

NOVEL ALGINATE AND CHONDROITIN BEADS BASED ON MG AND SI CO-SUBSTITUTED HYDROXYAPATITE

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Introduction

Hydroxyapatite (HA, $\text{Ca}_{10}(\text{PO})_4(\text{OH})_2$), due to its similarity to the inorganic component of mineralized tissues is a highly biocompatible, bioactive and osteoconductive material. Therefore, HA plays a crucial role in implantology, dentistry and bone surgery [1,2]. Moreover, ease of ionic substitution allows the introduction of elements having a beneficial effect on bone metabolism – such as magnesium and silicon [3]. Co-substitution of Mg^{2+} and SiO_4^{4-} is believed to stimulate activity and proliferation of osteoblasts, enhance collagen type I synthesis and improve biocompatibility of obtained material [4,5]. Dense HA-based beads, with improved mechanical properties, could serve as bone defect filling material [6]. Future studies will involve the use of granules for local delivery of drug substances to the injured tissue.

Materials and Methods

All samples of pure, as well as substituted HAs, were synthesized via the precipitation method. The obtained samples were physicochemically examined using various analytical methods: mid-infrared spectroscopy (FT-IR), solid-state nuclear magnetic resonance (ssNMR), powder X-ray diffractometry (PXRD) and transmission electron microscopy (TEM). The elemental analysis was conducted by inductively coupled plasma optical emission spectrometry (ICP-OES). The preliminary *in vitro* cytocompatibility was demonstrated on BALB/c 3T3 mice fibroblasts according to ISO guidelines. Then, composite beads based on Mg and Si co-substituted HA, sodium alginate (SA) and chondroitin sulphate (CS) were prepared. Novel alginate-crosslinking reaction based on Mg^{2+} ions as crosslinking agents was used to elevate magnesium concentration in the outer layer of composites.

Results and Discussion

All samples were composed of a single crystalline apatitic phase. As confirmed by TEM imaging, samples were nanocrystalline, with elongated, needle-like crystals. All FR-IR spectra indicated the presence of characteristic bands of HA. All samples turned out completely cytocompatible – there were no detectable zones of growth inhibition or damaged cells. ICP-OES measurements indicated the presence of introduced elements in the amount of approx. 0.25 wt% of Mg and 0.6 wt% of Si, which corresponds to the 85% and below 50% efficiency of Mg and Si substitution respectively. The reduced yield of orthosilicate ions substitution is probably due to the competition with carbonate ions, derived from the air and the reagents. Multicomponent granules,

composed of MgSi-HA, SA and CS were successfully obtained. Crosslinking of Mg^{2+} ions allowed the introduction of additional 2.6 wt% of magnesium in the composite beads. The obtained material is characterised by low porosity, which is probably caused by the addition of CS. Thus, we anticipate a gradual release profile, which will be examined in the next stage of our research.

Conclusions

The current research concerned the synthesis and subsequent physicochemical characterization of HA doped with Mg^{2+} and SiO_4^{4-} ions, including their co-substitution. Single-phase, nanocrystalline and cytocompatible HAs with approx. 0.25 wt% of Mg and 0.6 wt% of Si were obtained. Novel hybrid composite beads were prepared, which could potentially be used for local delivery of ions and drugs.

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References

- [1] M. Vallet-Regi, J.M. Gonzales-Calbet, Prog. Solid State Chem. 32 (2004) 1-31.
- [2] J. Kolmas, S. Krukowski, A. Laskus, M. Jurkitewicz, Ceram. Int. 42 (2016) 2472-2487.
- [3] M. Supova, Ceram. Int. 41 (2015) 9203-9231.
- [4] G. Qi, S. Zhang, K.A. Khor, S.W. Lye, X. Zeng, W. Weng, C. Liu, S.S. Venkatraman, L.L. Ma, Appl. Surf. Sci. 255 (2008) 304-307.
- [5] K. Szurkowska, J. Kolmas, Prog. Nat. Sci. Mater. Int. 27 (2017) 401-409.
- [6] J. Venkatesan, S.K. Kim, J. Biomed. Nanotechnol. 10 (2014) 3124-3140.