Controlling Electrospinning Jet Using Microscopic Model for Ideal Tissue Engineering Scaffolds

Shima Maghsoudlou, Department of Engineering, University of Gulian, Gulian, Iran
Sulmaz Poreskandar, Department of Engineering, University of Gulian, Gulian, Iran

ABSTRACT

Electrospinning has recently emerged as a widespread technology to produce synthetic nanofibrous and the best candidates for many important applications like scaffolds in tissue engineering. Creating porosity is the primary challenge of tissue engineering scaffolds. But, the most important challenge is to create uniform nanofibers. For these reasons, controlling producing of electrospun nanofiber becomes important. The most suitable method for controlling instability is using modeling and computer simulations. The dynamic analysis of the jet formation and its instability is difficult during the process. In this study, the behavior of the electrospinning process has been investigated by using bead-spring model to see the process in detail. Simulation of this model showed the jet behavior from the first second to the end by bringing in one bead step by step. Therefore, by increasing the number of beads, the behavior of jet during whipping part was obviously expressed.

KEYWORDS
Electrospinning, Modeling, Nanofibers, Scaffolds, Simulation, Tissue Engineering

INTRODUCTION

Tissue engineering is an interdisciplinary field that uses the principles of chemistry, physics, materials science, engineering, cell biology and medicine to develop biological substitutes that restore and improve tissue/organ functions (Cui, Zhou, & Chang, 2010).

It involves the design and manufacture of three-dimensional substitutes to mimic and restore the structural and functional properties of the original tissue. First, cells are harvested from the patient and are expanded in cell culture medium. After enough expansion, the cells are seeded into a porous scaffold along with signaling molecules and growth factors which can promote cell growth and proliferation. The cell-seeded scaffold will be then placed into a bioreactor before being implanted into the patient’s body. Nevertheless, in tissue engineering, the generated tissue should have similar properties to the native tissue in terms of biochemical activity, mechanical integrity, and function (Temenoff & Mikos, 2000). The Principle of tissue engineering is shown in Figure 1.

The purpose of tissue engineering is to repair, replace, or increase the use of a particular tissue or organ. The core technologies intrinsic to this effort can be devised into three fields (J. Fang, Niu, Lin, & Wang, 2008):

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Making and creating porosity is the main challenge of tissue engineering. In this relation, the percentage of pores, the diameter of the hollows and the value of porosity are important (Mouthuy & Ye, 2011; Weber, Lee, Shanmugasundaram, Jaffe, & Arinzeh, 2010).

Successful tissue engineering needs synthetic scaffolds to bear similar chemical compositions, morphological, and surface functional groups to their natural counterparts (Lu & Ding, 2008).

Today, scientists in tissue engineering have turned to nanotechnology, specifically, nanofibers, because the characterization of these nanofibrous structures is essential for tissue engineering applications (Barnes, Sell, Boland, Simpson, & Bowlin, 2007).

Nanofibers have varied characteristics such as a high area to surface and high porosity, are widely attracted the attention of used in making scaffolds in tissue engineering (J. Fang et al., 2008; Huang, Zhang, Kotaki, & Ramakrishna, 2003; Ramakrishna et al., 2006).

Also, nanofibers have a desirable path for sending and receiving biochemical symbols. In addition to this feature, a nanofibrous structure is more suitable for adhesion and cell increasing (Smith & Ma, 2004).

There are different methods such as electrospinning, self-assembly, and phase separation for creating scaffolds (Smith & Ma, 2004).

The applied science of producing nanofibers especially electrospinning has drawn more attention from scientists and researcher because of three-dimensional scaffolds similar to the extracellular matrix of natural tissue (Weber et al., 2010).

The physical reasoning problem, like electrospinning phenomena, has usually required a representational apparatus that can deal with the vast amount of physical knowledge that is used in reasoning tasks (Bhaskar & Nigam, 1990).

Analysis dynamics instability of the jet formation is difficult during the electrospinning process. This instability makes unsuitable aligned nanofibers which are vital for producing scaffolds. Controlling this instability is essential for creating more suitable scaffolds (Zhou, 2007).
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