JOURNAL OF THE MECHANICAL BEHAVIOR OF BIOMEDICAL MATERIALS 4 (2011) 180–189

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/jmbbm

Research paper

Multiscale modeling and simulation of soft adhesion and contact of stem cells

*Xiaowei Zeng, Shaofan Li**

Department of Civil and Environmental Engineering, University of California, Berkeley, CA 94720, USA

ARTICLE INFO

Article history:
Received 13 December 2009
Received in revised form
2 June 2010
Accepted 11 June 2010
Published online 19 June 2010

Keywords:
Cell
Focal adhesion
Cell spreading
Liquid crystal
Meshfree method
Multiscale simulations
Soft contact
Stem cell

ABSTRACT

Recently, we have developed a multiscale soft matter model for stem cells or primitive cells in general, aiming at improving the understanding of mechanotransduction mechanism of cells that is responsible for information exchange between cells and their extracellular environment. In this paper, we report the preliminary results of our research on multiscale modeling and simulation of soft contact and adhesion of cells. The proposed multiscale soft matter cell model may be used to model soft contact and adhesion between cells and their extracellular substrates. This model is a generalization of the Fluid Mosaic Model (Singer and Nicolson, 1972), or an extension of Helfrich's liquid crystal membrane model (Helfrich, 1973). To the best of the authors' knowledge, this may be the first time that a soft matter model is developed for cell contact and adhesion. Moreover we have developed and implemented a Lagrange type meshfree Galerkin formulation and the computational algorithm for the proposed cell model. Comparison study with experimental data has been conducted to validate the parameters of the model. By using the soft matter cell model, we have simulated the soft adhesive contact process between cells and their extracellular substrates. The simulation shows that the cell can sense substrate elasticity by responding in different manners from cell spreading motion to cell contact configurations.

1. Introduction

Stem cells are unspecific cells that have two defining properties: (1) they have the ability to differentiate into all other functional cells in human body, and (2) they have the ability to self-regenerate. Even though it is generally believed that transcription regulation, or genetic factor, plays an important role in this decision-making process, neither the topology nor the dynamics of the regulatory networks are known at the moment.

Recent developments on stem cell research have revealed that the fate or lineage specification of stem cells depends sensitively on both the rigidity as well as surface microstructure of the extracellular matrix (ECM). For example Discher et al. (2005) and Engler et al. (2006) reported that matrix elasticity directs stem cell lineage specification. Rehfelt et al. (2007) reported that results with drug treatments of various cells on soft, stiff, and rigid matrices show a broad range of possible matrix-dependent drug responses; and cells on soft gels might be relatively unaffected in cell spreading or apoptosis induction whereas cells on stiff substrates seem more sensitive to diverse drugs in terms of spreading. All these indicate a significant influence of matrix elasticity on

* *Corresponding author.*
E-mail address: shaofan@berkeley.edu (S. Li).

1751-6161/$ - see front matter
doi:10.1016/j.jmbbm.2010.06.002