Acta Biomaterialia 8 (2012) 2969–2977

Contents lists available at SciVerse ScienceDirect

Acta Biomaterialia

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

Surface modifications by gas plasma control osteogenic differentiation of MC3T3-E1 cells

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ARTICLE INFO

Article history:
Received 10 January 2012
Received in revised form 16 March 2012
Accepted 11 April 2012
Available online 20 April 2012

Keywords:
Biomaterials
Surface characterization
Protein adsorption
Cell adhesion
Osteogenic differentiation

ABSTRACT

Numerous studies have shown that the physicochemical properties of biomaterials can control cell activity. Cell adhesion, proliferation, differentiation as well as tissue formation in vivo can be tuned by properties such as the porosity, surface micro- and nanoscale topography and chemical composition of biomaterials. This concept is very appealing for tissue engineering since instructive properties in bioactive materials can be more economical and time efficient than traditional strategies of cell pre-differentiation in vitro prior to implantation. The biomaterial surface, which is easy to modify due to its accessibility, may provide the necessary signals to elicit a certain cellular behavior. Here, we used gas plasma technology at atmospheric pressure to modify the physicochemical properties of polylactic acid and analyzed how this influenced pre-osteoblast proliferation and differentiation. Tetramethylsilane and 3-aminopropyl-trimethoxysilane with helium as a carrier gas or a mixture of nitrogen and hydrogen were discharged to polylactic acid discs to create different surface chemical compositions, hydrophobicity and microscale topographies. Such modifications influenced protein adsorption and pre-osteoblast cell adhesion, proliferation and osteogenic differentiation. Furthermore polylactic acid treated with tetramethylsilane enhanced osteogenic differentiation compared to the other surfaces. This promising surface modification could be further explored for potential development of bone graft substitutes.

1. Introduction

Bone tissue engineering has emerged as a field providing alternatives to autologous bone grafts, which are still considered the gold standard treatment for healing bone defects [1–3]. Tissue-engineering strategies focus on the development of scaffolds and/or on the combination of scaffolds with cells. Traditionally cells are pre-differentiated into an osteogenic lineage through addition of growth factors or steroids, such as bone morphogenetic proteins (BMPs) or dexamethasone [4–8]. Alternatively, cell differentiation may be controlled by the physicochemical properties of the scaffold material [9–11]. This represents a more economic and expeditious approach and has the additional advantage that biologically relevant molecular signals are still transmitted to the cells through cell–surface interactions after the graft has been implanted. For example, induction of bone formation is known to be influenced by the pore size of biphasic calcium phosphate ceramic granules [12], the depth of surface concavities in hydroxyapatite ceramic discs [13] and the chemical composition of the ceramic materials [14]. This demonstrates the relevance of material properties for clinical application.

In addition to changing bulk properties of a biomaterial, one can also change the surface properties, such as topography or chemistry. For instance, it has been noted that NH_2-enriched surfaces promoted osteogenesis of human bone marrow derived mesenchymal stromal cells (hMSCs), whereas chondrogenesis was favored by COOH and OH groups [15]. However, Phillips et al. could not ascribe expression of chondrogenic markers to one specific group [16]. Changes in surface chemistry are accompanied by differences in material–protein interaction, which may account for the observed

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http://dx.doi.org/10.1016/j.actbio.2012.04.021