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Research review paper

Bacterial cellulose as a material for wound treatment: Properties and modifications. A review

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ABSTRACT

Advanced approaches to wound healing have attracted much attention in the last decades due to the use of novel types of dressings that provide a moist environment and take an active part in wound protection and tissue regeneration processes. The materials for novel wound dressings should have a set of features that will contribute to efficient skin recovery. The use of bacterial cellulose (BC) is attractive for advanced wound management because of the favorable characteristics of BC, such as its biocompatibility, non-toxicity, mechanical stability, and high moisture content. Numerous approaches can be taken to modify BC to address the shortcomings of the native material and to optimize its biocompatibility, water uptake and release, and antimicrobial activity. This review highlights possible pathways for functionalization of BC, affecting all levels of its structural organization. The focus is on post-production treatment of BC, although selected studies concerning *in situ* modifications during the biosynthesis process are also emphasized.

Contents

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1. Introduction

People have used wound dressings for treatment of severe skin burns and injuries for centuries. Historically, the principal role of a dressing in the healing process was considered to be passive protection of the wound. The primary function of traditional gauze-based dressings, such as woven and non-woven sponges as well as natural and synthetic bandages was to keep the wound dry. Exudate absorption and evaporation, together with prevention of bacterial invasion, were believed to play a key role in successful wound healing. This view on wound management, however, has been changing significantly over the last few decades. A dressing is no longer considered a passive supplement, but an active component of the healing process that is designed to control infection and provide a propitious healing microenvironment. A warm, moist environment is now recognized as one that encourages fast and effective healing, and is particularly important when dealing with chronic wounds (Bergstrom et al., 2005; Lee et al., 2009).

The global market currently offers different types of wound dressings for advanced wound management based on various materials—including natural or synthetic polymers, as well as their combinations. Implemented in different forms (films, foams, hydrocolloids, and hydrogels), these materials may contain drugs, growth factors, peptides, and other bioactive substances that can accelerate recovery (Bergstrom et al., 2005). The actual requirements of an "ideal dressing" are quite demanding: it must provide a moist environment, thermal insulation, and effective oxygen circulation; ensure liquid drainage and epithelial migration; aid in absorption of wound exudates; provide wound protection from bacterial loads and secondary infections; it must be easy to apply and painless to remove; and it should be biocompatible without provoking allergic reactions (Fonder et al., 2008; Watson and Hodgkin, 2005). This diversity of desirable characteristics imposed on modern wound healing devices is summarized in Fig. 1. These individual physicochemical characteristics of a dressing may alter wound healing, but the specific and complex process of wound recovery is affected by many other factors, such as the type of wound being treated (e.g., acute, chronic, exuding, or dry wounds, etc.), patient health conditions (the presence of other diseases, e.g., diabetes, anemia), and the social environment. Therefore, the selection of an appropriate dressing is determined by the particularity of every individual occurrence, since none of the currently existing materials is able to fulfill all the requirements of an "ideal dressing" (Lagana and Anderson, 2010). Among different dressing materials, hydrogels are currently highlighted for the treatment of burns and chronic wounds. These naturally occurring or chemically cross-linked three-dimensional (3-D) networks of polymer chains or macromolecules are filled with a significant amount of liquid and provide a supportive environment for tissue regeneration. These materials follow the contours of the wound surface and ensure oxygen and water permeation while protecting the surface from bacterial invasion (Quinn et al., 1985). One naturally derived hydrogel material that is widely used for dressing production is bacterial cellulose (BC).

BC is a polymer produced by some bacteria belonging to the genera *Acetobacter*, *Rhizobium*, *Agrobacterium*, *Aerobacter*, *Achromobacter*, *Azotobacter*, *Salmonella*, *Escherichia*, and *Sarcina* (Shoda and Sugano, 2005). It was originally served as food (nata de coco) in Asia, in form of sweet candies or custards, but its unique properties have also led to its use as a wound dressing. BC production for the specific purpose of wound dressing dates back to the early 1980s (Farah, 1990; Ring et al., 1986). Its use as a wound healing material is governed by its peculiar features: it has a high tensile strength, flexibility, and water holding capacity, a pronounced permeability to gases and liquids, and a great compatibility with living tissues (Czaja et al., 2006a). BC in its pure form also can undergo modifications that can give it tailor-made properties to fulfill all the requirements essential to function as a wound dressing material (Fig. 1). Its high porosity and surface area allows the potential for introduction and release of antimicrobial agents, medicines, and other biofunctional materials (Shah et al., 2013). The presence of chemically reactive sites within its structure provides the additional possibility for the introduction of specific non-native functionalities (Siró and Plackett, 2010). The inclusion of other compounds that can accelerate sore healing, the preparation of BC-based composites, and the chemical reactivity of the polymer chain could all

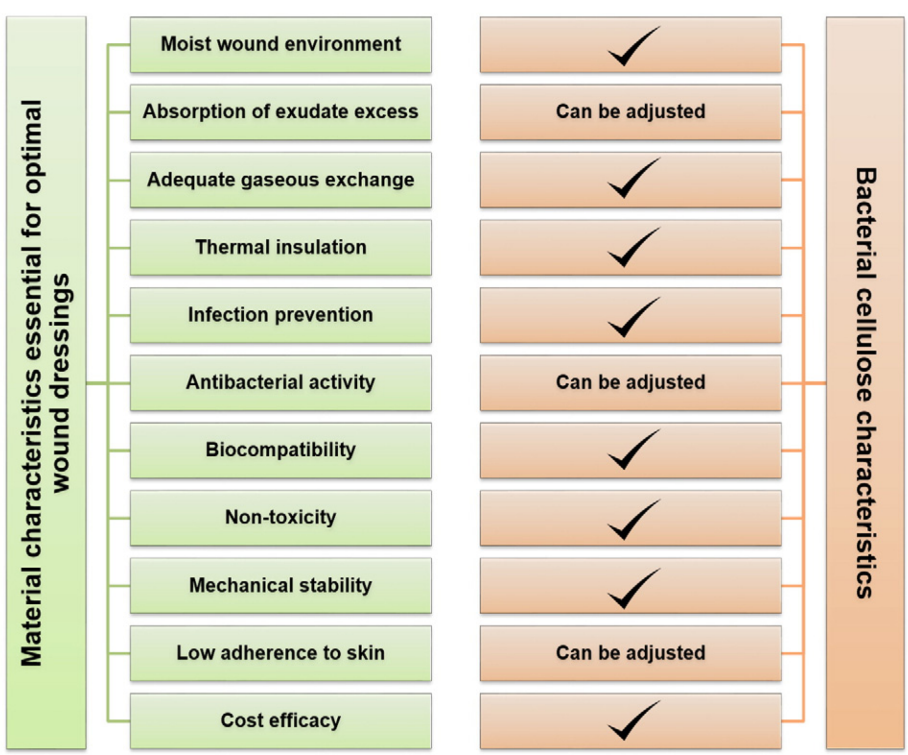

Fig. 1. An overview of bacterial cellulose characteristics with respect to the general requirements for wound dressing materials.