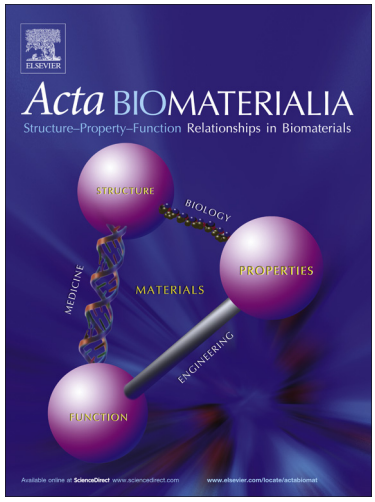

Review article

Carbon nanotubes, graphene and boron nitride nanotubes reinforced bioactive ceramics for bone repair

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Carbon nanotubes, graphene and boron nitride nanotubes reinforced bioactive ceramics for bone repair

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ABSTRACT

The high brittleness and low strength of bioactive ceramics severely restricted their applications in bone repair despite they have been regarded as the most promising biomaterials. In the last few years, low-dimensional nanomaterials (LDNs), including carbon nanotubes, graphene and boron nitride nanotubes, have gained increasing attention owing to the favorable biocompatibility, large surface specific area and super mechanical properties, which makes LDNs potential nanofillers in reinforcing bioactive ceramics. In this review, the types, characteristics and applications of the commonly used LDNs in ceramic composites are summarized. And the fabrication methods for LDNs/ceramic composites, such as hot pressing, spark plasma sintering and selective laser sintering, are systematically reviewed and compared. Emphases are placed on how to obtain the uniform dispersion of LDNs in ceramic matrix and maintain the structural stability of LDNs during the high-temperature fabrication process of ceramics. Afterwards, the reinforcing mechanisms of LDNs in ceramic composites are discussed in-depth. Moreover, the in vitro and in vivo studies of LDNs/ceramic in bone repair are summarized and discussed. Finally, new developments and potential applications of LDNs/ceramic composites are further prospected on the basis of experimental and theoretical studies.

Keywords: Low-dimensional nanomaterials; Bioactive ceramics; Reinforcing; Fabrication methods; Bone repair

1. Introduction

Tens of millions of people around the world have become victims of serious diseases and accidents every year, resulting in an urgent and increasing demand for biomaterials for the diagnosis, treatment and rehabilitation of tissues and organs [1]. In USA, ~8 million of surgeries per year are performed for these patients, but this is insufficient to avoid being disabled or even save the life of every patient. Each year, over 100,000 people die while waiting for organ transplants [2]. In 2016, the global market of biomaterials has reached 70.90 billion dollars and is expected to reach up to 149.17 billion dollars by 2021 at a compound annual growth rate of 16.0% [3]. Especially in recent years, bone defects grow rapidly due to various diseases, sport injuries,