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Hydroxyapatite Bio Ceramics Characterization and *In Vitro* Compatibility

G. Mark*

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

Introduction

Bone healing under osteoporotic pathological condition with impaired angiogenesis ontogenesis and remodeling. In the present study, the effect of Ca, Mg, Si containing akermanite bioceramics ($Ca_2MgSi_2O_7$) extract on cell proliferation, osteogenic differentiation and angiogenic factor expression of BMSCs derived from ovariectomized rats (BMSCs-OVX) as well as the expression of osteoclastogenic factors was evaluated. The results showed that akermanite could enhance cell proliferation, ALP activity, expression of Runx2, BMP-2, BSP, OPN, OCN, OPG and angiogenic factors including VEGF and ANG-1. Meanwhile, akermanite could repress expression of osteoclastogenic factors including RANKL and TNF-α. Moreover, akermanite could activate ERK, P38, AKT and STAT3 signaling pathways, while crosstalk among these signaling pathways was evident. More importantly, the effect of akermanite extract on RANKL-induced osteoclastogenesis was evaluated by TRAP staining and real-time PCR assay. The results showed that akermanite could suppress osteoclast formation and expression of TRAP, cathepsin K and NFATc. The in vivo experiments revealed that akermanite bioceramics dramatically stimulated osteogenesis and angiogenesis in an OVX rat critical-sized calvarial defect model. All these results suggest that akermanite bioceramics with the effects of Mg and Si ions on osteogenesis, angiogenesis and osteoclastogenesis are promising biomaterials for osteoporotic bone regeneration [1,2].

Description

Our skeletal system that plays a key role in our lives, supporting our bodies and enabling us to have mobility. Since in the early days of Hippocrates in ancient Greece, it has been recognized that bones are very dynamic tissue with unique capacities to heal and remodel under appropriate conditions without leaving a wound. This set of properties are associated with its capacity to withstand load bearing makes bone a very complex system to be substituted using synthetic materials. Thus, it is the great challenge for all of the bone functions when it is damaged or injured through accidents and by diseases. This regeneration of bone tissue using the body's own self-healing mechanisms is the ideal approach for the bone repair which is a major goal of tissue engineering, restoring diseased or impaired tissue to its original states and functions, reducing the need for transplants and replacements. 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 [3].

***Address for Correspondence:** G. Mark, Department of Materials Science and Engineering, Tel Aviv University, Israel, E-mail Mark12@gmail.com*

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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 [4,5].

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 bioceramics 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, nanosized crystal dimensions, and a relative crystallinity when assuming 100% for stoichiometric HA. The non-stoichiometry of the biological apatites 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 [3-5].

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.

Conflict of Interest

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

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