modulus and stress-strain rates, which reveal a mechanical behavior similar to the characteristic 'J-shape' curve of the skin. This behavior consists of a low-mechanical stiffness at the beginning of the simulation, associated to the initial 'unfolding' of the structures, which is followed by a stiffening caused by the alignment of the fibers within the stretching direction that finally ends producing plastic deformation at high strain rates in some fibers, which is considered to be the use limit of the scaffold. With the aim of analyze these results for a possible clinic application, appropriate skin scaffold mechanical properties [4], along with Poisson's ratio of the skin [5], are taken from literature and can be seen in Table 1, where they are compared with some representative results from the auxetic scaffold stretching simulations.

	Elastic Mod. [MPa]	Min. Poisson's Ratio [-]
Ref. Values	4.5 – 25 MPa	– 1.7
Num. Res.	5 – 60 MPa	– 2.4

Table 1: Comparison of literature reference values [4][5] with some representative numerical results.

Both stiffness values are in a similar scale range and the 'more auxetic' Poisson's ratio measured experimentally on skin [5] (-1.7) is among the values achievable by the auxetic designs.

Discussion

Auxetic design influence in the mechanical behavior of the scaffold has been numerically simulated and results show that auxetic scaffolds have tunable mechanical properties within skin-compatible value ranges, which opens the way for their use in custom-fit applications.

References

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