

Mechanical Properties of 3D Printed Porous Ti-6Al-4V Alloy for Biomedical Applications

Markéta Straková (0000-0003-4349-6942), Jiří Kubásek (0000-0001-6008-0127), Dalibor Vojtěch (0000-0002-6910-3206)

Faculty of Chemical Technology, University of Chemistry and Technology, Technická 5, Praha 6 – Dejvice, 166 28 Prague. Czech Republic. E-mail: strakovm@vscht.cz

Optimising the mechanical properties required for biomedical applications is something that porous Ti-6Al-4V structures offer the opportunity to do. Triply periodic minimal surface (TPMS) structures, such as the Diamond and Gyroid structures, provide interconnected pores that can be used to adjust strength, stiffness and deformation. The mechanical behaviour of these two architectures under compressive and bending loads is compared in this study, with the use of additively manufactured samples. The results demonstrate that pore geometry significantly impacts mechanical behaviour. Diamond structures exhibit higher stiffness and strength, whereas Gyroid structures provide a more isotropic and flexible response. These findings emphasise the importance of architecture when designing implants and other components for which optimised mechanical properties and geometry are essential.

Keywords: Diamond, Gyroid, Ti-6Al-4V, Porous Structures, TPMS

1 Introduction

Titanium and its alloys, particularly Ti-6Al-4V, are widely used in biomedical engineering thanks to their combination of strength, low density, corrosion resistance and biocompatibility [1–7]. However, despite these favourable properties, solid implants often cause stress shielding due to a mismatch in stiffness between the implant and the surrounding bone. Introducing porosity into the structure can reduce the effective modulus, enhance osseointegration and permit tissue ingrowth, thereby improving implant performance [8–112].

Among the various porous designs, triply periodic minimal surface (TPMS) structures, such as Diamond and Gyroid, are of particular interest. These geometries offer a highly regular, interconnected network of struts and pores that can be adjusted to control mechanical properties, energy absorption and cell adhesion. Diamond structures typically provide higher stiffness and strength, while gyroid structures offer improved flexibility and a more isotropic mechanical response. This makes both architectures promising for biomedical implants [12–15].

This study focuses on the mechanical comparison of Diamond and Gyroid porous Ti-6Al-4V structures produced by additive manufacturing. The aim is to shed light on how pore architecture influences compressive and flexural behaviour, providing guidance for designing implants that more closely mimic the mechanical environment of human bone.

2 Experiment details

Porous Ti-6Al-4V scaffolds featuring triply periodic minimal surface (TPMS) geometries — specifically Diamond and Gyroid — were fabricated for the purpose of studying their mechanical performance. The samples were designed using CAD software and generated with MSLattice to ensure interconnected pore networks and a target porosity of 70%, see Fig. 1. Elementary unit cells and larger assembled structures were printed on a thin, non-porous substrate to provide structural support during the additive manufacturing process.

Additive manufacturing was performed using a ConceptLaser M2 Cusing LPBF printer fitted with a 200 W Yb:YAG fibre laser, in an atmosphere containing less than 0.5% O₂. The layer thickness was 30 µm, the scanning spacing was 80 µm, and the scanning speed varied between 800 and 1250 mm s⁻¹ depending on the study. Both the Diamond and Gyroid structures were printed vertically and subsequently evaluated in as-built and post-processed conditions.

The Ti-6Al-4V powder was gas-atomised and spherical, characterised by a particle size distribution of d₁₀ ≈ 23 µm, d₅₀ ≈ 33 µm and d₉₀ ≈ 48 µm. Gravimetric measurements confirmed that the experimental porosity closely matched the designed value of 70% (approximately 69% for the Diamond structure and 67% for the Gyroid structure), with minor deviations attributed to partial melting or powder adhesion.

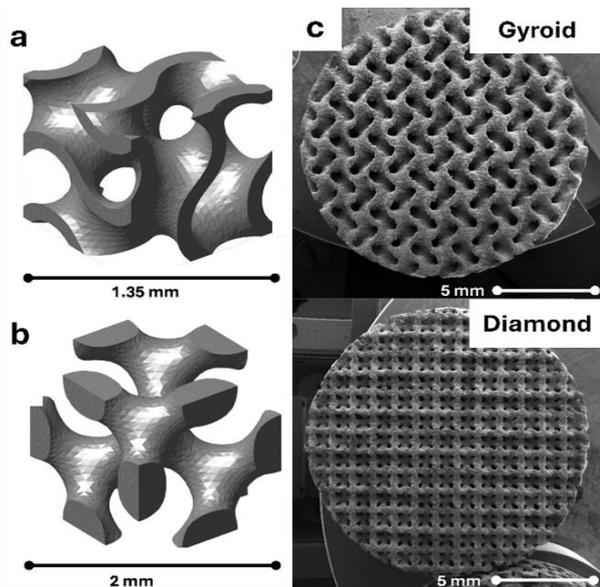


Fig. 1 Porous gyroid and diamond structures: (a) - elementary cell gyroid (G), (b) - elementary cell diamond (D), (c) samples with diamond and gyroid structures in their initial state after printing – SEM

