Carbon Nanotubes as Innovative Materials for Bone Grafting Applications

Ahmed A Haroun*
Chemical Industries Research Division, National Research Centre, Dokki, Giza, Egypt

Abstract

When carbon nanotubes (CNTs) stability of the bone tissue affects the formation of bones are important issues. There is also a lot of attention to the impact of CNTs on the bone. CNTs can be considered as osteoprotective material in terms of bone regeneration, which can produce both intracellular and extracellular cell response on the material surface, which is beneficial in bone regeneration as they facilitate rapid production of bone integration. Multi-walled carbon nanotubes (MWCNTs) have excellent compatibility with bone tissue and help to repair the bone by accelerating its growth. In addition, CNTs are closely integrated without toxic effect in the grown bone. Such results will encourage the design of modalities of clinical treatment involving CNTs. Our previous studies also showed that the MWCNTs/chitosan/TiO2 nanocomposite manufactured through the technique of solvent evaporation improved implanted material resorption and increased proliferation of bone cells.

Keywords: Carbon nanotubes; In vitro bone bioactivity; Cytotoxicity; SBF, Scaffolds; Allografts

Introduction

Bone is a natural composite material that comprises approximately 45-60% minerals, 20-30% matrix and 10-20% liquid by weight. Including the water fraction in the organic phase can simply represent the composition of the bone. The matrix is the organic element composed primarily of the Type I collagen protein. The cell portion consists of osteoblasts (bone-forming cells), osteoclasts (bone-destructive cells), osteocytes (bone-preserving cells that are inactive osteoblasts stuck in the extracellular matrix) and bone lining cells (inactive cells that are thought to be precursors of osteoblasts). A calcium phosphate known as hydroxyapatite (HA) is the mineral inorganic element of bone. The chemical structure of hydroxyapatite is described by formula Ca_{10}[PO_4]_6[OH]_2 [1-3]. Bone grafts are used when bone is lost due to injury or illness to play both a mechanical and biological function, helping to restore skeletal integrity, fill voids, and improve bone repair. Worldwide, more than 2 million bone grafting procedures are carried out annually. Ninety percent of these procedures used natural bone (from the patient’s own body) or allografts (from a corpse) [4]. Because of some restrictions on the use of autographs or allografts, tissue engineering approaches have been used to try to repair bone defects using biodesorbable scaffolds to support cell attachment, migration, proliferation and differentiation [5]. An ideal material for reinforcement would provide the composite with mechanical integrity at low loads, without reducing its bioactivity. Carbon nanotubes (CNTs) have excellent potential to achieve this with their small size, high aspect ratio (length to diameter) and high strength and rigidity. Recent studies have even indicated having such bioactive properties [6-11]. Haroun AA [12] reported that MWCNTs/β-cyclodextrin or MWCNTs/dodecenyl succinic anhydride encapsulated beta vulgaris leaves extract to form bio-nanocomposites with good antioxidant properties [12,13].

Toxicity of CNTs

Toxicity, the key drawback of the use of CNTs for bone tissue engineering applications, has effectively reduced the flexibility of the surface. Compared to single walled carbon nanotubes (SWCNTs-COOH) with diameters (0.5-2nm) it was found that oxidized multi-walled carbon nanotubes (MWCNTs-COOH) with larger diameters (2-80nm) better promotes both proliferation and osteogenic differentiation. MWCNTs are shown to be well compatible with bone tissue, enabling bone regeneration and closely integrated with bone tissue.
Beta-cyclodextrin used previously for functionalization of MWCNTs to minimize their toxicity and enhance the biocompatibility [14] (Figure 1). Besides, Haroun and his coworkers [15], prepared and in vitro bioactivity examined of MWCNTs-COOH after soaking in simulated body fluid (SBF), as a standard tool to test the apatite ability formation [16]. The use of carbon nanotubes as scaffolds for bone regeneration has been evaluated with the aid of Streitzel et al. [17], which reported about MWCNTs containing mouse-implanted human bone morphogenetic protein-2 (rhBMP-2). Also, Rajesh et al. [18] used CNTs to enhance hydroxyapatite that was once inserted in the femur of the rabbit as a bone defect. White et al. [4] validated similar findings, suggesting that CNTS have to be functionalized to decorate their potential for rapid formation of new bones and this used to be evident in our preceding study [19]. However, it can also be suggested that the usage of them as carriers or bettering other bone alternative materials mechanical properties can also yield better results.

**Conclusion and Future Perspectives**

MWCNTs-based composite substances are gaining multiplied attention as synthetic picks to bone grafting materials. Promising outcomes have been completed indicating that these novel nanomaterials should be recommended their application in tissue engineering after further investigations, in particular in the histological conduct following grafting of CNTs as properly as their cytotoxic consequences on organs and tissues.

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**Figure 1:** TEM images of functionalized MWCNTs with β-CD in comparison with oxidized MWCNTs and SEM-micrograph of ox-MWCNTs after soaking in SBF for 7 days.
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