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Design and characterization of bioceramic scaffolds for bone tissue engineering.

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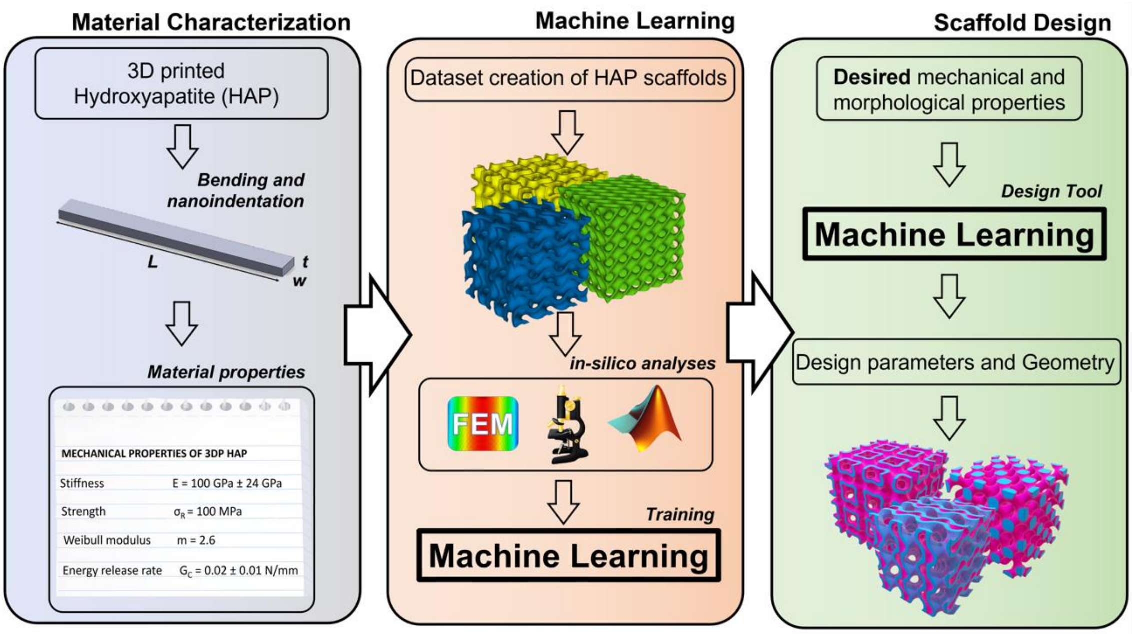
Project: Artificial Intelligence-based design of 3D PRINTed scaffolds for the repair of critical-sized bone defect



Abstract

Critical size bone defects represent a pathological condition where native bone is not able to heal spontaneously. Among biocompatible materials, bioceramics are able to generate a strong bond with the hosting tissue, thanks to their chemical affinity to the native bone tissue. The main limitation of bioceramics is represented by their intrisic brittleness, that brings to a catastrophic failure. The knowledge of the mechanical properties of bioceramic, combined with a proper design of scaffold may produce effective devices overcoming the above mentioned drawback.

An extensive mechanical characterization has been performed on 3D printed hydroxyapatite and an experimental formulation of glass ceramic. Beam-shaped hydroxyapatite samples have been obtained through vat photopolymerization (VPP). Synchrotron light radiation has been used to assess the intrinsic porosity of the samples, confirming VPP able to produce bulk samples with negligible porosity. A combined approach of micro-bendings and nanoindentations restituted the stiffness, the strength and the Weibull modulus of the material. A novel approach of fracture nanoindentations has been applied to characterize the stiffness and the strength of the glass-ceramic. The mechanical properties have been related to 6 different sintering temperatures, revealing that higher sintering temperatures generate a higher degree of cristallinity and thereby higher stiffness and strength.

An other key factor for suitable bioceramic scaffold is the knowledge of the printing fidelity. For the accomplishment of this task, microCT performed on the 3D printed scaffold have been run to take into account of the micro defects and the distortion of the geometry that occur during the manufacturing process. MicroCT-based Finite Element Models (FEM) have been used effectively to get the elastic and fracture properties of scaffolds, and to assess how micro defects affect the mechanical performances.

Once the bulk material properties are known and the FEM validated, the attension has been focused on the design of optimized micro-architectures, based on Triply Periodic Minimal Surfaces (TPMS). Since different targets and constraints has to be addressed, a Machine Learning (ML) approach has been used to generate TPMS scaffolds with prescribed properties and features, considering in the same time the mechanical properties, the mechano-biologic aspects and the manufacturing constraints.