Fabrication of Calcium Phosphates/Poly(caprolactone) Composite Using 3D Printing Technique for Bone Tissue Engineering

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INTRODUCTION

With the increase of the average life expectancy, the challenges towards healthier ageing are greater. Every year, there are millions of people suffering from severe tissue loss and particular attention has been paid to the development of new surgical procedures and new materials for bone replacement/ regeneration [1], with tissue engineering becoming an area of great interest. Three-dimensional (3D) scaffolds fabricated by additive manufacturing are a promising strategy in tissue engineering for the replacement and regeneration of damaged tissue. The scaffolds are physical substrates for cell attachment, proliferation, and differentiation, ultimately leading to the regeneration of tissues, and they must be designed according to specific biomechanical requirements, i.e., certain standards in terms of mechanical properties, surface characteristics, porosity, degradability, and biocompatibility [2]. The optimal design of a scaffold for a specific tissue strongly depends on both materials and manufacturing processes, as well as surface treatment. Polycaprolactone (PCL)-based scaffolds have been extensively proposed for bone regeneration; however these present long degradation times, high hydrophobicity and poor bioactivity (osteointegration, osteoconduction and osteoinduction). To overcome these limitations, PCL has been combined with different inorganic materials such as hydroxyapatite (HA), tri-calcium phosphate (TCP) and bioglass [3,4].

Aims

Study the use of polymer-ceramic composite scaffolds for bone tissue engineering.

Blending of ceramic materials (biphasic calcium phosphate HA / β-TCP) with PCL
+
Production of scaffolds by extrusion-based additive manufacturing system (3D Bioplotter™).

MATERIALS AND METHODS

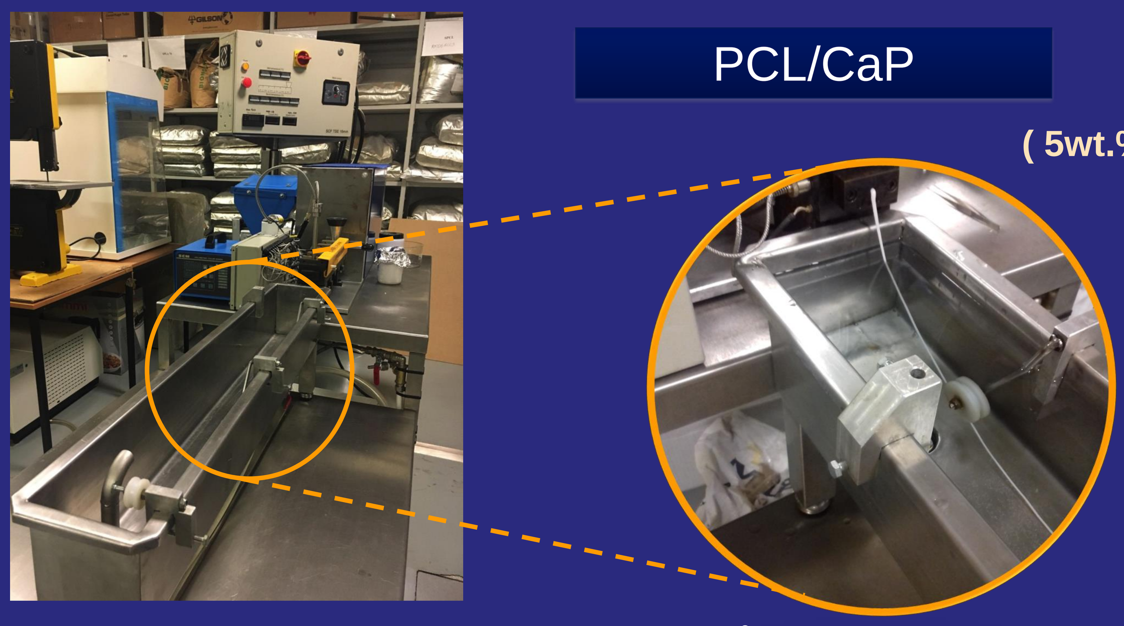
❑ Synthesis of biphasic calcium phosphate powder (HA / β-TCP)

Aqueous Precipitation Method

- ❑ Ca/P = 1.62
- ❑ 90 ˚ C
- ❑ pH 9

- The synthesized powders were calcined at 1000 ˚ C.
- Dry milled for 30 min in a high energetic ball mill.

