Bone Tissue Engineering via Collagen Hydrogel-Coated PHBV-BG Scaffolds: Mimicking Both Rigid and Soft Tissues

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Introduction: Bone is a highly vascularized organ composed of rigid (trabecular and cortical) and soft (bone marrow) tissues. Hydrogels are ideal biomaterials for mimicking soft tissues. This work focuses on functionalizing 3D-printed scaffolds with collagen hydrogel to improve biological performance without compromising mechanical integrity.

Methods: Scaffolds were 3D printed using filaments composed of polyhydroxybutyrate-co-valerate (PHBV) and bioactive glass (BG 45S5) with a rectilinear pattern and two infill percentages: 20 and 55%. Two surface treatment protocols were evaluated: *Protocol 1*: Scaffolds were immersed in PHBV solution and 1 M NaOH, coated with 0.1% m/V collagen, gelled at 37 °C for 1 h, and lyophilized. *Protocol 2*: Scaffolds were treated with BG suspension in toluene and collagen coated, using the same gelation and lyophilization conditions. Collagen presence, morphology, and hydrophilicity were evaluated via SEM and aniline blue staining, and contact angle measurements. Adhesion was tested according to ISO 2409 and dynamic mechanical analysis (DMA), and stability was evaluated after 96 h of immersion in simulated body fluid (SBF).

Results: The 3D printed scaffolds exhibit dual porosity as a result of the printing parameters, mimicking the hierarchical distribution of interconnected pores found in native bone. Both surface treatment protocols allowed collagen gel attachment without altering macroscopic mechanical properties. SEM revealed collagen on the surface and within the pores of the 3D structure. Protocol 1 produced uniform coatings and dual porosity with surface pores between 1 to 10 μm; Protocol 2 led to a heterogeneous collagen distribution. No detachment or cracking was observed in adhesion tests. Collagen remained stable after SBF incubation, indicating retention under physiological conditions. Mechanical properties of scaffolds resemble those of trabecular bone (600 MPa).

Conclusions: The surface treatments preserved mechanical integrity and enabled stable collagen attachment, offering a bioactive scaffold for bone tissue engineering.