NEW CEMENT-TYPE MATERIALS BASED ON Ag AND Si DOPED HYDROXYAPATITE FOR BONE REGENERATION

DOMINIKA SIEK*, JOANNA CZECHOWSKA, ANETA ZIMA, ANNA ŚLÓSARCZYK

FACULTY OF MATERIALS SCIENCE AND CERAMICS,
AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY, POLAND
*E-MAIL: DOMINIKASIEK@GMAIL.COM

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Introduction

Calcium phosphates (CaPs) are widely used in orthopedic and maxillofacial surgery due to their excellent biological properties. The interesting alternative for high-temperature calcium phosphate ceramics are calcium phosphate cements (CPCs) which are not only biocompatible but also moldable and self-setting. CPCs are valuable and effective bone fillers. Recently they have been also considered as the basis for drug, growth factors or cells delivery systems [1]. The most frequently used CaP is hydroxyapatite (HA, $Ca_{10}(PO_4)_6OH_2$). In recent years more attention has been paid to the ionic substitutions in the crystal lattice of HA. The various ions were introduced into the HA structure in order to improve its physicochemical and biological performance [2]. Simultaneous incorporation of silver and silicon into the structure of HA may lead to development of antibacterial materials with enhanced biological properties. Hydroxyapatite is generally considered to be non-resorbable *in vivo* [3]. In order to improve the resorption rate of HA based materials the addition of more soluble and resorbable phases such us α-tricalcium phosphate (α-TCP), $CaCO_3$ or calcium sulphate (CS) has been proposed.

Materials and Methods

In this work new potential bone substitutes in the form of moldable cement pastes were developed and evaluated. Silver and silicon doped hydroxyapatite (Ag-Si-HA) and α-TCP were synthesized by the wet chemical method. Ag-Si-HA was calcined above 700°C. Three powder batches of the cements were prepared by mixing heat treated Ag-Si-HA with α-tricalcium phosphate, $CaCO_3$ or calcium sulphate. Chitosan or methylcellulose solutions were applied as liquid phases (TABLE 1). The phase composition (XRD, D2 Phaser, Bruker), initial (I) and final (F) setting times (Gillmore Needles), open porosity (Auto Pore IV, Micromeritics) and compressive strength (Instron 3345) were tested. The chemical stability and bioactivity were evaluated *in vitro*.

TABLE 1. Initial composition of the cements.

Material	Powder phase	Liquid phase	L/P [g/g]
A	Ag-Si-HA, CS	chitosan solution	0.68
B	Ag-Si-HA, α-TCP	methylcellulose solution	0.54
C	Ag-Si-HA, α-TCP, $CaCO_3$		0.44

Results and Discussion

Three cement-type materials based on silver and silicon doped hydroxyapatite were obtained. Application of chitosan and methylcellulose solutions as liquid phases improved surgical handiness of the cements. Their setting times differed in the range of 5-13 min (I) and 8-45 min (F). The compressive strength of final cement bodies was from 5 to 8 MPa (FIG. 1).

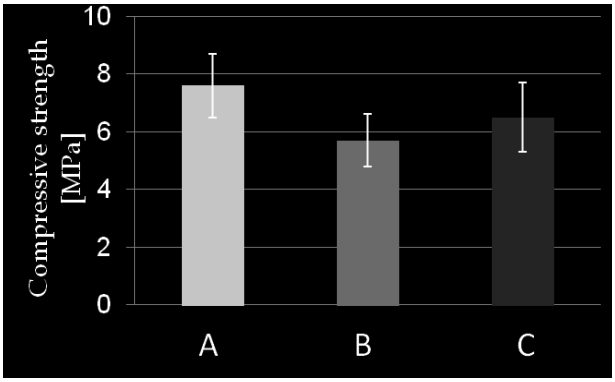

FIG. 1. The compressive strength of cements 7 days after setting and hardening.

Developed materials revealed bimodal pore size distributions with pores below 1.4 μm. Open porosity of the cements was ~50vol.%. Obtained materials showed excellent chemical stability and high bioactivity. SEM observations showed that as soon as after 7 days of incubation in simulated body fluid (SBF) the surfaces of tested materials were covered by the cauliflower-like CaPs structures (FIG. 2).

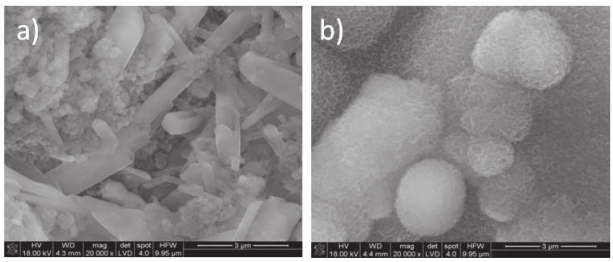

FIG. 2. SEM micrographs of cement A: a) non-incubated and b) incubated for 7 days in SBF.

Conclusions

New bioactive and biodegradable bone substitutes based on Ag-Si-HA and α-tricalcium phosphate, $CaCO_3$ or calcium sulphate were developed. They may be attractive for filling bone defects in the low-load bearing places. Further studies including antibacterial evaluation are conducted.

Acknowledgments

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References

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