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Injectable and Self-Pore-Forming Bone Repair Material Based on Polyphosphate Coacervates

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INTRODUCTION & AIM

Injectable and self-setting bone substitutes hold significant value for minimally invasive repair of bone defects. However, these materials typically possess a dense structure, which conflicts with the porous architecture required for cell infiltration and bone regeneration. Conventional porogen strategies (e.g., porogen leaching and gas foaming) often compromise injectability or result in isolated pores, leading to suboptimal repair outcomes.

In this study, polyphosphate coacervates were used as the injectable matrix, and magnesium phosphate (MgP)-gelatin core-shell powders were introduced as functional porogens. This design allows for the in situ construction of an interconnected hierarchical porous structure while maintaining injectability and self-setting properties.

METHOD

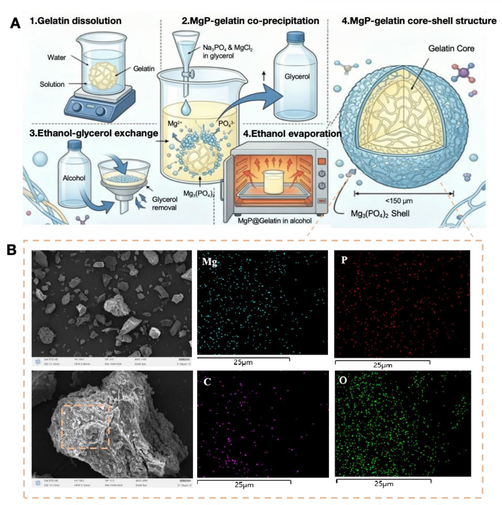

Figure 1. (A) Schematic illustration of the MgP-Gel core-shell structure preparation. (B) SEM images and corresponding EDS elemental mapping of the MgP-Gel core-shell structures.

We mixed MgP-gelatin core-shell powders (mass ratio 5:1) with acidic Ca-polyP coacervates. The MgP shell's rapid acid-base neutralization triggers solidification-induced phase separation (SIPS), forming 5–10 μm micropores while preventing premature gelatin swelling. After the material fully sets, the gelatin core slowly dissolves (peaking at ~5 days) to generate interconnected 30–60 μm macropores. Finally, setting behavior, porous structure, and biological functions (in vitro and in vivo) were systematically evaluated.

RESULTS & DISCUSSION

1.Structural Design: Through the magnesium phosphate-gelatin core-shell design, we successfully constructed a bone repair scaffold with a hierarchical structure of “microporous walls + macroporous channels.” The macroporous structure progressively developed from day 1 to 5 as the gelatin dissolved, and stabilized between days 5 and 10.