The Vickers hardness, compressive and bending strength of Diamond and Gyroid porous Ti-6Al-4V

structures were evaluated. Hardness measurements were taken from the surface and cross-section of both materials, while compression and bending tests were carried out on each porous material using a LabTest 5.250SP1-VM universal testing machine at room temperature. Three compression tests (Fig. 2a) and three bending tests (Fig. 2b) were performed for each geometry. The compression properties were evaluated at a constant loading rate of 5 mm/min. The bending test was done with three pins. Two pins were put through the porous section. A third pin was used to push down on the base of the sample (Fig. 2b). The test specimens were cut from the printed discs into 11–15 mm long, 3 mm wide and 3 mm high pieces. Due to the limited number and small size of the samples, it was not possible to follow a specific ASTM C1161 standard for flexural testing. During testing, the dense base was kept in place and positioned on the compression side (the top). In every case, the fracture occurred in the porous structure rather than at the base, indicating that the mechanical behaviour was governed by the porous region. The base might have affected how the stress was spread, which is a problem with the test setup.

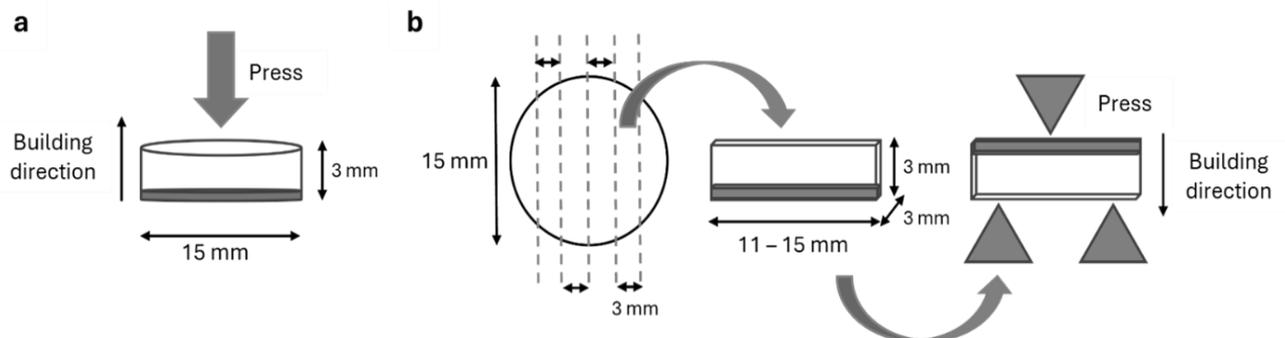


Fig. 2 Schematic representations of the test setups: (A) The setup for the uniaxial compression test; (B) The preparation of specimens for three-point bending tests is outlined here

3 Result and discussion

3.1 Microstructure

The Diamond and Gyroid TPMS structures differ in both geometry and the angle and thickness of the individual struts, which has a significant effect on their mechanical performance. In this study, the average strut diameter was approximately 0.3 mm for the Diamond structure and 0.2 mm for the Gyroid structure, see Fig. 3. Previous studies have shown that deviations from the CAD design occur during manufacturing: horizontal struts tend to be thicker, with discrepancies of up to 198 μm for gyroid and up to 105 μm for diamond. Meanwhile, vertical struts remain closer to the designed thickness [16, 17]. This implies that the effective strut thickness depends heavily on build orientation, influencing both stiffness

and strength. Furthermore, comparative studies suggest that Diamond structures generally demonstrate greater compressive stiffness and strength than Gyroid structures, primarily due to the distinct distribution of stress and load-bearing capacity within the unit cell [18, 19].

The LPBF-processed Ti-6Al-4V exhibits a predominantly martensitic α' microstructure, which is typical for rapid cooling rates inherent to this technique [20, 21]. Both D and G structures display visible micro-pores inside the struts, acting as potential stress concentrators. The martensitic morphology is expected to provide high strength but limited ductility. Future HIP treatment would transform this into an equilibrium $\alpha+\beta$ structure, improving toughness and fatigue resistance [20].

