

Development of Novel Bone Filler Composites with Enhanced Bioactivity and Biological Response

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Abstract

Musculoskeletal defects remain a major challenge in orthopedic and regenerative medicine. Injectable calcium phosphate cements (CPCs) are promising bone void fillers due to their biocompatibility, osteoconductivity, and ability to conform to irregular defects, although limitations in mechanical and biological performance remain. In this work, mesoporous bioactive glass nanoparticles (MBGNs) were investigated as multifunctional additives for injectable CPC-based composites [1]. Furthermore, incorporation of bismuth into the glass composition provides additional functionalities of interest for bone regeneration, including radiopacity and potential antibacterial effects [2]. Mesoporous silica nanoparticles were synthesized by a dual-surfactant sol-gel method, sequentially impregnated with calcium and bismuth, and calcined. The resulting MBGNs had an 85SiO₂–15CaO mol% composition, with 2 mol% Bi₂O₃ in the Bi-doped formulation. They were incorporated into an apatite-forming α -tricalcium phosphate cement synthesized by a wet chemical method and mixed with an aqueous methylcellulose solution. Three formulations were studied: CPC, CPC + 10 wt% MBGNs, and CPC + 10 wt% Bi-doped MBGNs. The incorporation of MBGNs significantly improved the compressive strength of the CPC, while no statistically significant difference was observed between the MBGN-containing formulations with and without bismuth. All formulations showed good cytocompatibility with MC3T3-E1 cells, with no significant differences in cell viability associated with bismuth incorporation. In contrast, bacterial viability of both *Escherichia coli* and *Staphylococcus aureus* was significantly reduced by the incorporation of MBGNs into the CPC, with the Bi-doped formulation producing a further antibacterial effect. The developed composites therefore represent a promising platform for multifunctional injectable bone substitutes for minimally invasive treatment of musculoskeletal defects.

Key words: Calcium phosphate cement; Mesoporous bioactive glass nanoparticles; Bismuth; Injectable bone substitute; Antibacterial activity.

References

- [1] Ö. Demir-Oğuz, A. R. Boccaccini, and D. Loca, "Injectable bone cements: What benefits the combination of calcium phosphates and bioactive glasses could bring?," *Bioact. Mater.*, vol. 19, pp. 217–236, Jan. 2023, doi: 10.1016/j.bioactmat.2022.04.007.
- [2] L. Wang *et al.*, "Multi-functional bismuth-doped bioglasses: Combining bioactivity and photothermal response for bone tumor treatment and tissue repair article," *Light Sci. Appl.*, vol. 7, no. 1, 2018, doi: 10.1038/s41377-018-0007-z.