Mathematical modelling of wound healing processes to help the treatment of chronic wounds

Problem raised by

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Exposition of the problem:

Wound healing is a highly orchestrated process that goes by three partly overlapping phases (inflammation, granulation tissue formation and remodelling) which involve a high number of biological events. Miscommunication between cells, substrate and biochemical and biomechanical signals leads to delayed or impaired wound healing. Examples of chronic wound are keloids (benign fibrotic tumours due to overgrowth of granulation tissue), pressure ulcers (lesions caused by unreleased pressure due to prolonged long-term bed rest or inadequate footwear) and venous ulcers (lesions caused by insufficient blood supply due to venous hypertension). Mathematical modelling can help to understand the biophysical interactions behind successful wound healing and help in the search for new and personalized treatments. This problem proposal arises from the collaboration of the Structural Mechanics and Material Modelling Group of the University of Zaragoza and the company Podoactiva, Centros de Podología y Biomécanica in the field of biomechanical behaviour of pressure ulcers in diabetes patients and falls within the scope of the National Project DPI2009-07514 granted by the Ministry of Science and Innovation.

The aim of this problem proposal is to familiarize the students with several well-established diffusion-reaction equations describing the progress of several processes in wound healing, and their numerical resolution through finite element formulations. In more detail, the students will work on models of re-epitheialization (i.e. repair of the dermis-epidermis connexion), angiogenesis (i.e. repair of the vascular system) and contraction (i.e. reduction of wound size due to cellular traction). Since wound edge can be seen as a moving boundary, the students will be introduced to these specific numerical techniques to capture moving interfaces as part of the solution.

Scheme of the work to be done:

1) Introduction of the problem, reduction to the simplified 1D models, and description of the finite element subroutines to be used.

2) Variation of the model parameter values to analyze the interactions between cells, growth factors and the mechanical environment through computer simulation. Determination of pharmacological and biomechanical strategies that yield a reduction in the healing time.

3) Study of the effect of wound shape in the healing process. Introduction of the 2D models. Description of the finite element subroutines to the used and mesh generation tools. Simulation of the healing process for different wound shapes.