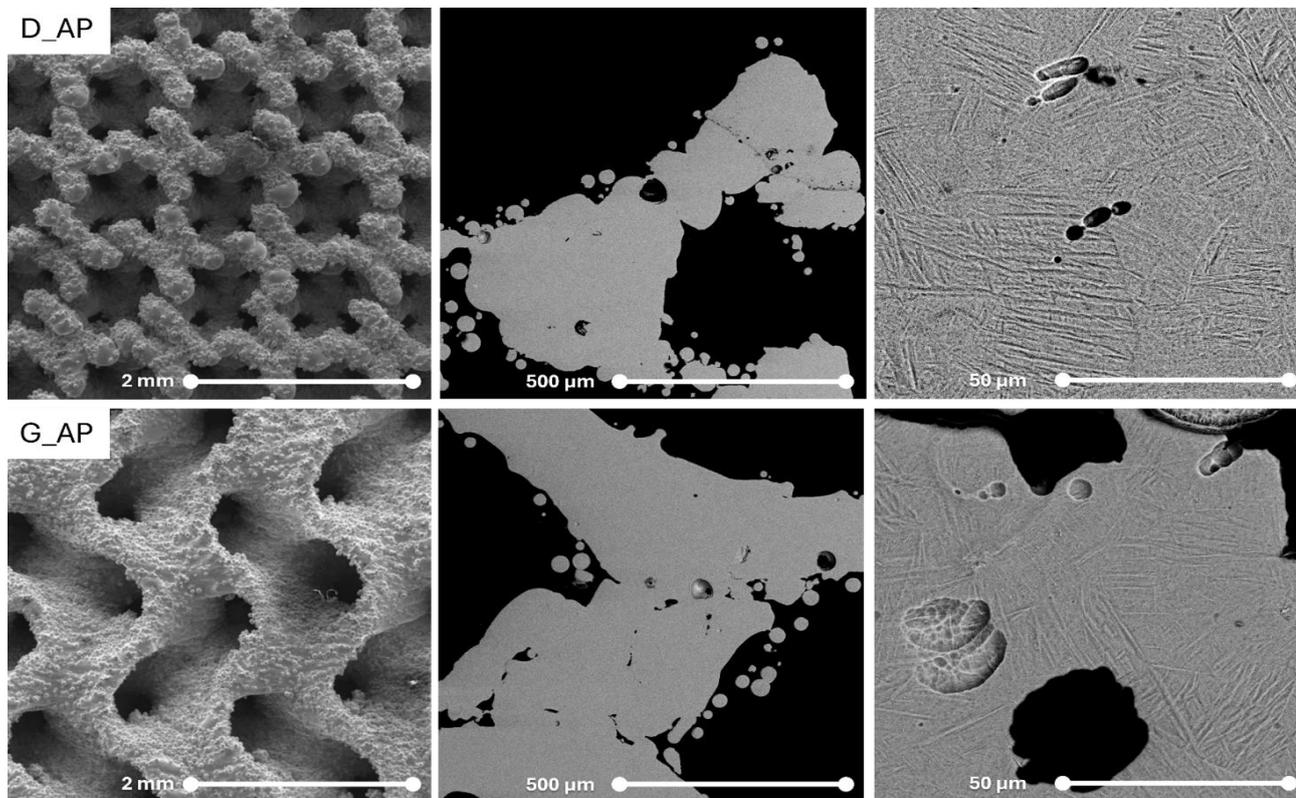


Fig. 3 SEM images of diamond (D) and gyroid (G) structures after LPBF fabrication: (a, b) show the diamond lattice at different magnifications; (c, d) show the gyroid lattice at different magnifications; In both cases, martensitic microstructure with visible pores is observed within the lattice struts

3.2 Hardness

Vickers hardness tests (HV0.5) revealed comparable values for both porous topologies, reaching 395 ± 18 HV0.5 for the Diamond and 415 ± 14 HV0.5 for the Gyroid. These values slightly exceed the hardness measured for bulk Ti-6Al-4V in the as-built state (353 ± 11 HV1), indicating the strengthening effect of the fine martensitic structure [20]. The results confirm that despite the high porosity, the local material properties of the struts remain close to, or even above, those of bulk LPBF-produced Ti-6Al-4V.

3.3 Compressive and bending properties

Compression tests revealed clear differences between the two TPMS topologies, see Fig. 4. The Diamond (D) structure achieved a compressive yield strength (CYS) of 81 MPa, whereas the Gyroid (G) structure exhibited a significantly higher value of 162 MPa. Both lattices exhibited an initial linear-elastic behaviour, followed by non-linear deformation due to the progressive collapse of the porous structure.

