Binder jetting 3D printing of porous Poly (L-lactic acid) - hydroxyapatite scaffolds intended for use in bone tissue engineering applications

Farid Salari[1], Tygo Cijsouw[1], Jasper Ford[1], Tosca Roncada[2], Paula Vena[3], Alan Nugent[4], Henrik Bjoerk[4], Miguel Castilho[3], Daniel Kelly[2], Jos Malda[5], Matteo Baldassari[1]

[1] CONCR3DE Printing B.V., Rotterdam, The Netherlands.
[2] Trinity Centre for Bioengineering, Trinity Biomedical Sciences Institute, Trinity College Dublin, Dublin, Ireland.
[3] Department of Biomedical Engineering, Eindhoven University of Technology, The Netherlands.
[4] IPC - Innovative Polymer Compounds, Kilbeggan, County Westmeath, Ireland.
[5] Department of Orthopaedics, University Medical Center Utrecht, Utrecht, the Netherlands.

Low-temperature binder jetting offers a promising technique for printing hydroxyapatite composite. In order to obtain appropriate mechanical properties, various design parameters, including binder and powder properties, must be optimized using this method. A bioresorbable medical grade polymer was chosen to combine with the HA: Poly(L-lactic acid) (PLLA). PLLA was compounded with HA testing different ratio of HA/PLLA, after this step the material was processed to achieve the desired granulometry for the binder jetting process (flowability and compaction). A water soluble and natural adhesive (BioBinder) was developed to achieve a green product which could bond particles prior to the sintering step. In order to achieve the required shape accuracy and strength, the printing parameters such as binder saturation, print speed, layer thickness, and spread speed have been adjusted using the concr3de Armadillo binder jetting 3Dprinter that was used to produce samples. Prior to de-powdering, printed parts were cured for 2h at 100 °C to have enough green strength. In order to achieve a mechanically strong part the object was sintered for 1h at 175 °C. The samples that were produced using the developed formulation were able to effectively create diverse cylindrical shape scaffolds that have varying macro-chamber dimensions (width: 0.4 and 0.8mm, depth: 0.6 and 1.2 mm, and wall thickness of 50 and 100 µm). Green and sintered scaffolds were analyzed using scanning electron microscopy (SEM), mechanical strength testing, and computed tomography (CT). The utilization of optimal printing parameters developed in this study can potentially enhance the structural, mechanical, and biological performances of PLLA-HA based 3D scaffolds that are manufactured through the binder jetting AM process. These scaffolds are explicitly intended for application in bone and cartilage tissue engineering.