Selenite and Strontium Co-substituted Hydroxyapatite: Preparation, Characterization, Antibacterial Activity, and In-vitro Biological Testing

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Statement of purpose

The dramatic rise in the antibiotic resistant bacterial strains worldwide has compelled antibiotic choices for infection control increasingly limited. The US Centre for Disease Control and Prevention (CDC) has classified antibiotic resistance as a serious burden on the US healthcare system as it is causing at least 2 million infections and 23,000 deaths a year resulting in a $55–70 billion per year economic impact [1]. The growing antibiotic resistance and infection rates emphasise the need to develop alternative local antimicrobial strategies. This research work has been focused on producing antibiotic free antimicrobial bone graft materials comprising of hydroxyapatite (HA) ($Ca_{10}(PO_4)_6(OH)_2$) substituted with selenite ions (SeO_3^{2-}) and strontium (Sr^{2+}) ions [2].

Experimental

HA samples substituted with five different concentrations of SeO_3^{2-} and Sr^{2+} ions comprising Se/(P+Se) & Sr/(Ca+Sr) molar ratio of 0.01, 0.03, 0.05, 0.1 and 0.2 were synthesised using a wet precipitation method. The samples were sintered at 900 °C for 3 hours. Comprehensive characterization techniques were used to evaluate the properties of synthesized materials.

Summary of results

The results highlight that SeO_3^{2-} and Sr^{2+} ions in required concentrations were successfully substituted in the HA lattice at PO_4^{3-} and Ca^{2+} sites respectively. Crystal structure analysis by XRD (figure 1) and Rietveld refinement showed that there was a proportional increase in both lattice parameters a-axis and c-axis, with substitution of SeO_3^{2-} and Sr^{2+} into the HA structure. Compositional analysis by XRF and EDX confirmed the presence of SeO_3^{2-} and Sr^{2+} ions in the required molar ratios. SEM results showed that ion substitution caused changes in HA particles morphology from uniform spheres to a plate-like aggregated structures. The ion release profile in PBS solution measured by ICP-OES for days 1, 3, 7, 14 and 21 revealed that there was a steady ion release of both selenite and strontium under dynamic conditions. Se-Sr-HA showed substantial antibacterial activity against both Gram-positive and Gram-negative bacteria (Figure 2). Cell viability assay (WST8) showed that cytotoxicity of SeO_3^{2-} was off-set by co-substituting Sr^{2+}, and therefore Se-Sr-HA was cytocompatible in contact with MG-63 osteosarcoma cell line. Thus, Se-Sr-HA is an excellent novel bioceramic for biomedical applications [2].

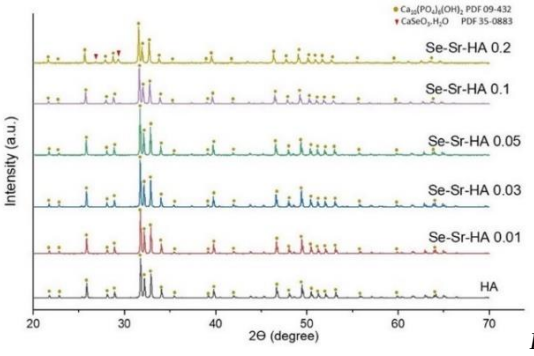

Figure 1: XRD diffractograms of Se-Sr-HA with different Se and Sr molar ratios, sintered at 900 °C.

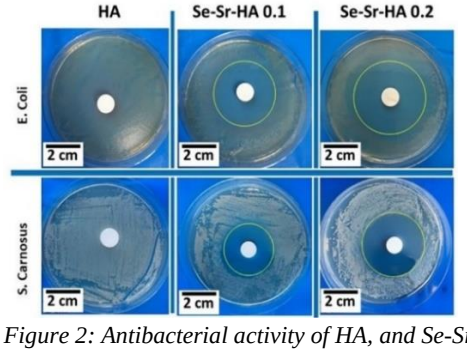

Figure 2: Antibacterial activity of HA, and Se-Sr-HA against Gram-negative (E. coli) and Gram-positive (S. carnosus) bacteria

References

1. Li, B. & Webster, T. J. Bacteria antibiotic resistance: New challenges and opportunities for implant-associated orthopedic infections. *J. Orthop. Res.* **36**, 22–32 (2018).

2. Maqbool, M. *et al.* Synthesis, characterization, antibacterial properties, and in vitro studies of selenium and strontium co-substituted hydroxyapatite. *Int. J. Mol. Sci.* **22**, 1–18 (2021).