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Tissue Repair and Reconstruction

Necdet Sağlam · Feza Korkusuz · Mesut Şam *Editors*

Nano-Biomaterials in Tissue Repair and Regeneration

Clinical Aspect—Soft Tissues

Springer

Tissue Repair and Reconstruction

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Preface

The soft tissues chapter of this book series focuses on nano-biomaterials in tissue repair and regeneration. The human body has an unlimited capacity of repair and regeneration. The soft tissues are among them and here we have focused on microneedle patches, electrospun nano-fibers, skin reconstruction, peripheral nerves, and vascular malformations.

Nano-biomaterials are cutting-edge technologies that aid the challenges of tissue regeneration. Traditional approaches, while valuable, often face limitations. Microneedle patches and electrospun nano-fibers based on new technology may promising solutions while offering a minimally invasive, targeted, and controlled approach of delivering therapeutic active agents directly to the site of injury. Skin lesions after burns or related to chronic disorders such as diabetes are major challenges in medicine. Conventional wound dressings, while effective to some extent, often fall short in addressing the complex needs of tissue repair and regeneration. The skin, which is the largest organ of our body, serves as a vital barrier, protecting us from external threats while facilitating essential physiological functions. The process of skin regeneration becomes a complex problem when compromised by injury or disease. Traditional approaches to wound management often rely on simple dressings or grafts, which may be insufficient for addressing the diverse needs of tissue repair. Nano-technology and nano-biomaterials recently study the basic elements of regeneration. Peripheral nerve injuries on the other hand need to be treated with precision. Traditional approaches to peripheral nerve repair, such as autografts and allografts, are limited by donor site morbidity, immunological rejection, and suboptimal regeneration outcomes. Tissue engineering offers a paradigm shift, leveraging the principles of biomaterials science, cellular biology, and regenerative medicine to develop novel strategies for nerve reconstruction. Vascular malformations of congenital anomalies are unique challenges in treatment. They may cause morbidity and impair the quality of life of patients. Complications are not rare and treatment options are limited with conventional approaches. Recently our understanding of vascular biology, imaging modalities, and therapeutic interventions have evolved and tissue engineering approaches covered in this book. This book offers a comprehensive overview of vascular malformations, from their pathophysiology and clinical presentation to the latest advances in diagnosis and treatment. Each chapter provides insights into the complexities of vascular anomalies and explores the evolving landscape of modern treatment approaches.

This book integrates basic science and clinical practice through contributions from leading experts in the field. A multidisciplinary framework is established by synthesizing knowledge from diverse disciplines. We aim to empower basic scientists and healthcare professionals with the insights and tools necessary to deliver personalized, evidence-based care to patients with soft tissue problems.

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Contents

Microneedle Patches for Soft Tissue Repair

Bugra Kagan Unal and Soner Cakmak

Abstract Microneedle technology, a minimally invasive method, consists of tiny needles. Since its first research for skin in 1998, it is taking interest and enlarging its application through other tissues. Unfortunately, tissue loss or damage is one of the most important problems encountered in the clinic due to its significant negative impact on the patient's life and comfort as well as its cost to social security institutions. Microneedle arrays have proved their effectiveness for different tissues, which makes this technology a promising method for tissue healing. Especially, various advantages of microneedles such as high bioavailability and patient compliance as well as enabling long-term drug delivery for localized sites, easy adjustment of physical and chemical properties, and high drug loading capacity, will increase their usage alone or together with other systems in the future. In this chapter, we have addressed the soft tissue applications as well as providing a comprehensive review of microneedle technology.

Keywords Transdermal drug delivery · Microneedle patch · Fabrication method · Soft tissue · Regeneration

1 Introduction

1.1 Microneedle History

The term 'microneedle' (MN) was firstly used in 1926 by Robert Chamber, as a microdissection technique to inject the nucleus of an echinoderm egg [1]. The concept of using solid and hollow microneedles for drug delivery through the skin was proposed in the patent filed in 1971 by Gerstel and Place [2]. The first microneedle-based device as well as the idea of coated microneedle were introduced

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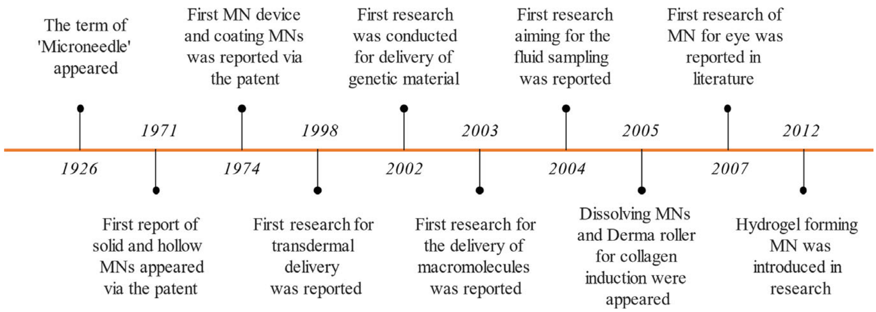

Fig. 1 Historical timeline of MN technology showing the crucial development and applications

via the patent filed in 1974 by Pistor [3]. In 1998, Henry et al. [4] reported the first microneedle research aiming to enhance drug delivery through the skin. They fabricated a microneedle array with black silicone and used it to increase skin permeability for calcein. This study was not only important as a first study but also promising to show the improved drug delivery with a painless method. In 2002, Mikszta et al. [5] developed a novel microneedle array to deliver genetic material, a naked DNA plasmid for genetic immunization.

In 2003, McAllister et al. [6] applied the solid and hollow microneedles to increase the permeability of skin for the macromolecules such as albumin, insulin, and polystyrene latex nanospheres (the diameters of 25 and 50 nm). In 2004, capillary effect-driven dermal interstitial fluid sampling through the microneedle array for in situ analyzing of glucose level was reported by Mukerjee et al. [7]. In 2005, a type of dissolving microneedles, which was made of maltose, was introduced by Miyano et al. [8]. In the same year, cosmetic application of microneedling was emerged with the microneedle roller used for collagen induction by Fernandes [9]. In 2007, Jiang et al. [10] published the first drug delivery application for the eye in which coated stainless steel microneedles were used to pierce sclera and deliver sulforhodamine. In 2012, the type of hydrogel-forming microneedles was revealed in the study conducted by Donnelly et al. [11]. Figure 1 summarizes the historical timeline of MN technology since its first emergence. Microneedle technology has been intensively studied in recent years due to its superior properties over conventional hypodermal needles and its potential to greatly increase the type of drugs that can be delivered transdermally. This technology will provide great benefits to the healthcare industry and, eventually, to patients.

1.2 Microneedle Technology: Principles and Advantages

Microneedle technology is a novel method aimed to bypass biological barriers such as stratum corneum and sclera. Although early studies of this technology are mostly relevant to transdermal delivery, other applications (e.g., biosensor) and tissues (e.g.,