ABSTRACT

Kocaer, A.F. (2026). Production and Biocompatibility Assessment of Hydroxyapatite-Containing Polycaprolactone Filament-Based Artificial Bone Material. PhD Thesis, Istanbul University, Institute of Health Sciences, Department of Biophysics. Istanbul.

Within the scope of this PhD thesis, high-purity hydroxyapatite (HA) was synthesized from waste eggshells, a sustainable source of calcium carbonate, for bone tissue engineering applications, and poly (ß-) caprolactone (PCL) matrix biomimetic scaffolds were developed. In the initial phase of the study, the crystallinity, functional groups, and surface morphology of the HA obtained via the wet chemical precipitation method were biophysically verified through FTIR, XRD, and SEM analyses, and it was determined that it exhibited a perfect stoichiometric match (Ca/P = 1.67) with natural bone mineral.

The synthesized HA was composited with PCL polymer and transformed into a unique filament form for Fused Deposition Modeling (FDM)-based 3D printing systems. During the production process, the effects of parameters such as infill density (10% - 100%), infill pattern (8 different types), shell thickness (0.2 - 0.4 - 0.6 mm), and layer orientation on structural integrity, porosity, and mechanical responses were systematically modeled using 741 different specimens. In the tensile tests performed, it was observed that the Tri-Hexagon pattern geometry and optimized shell thickness, in particular, radically increased the biomechanical performance of the material by distributing stress triaxially, establishing an ideal biophysical bridge between cortical and trabecular bone with 61.5 MPa. In in vitro bioactivity tests, ion diffusion and surface mineralization of the samples in Simulated Body Fluid (SBF) were examined; at the end of an 8-week period, it was determined that cauliflower-like apatite crystals completely masked the PCL matrix (masking effect). MTT analyses confirmed that HA reinforcement played a supportive role on cell adhesion and proliferation (MC3T3-E1) without harboring any cytotoxic effect. In the in vivo section of the thesis, the optimized scaffolds were implanted into critical-sized bone defects in mouse calvaria. Micro-CT imaging and volumetric processing analyses revealed that vertical bone bridging at the implant-bone interface exhibited a statistically significant (P = 0.0059) regeneration success.

Consequently, this study offers a holistic contribution to load transfer mechanisms in patient-specific implant design, tissue regeneration, healing, and the development of next-generation artificial bone scaffolds through the biophysical optimization of naturally derived HA and the scientific modeling of 3D printing parameters.

Key words : Biophysics, Bones and Bones, Biopolymer