❑ Preparation and optimization of the CaPs/PCL formulations for the 3D printing in Bioplotter



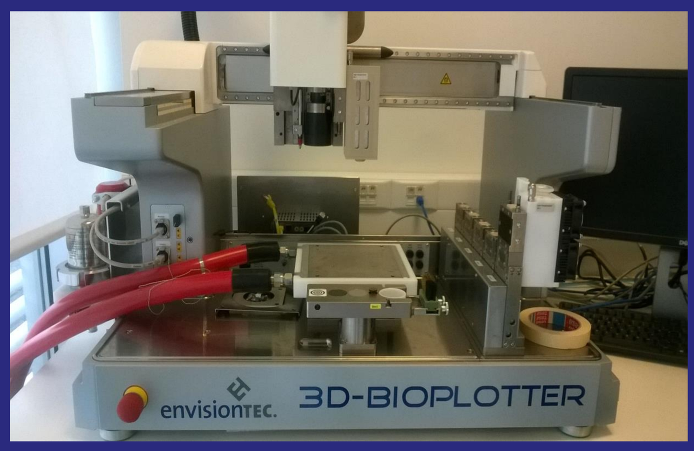
PCL/CaP

(5wt.% of CaPs)

Twin Screw Extruder

- Melt Temperature: 60 ˚ C
- Speed: 50 rpm
- Die Pressure: 25 psi
- Torque: 7.3 Nm

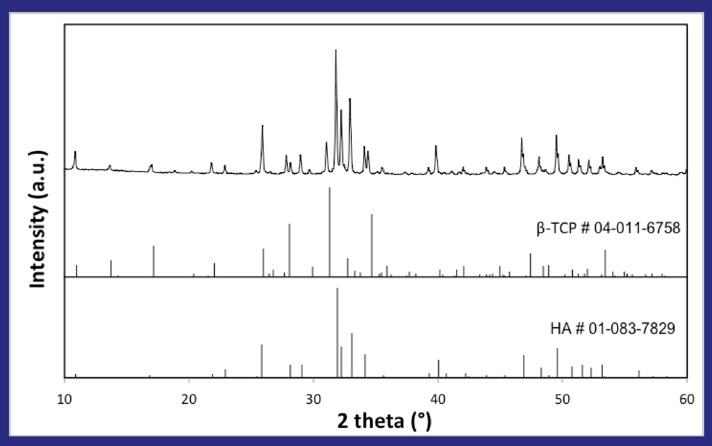
❑ Production of PCL/CaPs scaffolds by 3D printing



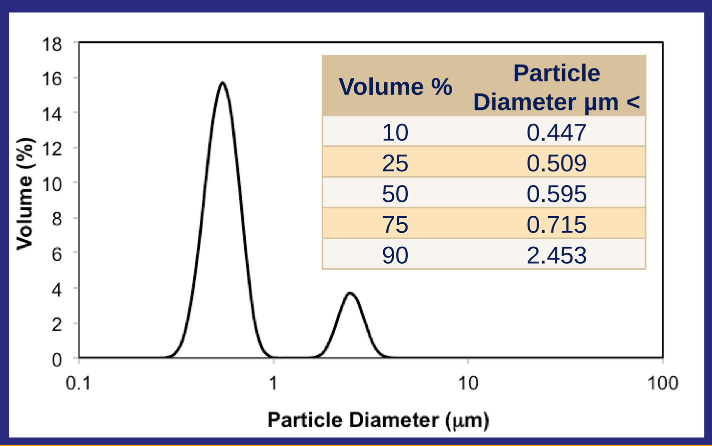
- 6 layers
- width x length: 10x10 mm
- distance between filaments: 0.5 mm / 90˚
- Pressure: 5.2 bar
- Moving speed: 2 mm/s

RESULTS

❑ Characterization of biphasic calcium phosphate powder



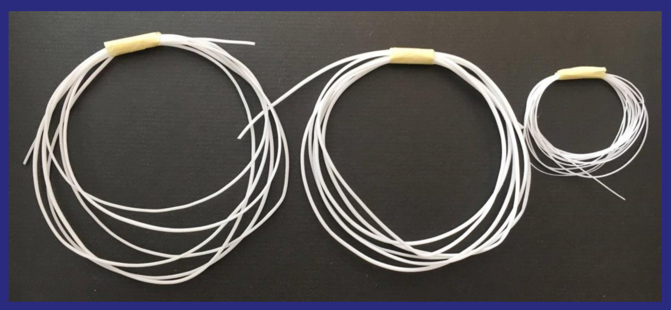
❖ XRD patterns of the synthesized biphasic calcium phosphates

