Chapter 14
Functional Coatings for Bone Tissue Engineering

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ABSTRACT

This chapter outlines the application of coatings for implants and/or scaffolds used for bone tissue engineering (TE). Previously orthopaedic implants and/or scaffolds were designed considering mainly their mechanical aspects. However, due to the criticality of osteointegration with the surrounding tissues after implanting, the biological aspects of implants and/or scaffolds are becoming crucial. Recent trend is to use functional coatings like anti-infective, Ca-P and biomolecules coatings onto implants and/or scaffolds to improve anti-infective, osteoconductive and osteoinductive properties, respectively; thereby improving the osteointegration of the implant and/or scaffold with the surrounding tissue. Here, the application of different types of coatings on implants and/or scaffolds for bone TE will be described. The use of coatings as a drug and gene delivery carrier will also be covered in brief. As many of the coatings are still in preclinical testing stage, challenges associated with successful clinical use will be discussed as well.

INTRODUCTION

Bone tissue engineering (TE) is a fascinating field of research with substantial research activities focusing on delivering implants and/or scaffolds that help to restore fractures, non-unions and deformities. Previously, the design of orthopaedic implants and/or scaffolds was mainly focused on the mechanical aspects. In this way, the implants and/or scaffolds provide support to the fractured location, and thus ensure less pain while using the injured limb and help to recover back to normal use. These classical implants and/or scaffolds, such as stainless steel, titanium, alumina, partially stabilized zirconia, and polyethylene scaffolds are bioinert thus having minimal interaction with the surrounding tissues when implanted. However, to accelerate bone healing process osteointegration with the surrounding is criti-

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cal. Thus, the biological aspects of implants and/or scaffolds are becoming imperative along with its mechanical properties.

To improve the biological aspects functional coatings on the implants and/or scaffolds can be considered as the surface of the implants and/or scaffolds is the first part that interacts with the host. Coatings was introduced approximately 35 years ago as a way to modify the surface of the implants and/or scaffolds (Abukawa et al., 2006). Recently, applying functional coating onto the implants and/or scaffolds has become a common trend to improve their bioactivity and osteoconductivity properties, and thereby, improving their osteointegration with the surrounding tissue while implanted *in vivo*. To some extent, the clinical advantage of functional coatings has already been proven through early osteointegration and long term stability of the implant and/or scaffold.

This chapter will discuss the recent trends and give a future insight on the application of functional coatings for bone TE. Challenges associated to the clinical use of such coatings will also be discussed.

CLINICAL RELEVANCE OF FUNCTIONAL COATIONS

In the United States alone, delayed bone healing has been reported in approximately 600,000 fractures per year, and 100,000 progress to non-union (Bishop, Palanca, Bellino, & Lowenberg, 2012). This intensive number of patients related to delayed healing from the bone diseases and injuries created the socio-economic need for continued research on bone tissue engineering (TE), where implant and/or scaffold is an integral part of treatment. For clinical use, the implant and/or scaffold should be anti-infective, osteoconductive and osteoinductive. This performance can be effectively achieved through functional coatings on the implant and/or scaffold.

Bacterial infection on the implants and/or scaffolds surface is a major cause of the delayed healing in orthopaedic diseases. Despite strict sterilization and aseptic procedures, in United States alone, the infection rates associated with orthopaedic implants have been reported around 4.3% (Darouiche, 2004). Along with the physical pain and sufferings, bacterial infection leads to economic burden with the direct medical costs exceeding annually USD 3 billion alone (Hetrick & Schoenfisch, 2006). As the majority of the patients having implants and/or scaffolds operation are older than 65 years old (Hetrick & Schoenfisch, 2006), with the increase in life expectancy implant associated bacterial infection deserves further attention to resolve. To prevent such bacterial infection inorganic coatings such silver, zinc oxide and antibiotics incorporated coating showed great potential (Hetrick & Schoenfisch, 2006; Zhang, Myers, Wallace, Brandt, & Choong, 2014).

To accelerate bone healing at early implantation time recent developments are also focused to use functional coatings. To improve the osteoconductive and osteoinductinve properties, and thereby to improve osteointegration, implants and/or scaffolds were coated with coatings such as Ca-P and components of extracellular matrix (ECM) e.g. collagen (Surmenev, Surmeneva, & Ivanova, 2014). It is also found that composite coatings of Ca-P/ECM components offer improved biological functionality over coatings consisting of merely inorganic Ca-P or organic ECM components (Goodman, Yao, Keeney, & Yang, 2013). The biological properties of functional coatings can be improved further by adding growth factors, gene and other molecules to produce a truly osteoinductive platform (Goodman et al., 2013).

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