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POROUS TITANIUM STRUCTURES FABRICATED BY ELECTRON BEAM MELTING: A VERSATILE SOLUTION TO USE AS BONE SCAFFOLDS

Alejandro Yánez[1], Alberto Cuadrado[1], Oscar Martel[1], Hernando Afonso[2], Donato Monopoli[2]

[1]University of Las Palmas de Gran Canaria, Mechanical Engineering Department, Campus Universitario Tafira, Edificio Ingeniería, 35017, Las Palmas de Gran Canaria, Canary Islands, Spain
[2]Instituto Tecnológico de Canarias, 35118 Arinaga, Canary Islands, Spain

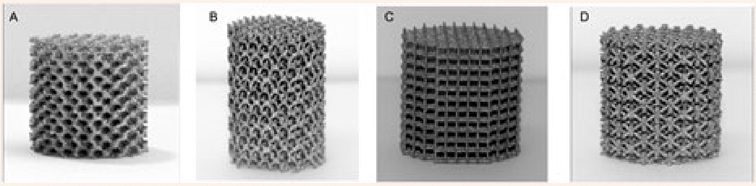
INTRODUCTION

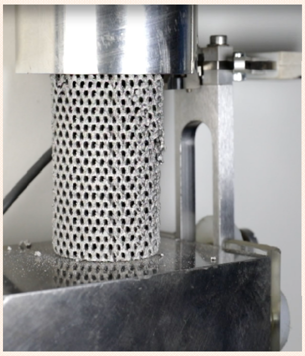
To obtain structures with greater strength capacity in the direction of loading and achieve an elastic modulus similar to that of cancellous bone, gyroid lattice structures were designed and compared with others structures.

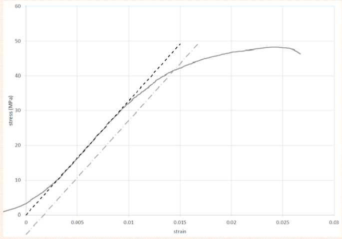
Additive manufacturing techniques such as selective laser melting (SLM) and electron beam melting (EBM) allow fabricating 3D structures with an interconnected porosity suitable for tissue ingrowth and vascularization that act as scaffolds. The objective is to match the mechanical properties, such as compressive strength and elastic modulus that are similar to those of human bone, so stress-shielding effects after implantation might be avoided.

METHODS

A total of sixty lattice porous structures were fabricated by EBM and submitted to compression tests. Titanium powder (Ti-6Al-4V) was used as raw material. All the specimens were loaded until failure. Structures studied were: normal gyroid, deformed gyroid, normal cube, cube to 45º. The shape of the pores of the normal gyroid was spheres whereas in the case of the deformed gyroid was ellipsoids with the largest radius in the direction of the load. The cube at 45º had a shape similar to the normal cube but the vertical struts were fabricated at 45 °. The porosities of the structures approached 85% and the bar thicknesses close to 0.65 mm. A finite element analysis is being also carried out in order to corroborate the experimental results.



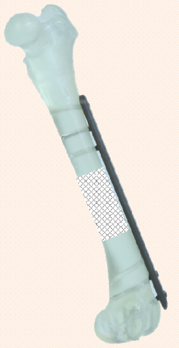




RESULTS

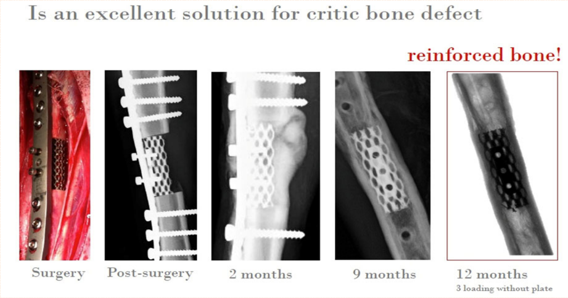
Table 1 shows the results (mean and standard deviation) of: porosity, Young's modulus (E), yield stress and specific strength. The specific strength of the structures was calculated as the ratio between the compressive strength and the apparent density.

Structure	Porosity (%)	Young's modulus MPa	Yield Stress MPa	Specific Strength MPa/(g/cm3)
Normal Gyroid	83.99 (0.13)	487.52 (19.61)	14.79 (0.39)	20.66 (0.50)
Deformed Gyroid	87.40 (0.23)	844.91(13.02)	15.77 (0.34)	28.01(0.47)
Cube	88.75 (0.04)	1613.86 (111.53)	16.39 (1.08)	32.60 (2.22)
Cube 45º	84.74(0.21)	328.13 (13.66)	8.58 (0.81)	9.42 (6.37)



DISCUSSION AND CONCLUSIONS

The elastic moduli were closed to the Young´s modulus range for human cancellous bone (100 – 1500 MPa). The best specific strength was presented by the cubic. However, the specific strength in the cubic at 45 ° was reduced. This means that, likely, for loads with a certain angle with respect to the vertical axis, the deformed gyroid will have the best behaviour. In conclusion, gyroid structures are suitable to adapt to different load directions. It's possible to deform the unit cell to reach good mechanical properties for any load direction. Finally, it is suggested to take into account the directions of the loads, as well as other types of loads, such as torsion, to choose the suitable porous structure in the reconstruction of bone defects.



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Corresponding author: alejandro.yanez@ulpgc.es