Transactions on Additive Manufacturing Meets Medicine
Trans. AMMM, 2026, Vol. 8, No 1, Suppl. 1, Article ID 2732, 1 Page

Infinite Science Publishing

Abstract

Impact of lattice-based Voronoi design and surface finishing on the functional performance of Ti-6Al-4V bone screws

M. Bracchi[1*], C. Mapelli[2], J. Fiocchi[1], A. Tuissi[1], C. Colombo[2], and C.A. Biffi[1]

[1] *National Research Council, CNR-ICMATE, Lecco, Italy*
[2] *Department of Mechanical Engineering, Politecnico di Milano, Milan, Italy*
[*] *Corresponding author, email: maddalenabracchi@cnr.it*

Ti6Al4V ELI bone screws are widely used in orthopedics for fracture fixation and osseointegration. Additive manufacturing (AM) enables the production of patient-specific implants with customized geometries and integrated trabecular lattice structures [1]. These porous architectures can enhance osseointegration, particularly in osteoporotic bone, while reducing implant stiffness to better match that of natural bone. In addition, the inherent micro-roughness of AM surfaces promotes osteoblast adhesion and spreading, supporting early bone integration [2,3].

In this study, bone screws manufactured via Laser Powder Bed Fusion (LPBF) with Voronoi lattice structure, placed in both longitudinal and transversal locations, were subjected to finishing treatment (sandblasting) to optimize their surface characteristics. Morphological characterization was performed through surface profilometry on both the lattice regions and the threaded surfaces, and the results were compared with those of untreated screws to evaluate the surface modifications induced by the treatments. Mechanical performance was subsequently evaluated through insertion tests, axial pull-out tests to assess primary stability in solid polyurethane foam with a density comparable to osteoporotic bone. Additionally, torsional tests were also carried out until failure in accordance with the ASTM F543-17 standard to determine the influence of surface treatments on the mechanical properties of the three types of screws. Secondary stability was also investigated by evaluating the mechanical behaviour of the screws embedded in PMMA bone cement, which simulates woven bone formed immediately after implantation by osteoblast activity. Finally, the experimental results were compared with Finite Element Method (FEM) simulations of the axial pull-out behaviour to validate the computational predictions and to determine the critical regions within the lattice structure, providing insights for further optimization of the screw design. Sandblasting plastically deformed adhering particles, either flattening or removing them, reducing roughness on both vertical and horizontal surfaces. Primary stability was not strongly influenced by surface treatment, whereas secondary stability was slightly reduced because of the reduced implant-PMMA interfacial area. This may be beneficial in case an implant revision procedure is needed.

AUTHOR'S STATEMENT

Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study.

REFERENCES

[1] C. Bregoli, F. Stacchiotti, J. Fiocchi, R. Ferrari, C.A. Biffi, K. Morellato, E. Gruppioni, A. Tuissi, *A biomechanical study of osseointegrated patient-matched additively manufactured implant for treatment of thumb amputees*, Medical Engineering and Physics, vol. 118, 2023.
[2] J. Deering, K.I. Dowling, L.A. DiCecco, G.D. McLean, B. Yu, K. Grandfield, *Selective Voronoi tessellation as a method to design anisotropic and biomimetic implants*, Journal of the Mechanical Behavior of Biomedical Materials, vol. 116, 2021.
[3] C. Bregoli, J. Fiocchi, C.A. Biffi, A. Tuissi, *Additively manufactured medical bone screws: an initial study to investigate the impact of lattice-based Voronoi structure on implant primary stability*, Rapid Prototyping Journal, vol. 30, 2022.

DOI: 10.18416/AMMM.2026.26062732