Biocompatibility and mechanical characterization of silica-enriched PLA composites for 3D-printed bone scaffolds

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Objetives

To develop and characterize biocompatible and biodegradable PLA/CP/DE scaffolds that mimic bone architecture and promote osteoblast proliferation, as a potential alternative to autologous bone grafting, reducing donor site morbidity and surgical complexity, with emphasis on biocompatibility as a key parameter for clinical translation.

Methodology

Composite Fabrication: Polylactic Acid, Diatomaceous Earth and Calcium Phosphate (PLA, CP, and DE) composites were prepared at varying ratios, cast, extruded into filaments, and 3D-printed via FDM.

Sterilization: Gamma irradiation, moist heat, and oxygen plasma were evaluated to determine the most suitable method.

Biocompatibility: MC3T3-E1 cells were used following ISO 10993. Viability and cytotoxicity were assessed by MTT and LDH assays.

Material Characterization: Mechanical (rheometry), thermal (DSC), and microstructural/compositional properties (SEM–EDX) were analyzed.

Degradation: Scaffold degradation was evaluated under physiological conditions (pH 7.4, 37 °C).

Cell–Scaffold Interaction: Adhesion and proliferation were analyzed over 30 days using Alamar Blue and fluorescence microscopy on scaffolds with 130%, 180%, and 230% porosity.

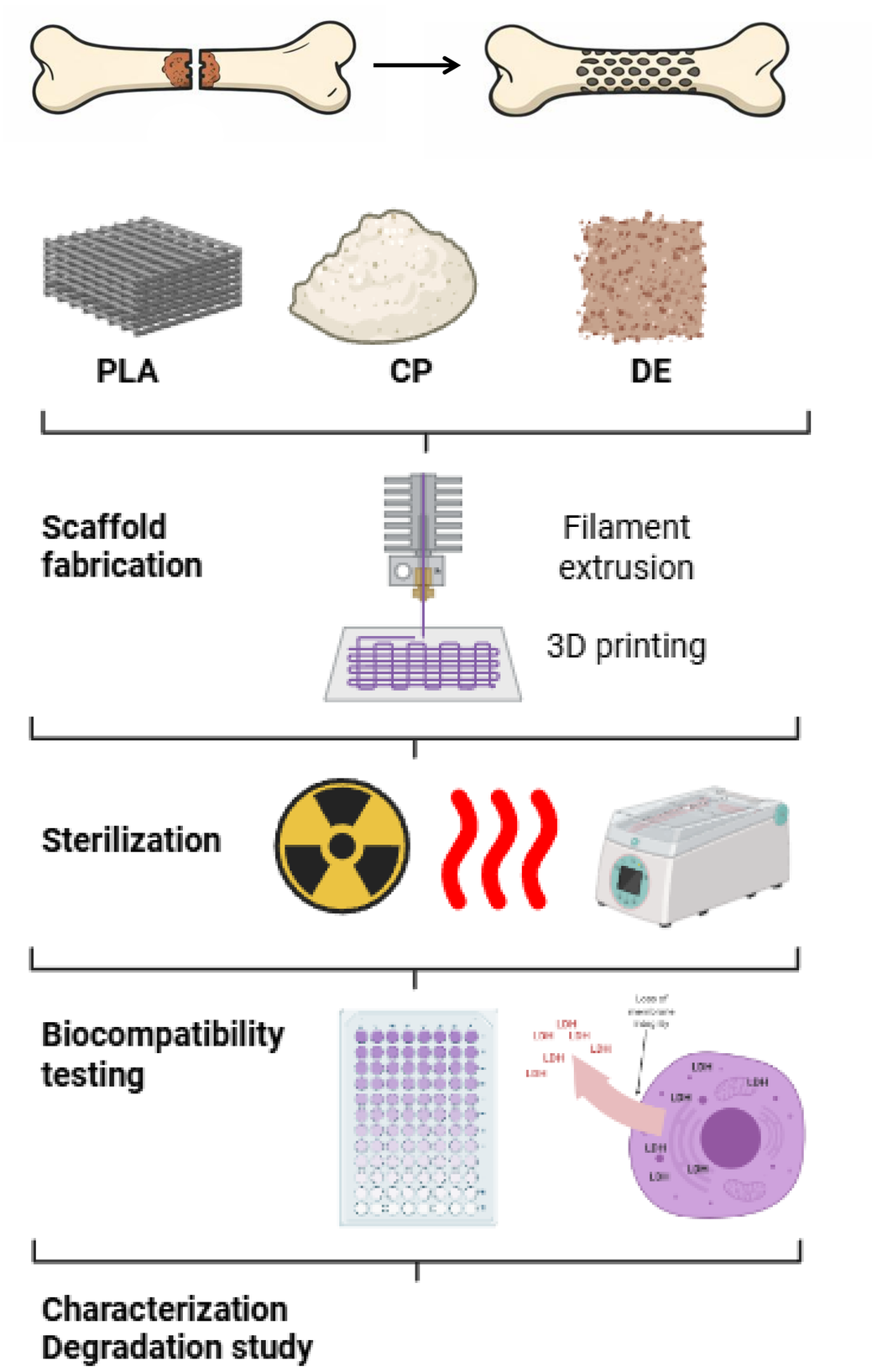


Figure 1. Methodology for fabrication, sterilization, and characterization of PLA/CP/DE 3D-printed scaffolds, including biocompatibility assessment using MC3T3-E1 cells.

Results

- Gamma irradiation maintained integrity and viability; plasma reduced viability; moist heat deformed scaffolds (PLA Tg ~60 °C)
- Mechanical stability sustained for 13 weeks; Young's modulus > cancellous bone (~0.442 GPa)
- DE increased porosity and cell adhesion; silica promoted proliferation, though excess reduced viability
- 130% porosity showed highest metabolic activity at day 30, indicating optimal osteoconductive structure

Conclusion

The 20PLA/1CP/1DE composite demonstrated suitable biocompatibility, mechanical performance, and osteoconductive potential, making it a promising candidate for bone tissue engineering. Characterizing biocompatibility across sterilization methods and scaffold architecture is essential for the safe and effective clinical application of novel biomaterials. Future work will focus on gene expression profiling and *in vivo* validation of these 3D-printed scaffolds.

Trejos-Soto, L., Rivas-Hernández, G. O., Mora-Bolaños, R., Vargas-Valverde, N., Valerio, A., Ulloa-Fernández, A., Oviedo-Quirós, J., García-Piñeres, A., Paniagua, S. A., Centeno-Cerdas, C., & Lesser-Rojas, L. (2024). *Composites of polylactic acid with diatomaceous earth for 3D-printing biocompatible scaffolds: A systematic study of their mechanical, thermal, and biocompatibility properties*. Bioengineering, 11(11), 1059. https://doi.org/10.3390/bioengineering11111059