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Hydrogel-based Scaffold with Strontium Doping for Enhanced Bone Tissue Regeneration

G. Mason

Department of Materials Science and Engineering, Tel Aviv University, Israel

Introduction

Large bone damage repair is a significant issue in the field of bone regeneration. It is required to create novel therapeutic strategies, such as tissue engineering with 3D scaffolds. The characteristics of the scaffold can be improved by adding a few bioactive components and trace elements. We created bioglass composite scaffolds with optimal characteristics for bone tissue creation using chitosan, alginate, and strontium. Utilizing the Sol-Gel process, bio glass (BG) and bioglasses doped with Sr (Sr-BG) were created. Using the freeze-drying process, alginate-chitosan (Alg/Cs) scaffolds and scaffolds containing various ratios (10%, 20%, and 30%) of BG or Sr-BG (Alg/Cs/BG10, 20, 30) were created.

Description

Bone is a tissue with many different functions that consists of an organic phase and a mineral phase. Type I collagen matrix makes up the majority of the organic phase, which accounts for around 30% of bone content while hydroxyapatite dominates the mineralized phase which accounts for 70% of bone composition. Bone is dynamic; there is a balance between bone creation and desorption, and it can rearrange itself to regenerate. In healthy individuals, minor bone injuries frequently heal on their own with little to no intervention. However critical-sized or enormous bone fractures brought on by infections cancer trauma or explosions are outside the typical range of bone regeneration, necessitating surgical procedures to regain initial function. However, when an area of damaged bone is excessively large for self-repair healing, the injured site must be repaired using alternative materials, such as auto grafts, Allografts and by the artificial materials. Additionally, an increasing clinical demand for synthetic and artificial bone substitutes has been observed due to the rapidly aging population worldwide. The two basic methods for regenerating significant bone injuries are implant implantation and tissue grafting. The paucity of donors, the potential for disease transmission and/or transplant rejection, the requirement for revision surgery (in the case of implants), and the high expense of these treatments are only a few of its drawbacks.

Currently in the order to address the problem, there are several classes for synthetic bone grafting biomaterials for the in vivo applications, such as- natural coral-derived materials, bovine demineralized bone, human demineralized bone matrix, bioactive glasses, glass-ceramics, alumina-based ceramic, hybrids and calcium orthophosphates (CaP). All of the biomaterials need to be biocompatible and osteo conductive for the cell proliferation and guiding the bone tissue growth leading to its tissue repair and remodeling. For the reason, over that last four decades, bioactive ceramic materials have gained highest attention for the scientific community and professionals because of the extraordinary potential use as a suitable bone substitutes. Commonly, bio ceramics are considered ceramics that are designed to induce specific biological activity for the repairing damaged organs. Since from the discovery of Biogas, many researchers has developed numerous types of bioactive ceramics, such as hydroxyapatite (Ca_{10} $(PO_4)_6(OH)_2$) and glass-ceramic .

Despite the fact that materials science technology has resulted in unquestionable advances in the field of bone replacement medicine and no totally satisfactory bone substitute, which fulfills all the requirements, have been developed yet. Hence, the development of the bioactive materials that is showing not only bioactivity but also the mechanical properties similar to the living bone is still much needed. Among several alternatives of the Ceramic-based materials for the bone replacements and repairs bio ceramics made of calcium phosphates (CaPs) appears very promisingly due to both excellent biocompatibility and their abilities to bond to live bone in the body, which is the intrinsically related to the abundance in nature and presence in the mammalian calcified tissues.

Hydroxyapatite (HA) is the most well-known CaP material since it is crystallographic ally and chemically similar to the mineral phase of human bone. Therefore, it has been intensive studied for use of biomaterial and scaffold for bone tissue regeneration. However, it is an important to note that the native bone apatite differs from the stoichiometric HA in a number of ways, including the non-stoichiometry Nano sized crystal dimensions, and a relative crystallinity when assuming 100% for stoichiometric HA. The non-stoichiometry of the biological apatite's is mostly caused from the incorporation of the foreign ions into the crystal lattice. Studies confirmed that substituting ions (anions or cations) present in native hard tissues such as strontium (Sr), magnesium (Mg), zinc (Zn) and niobium (Nb) into CaPs can lead to the beneficial effects on the biomaterial properties such as the degree of structural order (i.e., crystallinity), morphology, thermal stability solubility mechanical properties degradability surface charge and dissolution rate under physiological conditions. Furthermore the doping with ionic species can play an important role in the biological responses for bone cells [1-5].

Conclusion

Masato Tamai reported that Nb(V) incorporated as niobates to biphasic calcium phosphate (HA and β-tri calcium phosphate, β-TCP) significantly promoted to the calcification of normal human osteoblasts and have the potential to promote alkaline phosphatase (ALP) activities an important factor in the generation of the new bone. Consequently, Nb(V) species can be considered as a key dopants for the incorporation in HA, as most niobium salt precursors (e.g., NbCl5) undergoes hydrolysis in alkaline aqueous medium leading to the formation of oxyanions (generic formula NbxOyz–) instead of Nb5. Thus, the main goal of this study is the synthesis and characterization of niobium-modified bio ceramics for potential use as a biomaterial in bone tissue repair. Although there were few published studies in this field, no research was found in the consulted literature where a systematic and an extensive characterization of morphology, structure, and the cytotoxicity of Nb-doped HA produced by a co-precipitation method under the same experimental conditions has been performed.

***Address for Correspondence:** G. Mason, Department of Materials Science and Engineering, Tel Aviv University, Israel, E-mail: Mason12@gmail.com*

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Conflict of Interest

The authors declare that there is no conflict of interest associated with this manuscript.

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