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Force induced encapsulated magnetic nanoparticles as a mechanical local stimulus for cell differentiation and proliferation: 3D computational analysis

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The mechanical stimulus is one of the essential stimuli for cell differentiation and/or proliferation. One of the recent challenges is how to apply this stimulus in a local and remote regimen. In this study, we proposed a pioneer approach to apply a mechanical local cell stimulus in a remote manner via encapsulated magnetic nanoparticles exposed to a magnetic field. This technique can help in an effective way to control the tissue regeneration process within the human body. The proposed strategy is formulated within a previously developed three-dimensional (3D) computational model, which is here extended, to study the cell behavior when it senses local changes in the mechanical properties of its extracellular matrix. We assumed that the cells are cultured within 3D nonlinear hydrogels, which is modeled as Neo-Hookean hyperelastic material. A comparison between the cell behavior within a force-free and force-induced substrates has been done for neurogenic (0.1-1 kPa), chondrogenic (20-25 kPa) and osteogenic (30-45 kPa) extracellular matrix. Our findings show that mesenchymal stem cells differentiation and proliferation can be triggered by inducing its substrate with an internal force. They need a longer time to grow and maturate within force-free substrates than within force-induced substrates. Besides, at the instance of mesenchymal stem cells differentiation into a compatible phenotype, the magnitude of the net traction force increases within chondrogenic and osteogenic substrates while it reduces within neurogenic substrates. This is consistent with experimental studies and numerical works recently published by the same authors. However, in all cases the magnitude of the net traction force considerably increases at the instant of cell proliferation because of cell-cell interaction.

Biography

Mohamed Hamdy Doweidar is an Associate Professor at the Mechanical Engineering Department, University of Zaragoza, Spain. Besides, he is a Member of the Biomedical Research Networking Center in Bioengineering, Biomaterials and Nanomedicine (CIBER-BBN) at the Aragon Institute of Engineering Research (I3A) and the European Society of Biomechanics (ESB). He has participated in many national and international investigation projects. He has authored and co-authored many books and numerous articles in international journals. His investigation interests include computational biomechanics, cell simulation, finite element method, natural element method and computational fluid dynamics.

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