Journal of Fiber Bioengineering & Informatics 4:1 (2011) 1–14
http://www.jfbi.org | doi:10.3993/jfbi04201101

Bioactive Nanofibres for Wound Healing Applications

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Abstract

Electrospun nanofibres have become an exciting area in textile product development, due to their unique properties such as high surface area and porosity. Indeed, many studies on nanofibres have demonstrated their feasibility in various applications. For example, nanofibre scaffolds were shown to be promoters for tissue cell adhesion and encapsulators for drugs. In the past decade, numerous studies revealed the areas in which nanofibres can be useful, and capability for scaling-up nanofibre production, which established a starting step in the development of a new generation of textile products. However, many challenges faced today are complicated in nature and require a multidimensional approach to solve, necessitating multifunctional products. This review explored recent efforts in developing a new class of active textiles for wound care. The wound care sector is one of the most advanced in the medical industry, with a massive global demand from patients suffering from wounds, burns, and diseases such as diabetes. Ensuring satisfactory wound healing is often difficult due to the dynamic nature of the skin, requiring fulfilment of multiple objectives at different stages of the healing process. We demonstrated that by controlling how wound dressing release therapeutic agents, its mechanical responses to the wound and in aqueous environment, a wound dressing that can interact with different wounds can be developed.

Keywords: Nanofibres; Wound Dressing; Drug Delivery; Biomedical; Electrospinning; Active Textile

1 Introduction

In the recent century, the textile industry has undergone a significant transition, from serving the basic functions such as clothing, containers, and decorations, to specialized uses such as filtration, structural reinforcement, biomedical, protection, automotive, and more. While such advanced textiles are becoming increasingly important for supporting a variety of scientific and industrial activities, the demand on performance for textile products is ever increasing. One of the objectives in advanced textiles is to facilitate a paradigm shift from traditional, passive textile products into active textiles. In the context of our studies, passive textile products are those that mainly serve a supportive function, without the ability to interact with the surrounding

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environment, with typical examples including clothing and cotton wound dressings. On the other hand, an active textile product can be functionally engineered to suit specific environments, and stimulate surrounding elements to perform functions beneficial for the intended applications. Examples of active textile products include shape memory fabrics, heat regulating clothing, and vapour absorbing fabrics. The abilities of active textile products to perform specific functions and stimulate activities by surrounding elements enable such products to approach multidimensional challenges that are typical in a variety of applications, thereby producing a great impact in different industries and markets. An important example of such passive to active textile product shift can be seen in wound care, owing to the dynamic nature of the human body and the intricate healing process involved.

The wound care sector is one of the most advanced areas in the pharmaceutical industry, with a worldwide market worth $13 Billion in 2008 and was expected to grow to $17 Billion over the next four years [1]. Contributions to the large demand on wound care are from both acute wounds from surgeries or burns, and chronic wounds from venous and diabetic ulcers. In the US there are nearly 500 000 burn patients annually requiring medical treatment, as well as over 120 000 surgical procedures performed daily [2]. Also, roughly 6 million US patients suffer from chronic wounds annually [3]. The demand on wound treatment is much larger globally, especially considering the aging population in many countries. Injuries to the skin are significant burdens to the healthcare systems worldwide. Besides the direct cost from patient care, the loss of productivity associated with lengthy treatment processes, such as for diabetic ulcers, also hampers the economy [4]. The skin is the largest organ of the body. With a major role in maintaining moisture balance, temperature and protection from environmental insult timely repair of the skin is essential for the patient.

Currently, autografting remains the standard for treatment of complicated wounds such as large burns, however many patients lack available donor sites or risk generating chronic wounds and problematic healing. Skin replacement products, such as Integra developed by Yannas and Burke [5-7], and injectable scaffolds [8] have shown feasibility for partial and full-thickness wounds, whereas various hydrogel, foam, and fibre scaffolds were used for partial thickness wounds. However, for artificial skin products such as Integra, multiple surgical procedures are required during treatment, whereas injectable scaffolds suffer from the lack of structural integrity. Recently, electrospun nanofibres were introduced to tissue repair as a mechanically robust form of material that can be more effective for tissue cell activities than other forms due to its large surface area available [9]. In addition, nanofibres are also structurally similar to the extracellular matrices in tissue, composed of nanofibrous collagen. The potential for nanofibre use for partial thickness wounds have been shown in numerous studies, including our previous work on alginate nanofibres that showed enhanced fibroblast cell proliferation compared to a commercial alginate-based wound dressing [10]. Nanofibres can also be added to existing systems for enhanced performance for partial and full-thickness wounds.

With the main focus on its surface and mechanical properties, as-spun nanofibres could only serve as a platform for cell activities for relative benign wounds, or as structural supports in wound care products in the early studies. However, recent studies have shown that electrospinning is a highly versatile technique that enables control over nanofibre properties such as surface area, hydrophilicity, extensibility, strength and biodegradability. To fully harness the versatile nature of nanofibres and their properties, it is desirable to devise a new class of multifunctional nanofibres that can be customized for specific wounds, thereby overcoming multidimensional challenges that are typical in wound healing.