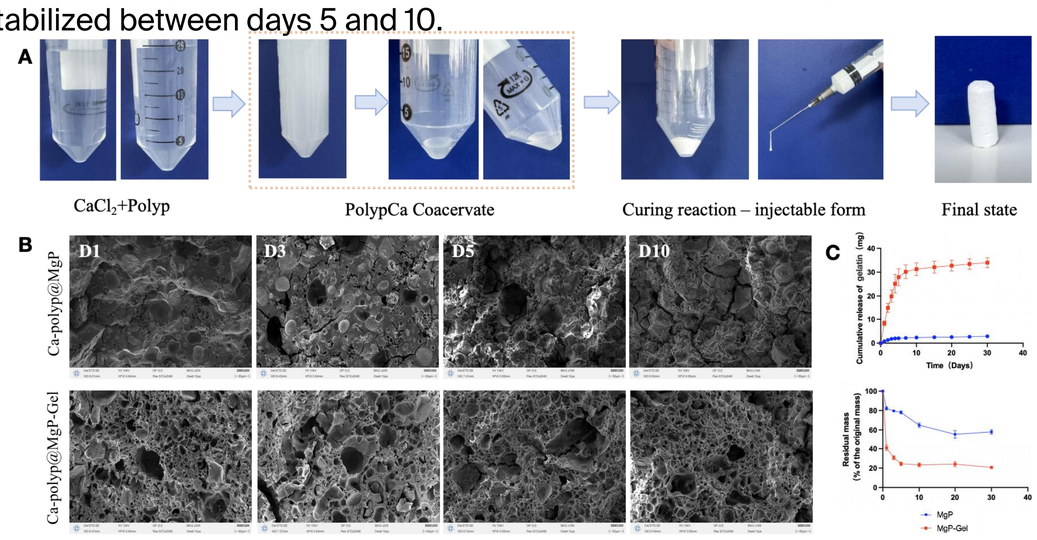

Figure 2. (A) Schematic of the material preparation process. (B) SEM images of the internal pores at different time points (D1–D10). (C) Gelatin release and material degradation profiles.

2.In Vitro Evaluation: The composite material significantly promoted the osteogenic differentiation of BMSCs, evidenced by increased alkaline phosphatase activity and significantly upregulated expression of osteogenesis-related genes (ALP, iBSP, Ocn, and Osterix).

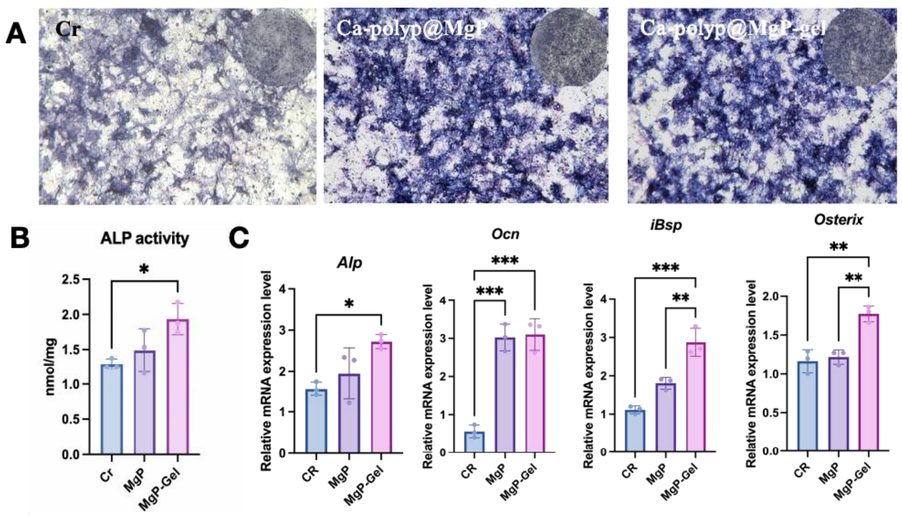

Figure 3. (A) ALP staining after 7 days of co-culture with bone mesenchymal stem cells . (B) Quantitative analysis of ALP activity. (C) RT-qPCR analysis of osteogenic-related gene expression.

3.In Vivo Evaluation: The hierarchical porous structure effectively guided host cell infiltration and new bone formation. Histological sections at 4 weeks post-implantation revealed that in the polypca-MgP-Gel group, bone tissue grew along the pores as the material degraded. Eight weeks post-implantation, the bone volume fraction (BV/TV) and trabecular thickness (Tb.Th) reached 1.37 times and 1.23 times that of the blank control group, respectively, indicating that the material can effectively promote the repair of rat femoral defects.

