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3D printed Bioactive interference Screw and PCL Bio-Filler for ligament fixation

Mafalda Rodrigues[1*], Rui Moreira[1*], Inês V. Silva [1*], Marta M. Duarte [1], Viviana P. Ribeiro[1], Ana L. Oliveira[1¥] and João B. Costa[1¥]

[1] *Universidade Católica Portuguesa, CBQF - Centro de Biotecnologia e Química Fina – Laboratório Associado, Escola Superior de Biotecnologia, Rua Diogo Botelho 1327, 4169-005 Porto, Portugal*

* *Co-first authors*

[¥] *aloliveira@ucp.pt; jpbcosta@ucp.pt*

Musculoskeletal injuries, widespread across all ages, genders and sociodemographic groups [1], are prevalent in the knee joint and require a range of treatments - from conservative methods to surgical interventions, such as meniscal resection, repair, reconstruction or tissue engineering (TE) approaches [2]. To address one of the most significant challenges in orthopedic procedures – long-term implant fixation – an innovative solution is being developed for knee ligaments and meniscus fixation. PLA screws are being developed through the combination of 3D printing, supercritical CO2 (scCO2) foaming and impregnation technologies, aiming to achieve a biodegradable and bioactive screw with improve bone integration ability. Additionally, to improve the anchor and fixation of the ligament treatments, PCL Bio-Fillers are being developed through the use of 3D printing, electrospinning and dipping methods with the final goal to induce the bone cells to reproduce itself (osteogenesis) and create a better grip between the ligaments and the bone.

PLA screws were manufactured by 3D printing and further process to induce porosity by scCO2 foaming, followed by EPS impregnation through scCO2. Scanning electron microscopy (SEM) was used to evaluate microporosity and the EPS impregnation. The CO2 concentration, density and expansion ratio of the PLA screws were evaluated. FTIR (Fourier-transform infrared spectroscopy) was performed to evaluate chemical composition changes of the samples. DSC (Differential scanning calorimetry) was applied to analyze thermal stability both before and after treatment. PCL Bio-Fillers were produced by 3D printing, coated with PCL using electrospinning and dipped with bruxite. Then, to study the PCL fibers and bruxite dispersion, we have used the scanning electron microscopy (SEM) method. Results: Several conditions of foaming were tested (pressure, time, temperature and controlled expansion measures) and then, analyzed through SEM imaging. Samples with greater porosity were selected for further testing and analysis. The CO2 concentration results revealed that the saturation increase is proportional to the increase in pressure and inversely proportional to the increase in infill density. The expansion ratio results demonstrated that it typically decreases with increasing infill density and batch pressure. To optimize the 3D printed Bio-Fillers coated with PCL several parameters were adjusted (PCL concentration, flow rate, distance, potential difference, and nozzle size). Firstly, samples with apparent macroscopy uneven coating were remove with further analysis being performed via SEM analysis. The SEM analysis showed that increasing the potential difference and decreasing the flow rate produced more dispersed and thinner fibers. It also revealed that increase PCL concentration led to higher fiber density and size. In the end, the parameters that resulted in the better PCL fibers dispersion were with a concentration of 7,5% w/v of PCL, 20 µL/min flow rate, 10 cm of distance between the nozzle and the Bio-Filler, 23 kV of potential difference and 20 G of nozzle size. Further work is being performed to optimize the dipping process with bruxite and achieve an even coating.

Conclusion: The sCO_2 methodologies implemented were efficient in terms of generating porosity and EPS impregnation. EPS-induced bioactivity will be studied in the future.

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