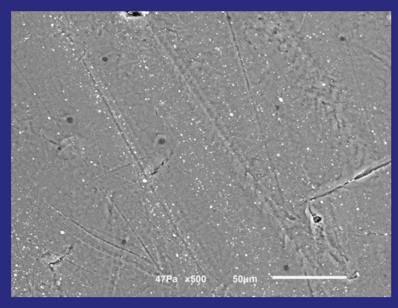


Volume %	Particle Diameter µm <
10	0.447
25	0.509
50	0.595
75	0.715
90	2.453

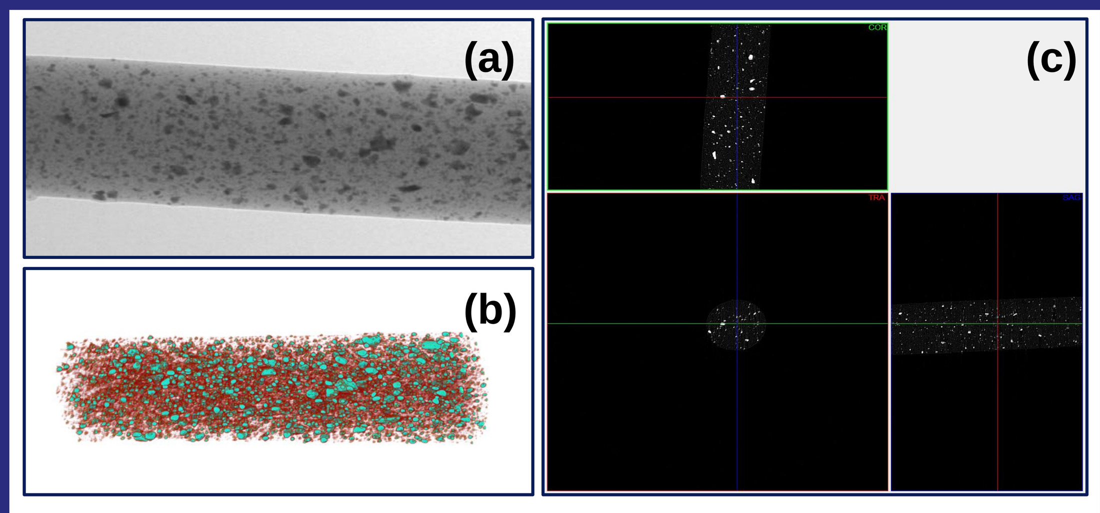
❖ Particle size distribution of the milled powders.

❑ Characterization of PCL/CaPs filament



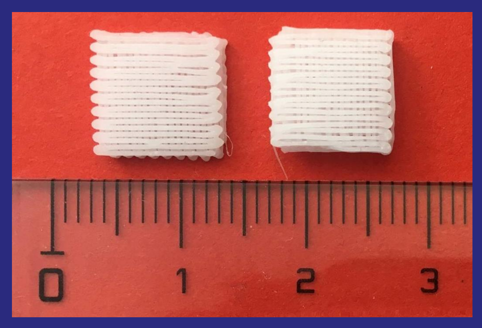


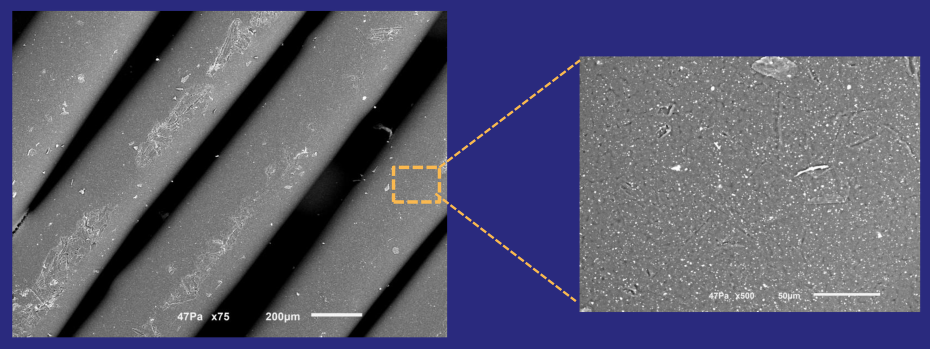
❖ SEM micrographs of the PCL/CaP filament



❖ Micro CT analysis of PCL/CaP filament: (a) X-Ray diffraction, (b) 3D reconstruction and (c) 2D images.

❑ Characterization of scaffolds printed





❖ SEM micrographs of the PCL/CaP scaffold

CONCLUSIONS

- ✓ The CaPs powders were successfully synthetized and after milling, the average particle/agglomerates sizes was ~0.6 µm with a bimodal distribution.
- ✓ PCL/ CaPs blends were efficiently mixed and an homogenous filament was produced with a twin screw extruder.
- ✓ The CaP/PCL filament was then reduced to pellets and, using the high temperature printing head, the printing of the mixture was possible, with CaP particles presenting a uniform distribution across the scaffold.

Future Work

- ❑ Other calcium phosphate will be used, namely, CaPs extracted from fish bones, with higher percentage of CaP powders.
- ❑ Studies of mechanical properties, degradation of the scaffolds and biological studies.

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