TWENTY YEARS OF RESEARCH ON GEL-DERIVED $CaO-P_2O_5-SiO_2$ BIOACTIVE GLASSES - WHAT NEXT?

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Introduction

Gel-derived bioactive glasses of $CaO-P_2O_5-SiO_2$ system have been developed by Laczka et al in 1995 year. The research was prompted by Li, Clark and Hench (1), who had reported by that time several advantages of gel-derived technology of bioactive glasses of $CaO-P_2O_5-SiO_2$ production.

Materials research

Three main gel-derived compositions were obtained by Laczka et al and compared with corresponding melted glasses:
A2 - $40SiO_2;54CaO;6P_2O_5$, T2 - $60SiO_2;36CaO;4P_2O_5$ and S2 – $80SiO_2;16CaO;4P_2O_5$ (mol%) (2-3). Since that time, these gel-derived bioactive glasses (SBG) have been studied in the form of homogenous sinters and coatings or incorporated into synthetic hydroxyapatite, ceramics (TiO_2) and polymers (PLGA and PCL) forming a composites (4-7). The latter were obtained either in the form of 2D films or 3D porous scaffolds. Produced materials were characterized with respect to chemical and phase compositions, microstructure, porosity, surface properties and ability of ions release to simulated body fluids. Moreover, bioactivity *in vitro* was estimate by simulated body fluid test. The ability to create a hydroxyapatite (HA) layer on the material surface was regarded as a sign of its biological activity and it was conditioned primarily chemical composition of biomaterials. Obtained results indicated that in the future it is appropriate to combine the *in vitro* SBF test with cell-basing experiments to a better evaluate the materials bioactivity.

Biological research

Both alone and as composite components these SBG-based materials have showed several osteogenic effects both *in vitro* and *in vivo*. Initially, SBG were examined for their immunological response in Wistar rats-derived macrophages, followed by rat osteogenic bone marrow cell cultures, later replaced by human bone marrow-derived mesenchymal stem cell osteogenic culture. Notably, despite different preparation forms, biological evaluations consistently showed some intrinsic osteogenic properties of these SBG materials, resulting in either their bone-forming (S2) or bone-remodelling ability (A2). Thus, we now come to conclusion that the chemical composition of these SBG materials plays primary role on contact with cells and tissues. The other SBG properties, such as amorphous/crystalline phase ratio, surface development and roughness, or material porosity do contribute to the overall osteogenic effects, but they play secondary role to these materials chemistry. Furthermore, the studies on T2 composition have been neglected for years due to initial results showing opposite to A2 and S2 immunological response, despite some promising data collected in rat bone marrow cultures. We now revaluate this T2 material as our most recent studies indicate that the moderate content of SiO_2 may be beneficial for early induction of osteogenesis by these materials in human bone marrow-derived cell cultures. Finally, all studied compositions belong to the bioactive group of materials, capable to form carbonate hydroxyapatite (HA) surface layer, which is believed to provide the prerequisite for bone tissue formation and integration. Despite this, most biological results have been obtained by us with “as-prepared” materials that were not pre-incubated to develop HA layer. Our recent studies with simulated body fluid pre-incubated materials indicate that the development of HA surface layer is beneficial for the overall osteogenic cell response, but it eliminates some key differences in the biological effects resulting from different material compositions. This correlates well with the gross amount of ions released from bioactive material surface before and after HA development. Altogether, the future applications of these and similar materials should focus on the material compositions, although examination of their different preparation forms is necessary, as the final product properties may either enhance or diminish the desired biological effects.

Acknowledgments

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