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New Approaches to Improve PCL Performances as Biomaterial for 3D Printing Of Bone Scaffolds

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Extended Abstract

Tissue-engineered scaffolds have become a strategic approach to repair or even replace injured tissues, overcoming some limitations of autografts, allografts, and xenografts. Most injuries involve bone tissues and, as bone plays critical functions in the human body, there is a special need for adequate bone grafts [1]. Nowadays, 3D printing (3DP) technologies are greatly increasing the performance of bone scaffolds. 3DP allows building, starting from a digital model, three-dimensional objects of virtually any complex geometry and architecture with high resolution, precision, and repeatability, guaranteeing highly innovative personalized solutions for a specific patient or a patient group [2]. Among the different 3DP techniques, Fused Filament Fabrication (FFF) is one of the most used for its high versatility, precision, feasibility, and cheapness [2]. But even if 3DP-FFF technology has become increasingly refined, the selection of biomaterials suitable for printing has remained limited. To date, the choice is mainly constrained to synthetic biodegradable polyesters, such as polylactic acid (PLA), polyglycolic acid (PGA), polycaprolactone (PCL), and the corresponding copolymers. Among polyesters, PCL is one of the most widely used, as it is cheap and readily available, biocompatible, bioresorbable and FDA approved for bone TE applications, compatible with various polymers and additives, and easily processable via FFF [3]. However, its hydrophobia, slow biodegradation, and lack of bioactivity often lead to the failure of the implant.

Hence, in this work, we propose different strategies to keep the positive features of this polyester, while enhancing its critical physicochemical properties. To achieve this goal, two main approaches were explored: **a)** development of PCL based hybrid materials by blending with both organic and/or inorganic components, and **b)** production of a partially chemically modified PCL. For the first approach, different materials, both inorganic (nanohydroxyapatite) and organic (alginate, microcrystalline cellulose and inulin-grafted-poly(D,L)lactic acid grafted copolymer [4]) were tested for blending with PCL. For the second approach, PCL was subjected to α-carbon functionalization with pendent ammino groups to introduce reactive moieties on the backbone for the following bioconjugation with Arg–Gly–Asp (RGD) peptide. In both cases, the resulting PCL-based biomaterials were first extruded in form of filament via hot melt extrusion, and then 3D printed via FFF as macroporous scaffolds. Finally, all the scaffolds were characterized in terms of physicochemical, technological properties (size, morphology and structural characteristics, mechanical properties, degradation profile), and in vitro biological performance (hemolysis, cytotoxicity, cell viability, and osteogenic activity assays).

Preliminary results confirm the validity of blending as an effective approach to obtain novel PCL-based hybrid biomaterials for 3DP of bone scaffolds. The 3D printed hybrid scaffolds showed size, 3D architecture and macroporosity values very close to those of the digital model, confirming the high precision and accuracy of FFF technology. Furthermore, all scaffolds retained the good mechanical properties and the biocompatibility of PCL (high hemocompatibility and adequate cytocompatibility), while the addition of blending materials allowed to successfully modulate critical properties such as wettability, surface roughness, swelling ability and in vitro biodegradation profile. Concerning the second approach, a novel PCL derivative, with pendent amino groups on the backbone, was successfully obtained, as confirmed by NMR and FTIR analysis. Further studies are in progress to verify its processability via FFF, both alone and in blend with other components, and to optimize its printing conditions. Furthermore, an in-depth technological and biological characterization of the obtained scaffolds will be performed, to assess the ability of biofunctionalization to improve material hydrophilicity, increase cell adhesion and modulate bone cell response.

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