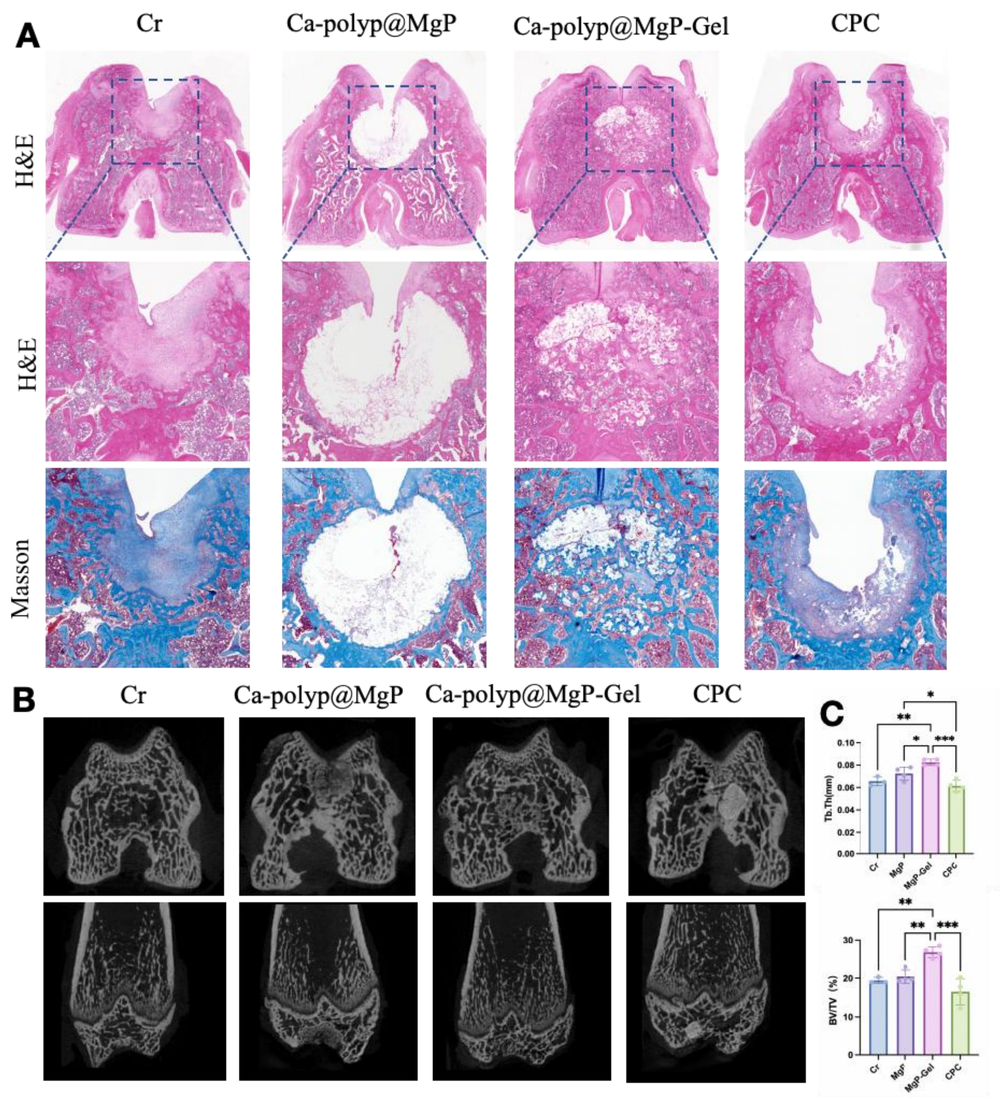

Figure 4. (A) H&E and Masson‘s trichrome staining of histological sections at 4 weeks after implantation into rat femoral defects. (B) Representative micro-computed tomography (micro-CT) images of the defect area at 8 weeks post-surgery. (C) Semi-quantitative micro-CT morphometric analysis (Tb.Th and BV/TV).

CONCLUSIONS

By introducing MgP–gelatin core–shell porogens, this study resolves the critical challenge of achieving interconnected macropores in injectable self-setting materials. This strategy offers a versatile platform for designing bone repair materials that combine injectability, self-setting capability, and ideal porous architecture.

FUTURE WORK/ REFERENCES/ACKNOWLEDGMENT

[1] Nguyen M, Karkanitsa M, Christman K L. Design and translation of injectable biomaterials [J]. Nature Reviews Bioengineering, 2024, 2(10): 810-828.

[2] Li P, Tang X, Zhou X, et al. A membrane-free electrochemical reactor for efficient oxygen removal via gravity-assisted product self-separation [J]. Nature Communications, 2025, 16(1): 4309.

[3] Tan J L T, Shimabukuro M, Tsuchiya A, et al. Influence of porogens on architecture and osteogenesis of porous carbonate apatite artificial bones [J]. Ceramics International, 2025, 51(15): 19963-19972.