ABSTRACT

Bone implants are commonly used to replace bones and joint defects; nevertheless, mechanical, biological, and structural incompatibilities between bones and implants can cause serious complications. Traditional bone implants used in orthopedic bone and joint replacements have solid and stiff components that shield the peri-implant bone stress and cause the implants to loosen prematurely. New porous materials are necessary to enable an implant to imitate the host bones, and this is the main focus of this research work.

In biomedical sectors, using additive manufacturing techniques has shown massive benefits such as flexibility in building micro and macro-scale structures based on computer models and analyses. Despite the fact that porous structures bring mechanical and biological environments closer to the host bone, poor internal architectural designs may compromise mechanical characteristics and structural integrity. As a result, the mechanical and biological performances of small-scale units of porous structure deserve additional investigation.

Titanium is one of the most prevalent and biocompatible metals. In orthopedics, the demand for Ti alloys and its use in clinical surgeries are constantly increasing. Because of its moderate Young's modulus, outstanding compressive strength, biocompatibility, and sufficient space for cell accommodation, the porous structures have been modeled for bone tissue engineering or orthopedic applications. Additive manufacturing (AM) technologies, particularly selective laser melting (SLM), can be used to create porous scaffolds with complicated internal and external shapes and both of these are most important for the repair of large sectional bone defects. As a result of this advantage, the SLM method is one of the most competitive AM technologies employed in biomedical applications. In this research, seven different Ti-6Al-4V porous scaffolds (Diamond, Grid, Cross, Vinties, Tesseract, Star, and Octet) of 15 mm cube with 65% porosity are designed using Rhino 6 software and manufactured using Ti-6Al-4V powders by SLM. Because of its high heating rate and low holding time, SLM can build nanoscale grain scaffolds. However, in most cases, this method results in insufficient compaction where desired functions are not achieved.

Compression test of all the seven scaffolds is performed on an INSTRON compressive testing machine with a maximum load cell capacity of ±25 kN to measure its mechanical properties. Actual porosity and surface roughness of the fabricated scaffolds are measured. Then all the scaffolds are analyzed by Ansys 2020 R2. The elastic modulus of fabricated samples is very similar to that of human bones (E=3-30 GPa), but compressive strength is

higher than that of human bone, which will minimize the stress-shielding effect and extend the implant's longevity. The Gibson-Ashby Correlation Model is used to investigate the samples relative elastic modulus. Ti-6Al-4V porous scaffolds have a low effective Young's modulus, high compressive strength, and enough cell accommodation space to meet medical needs for clinical demands. Porous Ti-6Al-4V scaffolds (Diamond, Grid, Cross, Vinties, Tesseract, Star, and Octet) have shown the relative elastic moduli and compressive mechanical strength are 6.5 GPa, 11.15 GPa, 10.33 GPa, 7.16 GPa, 5.87 GPa, 7.9 GPa & 11.16 GPa and 96.41 MPa, 98.42 MPa, 101.39 MPa, 95.63 MPa, 94.02 MPa, 88.71 MPa & 90.49 MPa respectively, which are comparable to human bone. The scaffolds made by SLM have a reasonably good pore structural accuracy and excellent mechanical strength. Grid type structure exhibits lower surface roughness value and better manufacturing ability whereas error percentage of porosity is lower than the other scaffolds.

It is found that using porous Ti-6Al-4V structures in orthopedic bone implants could be a better option for load-sharing implants because it balances stability, maintains bone matching stiffness, decreases bone stress shielding, and possibly extends implant longevity.