The superior performance of the gyroid can be explained by its continuous surface architecture and finer structure (with finer struts at 0.2 mm compared to 0.3 mm in the D structure), which allows for a more uniform distribution of stress and prevents localised failure. Similar trends have been reported in the

literature, where gyroid scaffolds often display a higher yield strength at comparable porosities due to their smooth stress distribution and reduced stress concentrations [22, 23]. However, other studies have noted that the diamond lattice can exceed the gyroid lattice when designed with thicker struts or lower porosity, highlighting the importance of relative density and manufacturing precision [24–26].

The measured CYS values typically fall within the wide range reported for porous Ti-6Al-4V scaffolds, which is usually between ~ 50 and 200 MPa, depending on the geometry and porosity [27–29]. Significantly, the gyroid structure in this study approaches the upper limit of this range, indicating its suitability for use in biomedical implants, where a balance must be found between strength and high porosity to enable bone ingrowth and minimise stress shielding [30, 31].

Three-point bending tests further emphasised the structural differences between the D and G lattices. As Fig. 4 shows, the Gyroid lattice exhibited a significantly higher ultimate bending stress (UBS) of approximately 261 MPa, whereas the Diamond lattice reached 164 MPa. Despite having finer struts (0.2 mm) than the diamond lattice (0.3 mm), the gyroid lattice's superior resistance under flexural load is demonstrated by this result. This superior bending performance is due to the Gyroid's continuous,

curved surface architecture, which enables tensile and compressive stresses to be distributed more effectively and uniformly during bending. This results in delayed localised failure compared to the strut-based Diamond geometry. The Ti-6Al-4V implant is a promising material for biomedical applications because it has low stiffness and high porosity [32]. Porous Ti-6Al-4V ELI reduces stiffness to 80 GPa and increases cell proliferation. In comparison to the study of Li X. et al. [33] (maximum bending strength of 126.3 MPa), both porous structures demonstrated higher initial bending strength values.

Fractographic analysis using a scanning electron microscope (see Fig. 5) revealed distinct failure modes for the two structures. In the diamond lattice, the fracture surfaces exhibited a combination of brittle cleavage and ductile dimples, which were frequently initiated at pores or adhered powder particles.

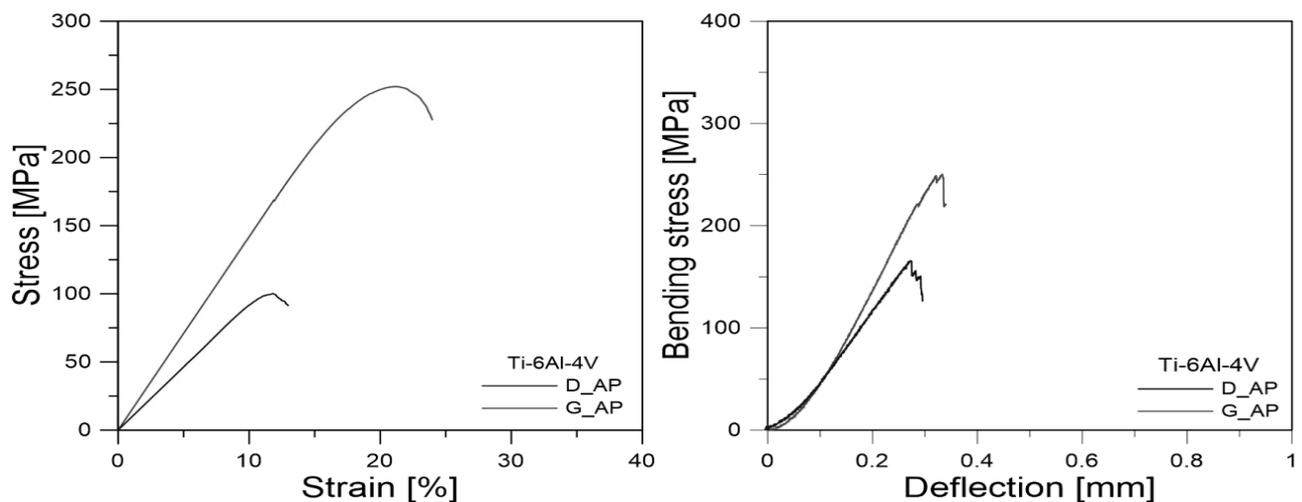


Fig. 4 The mechanical properties of the Ti-6Al-4V alloy are shown in the form of compressive stress-strain diagrams and bending stress-strain curves for the porous samples

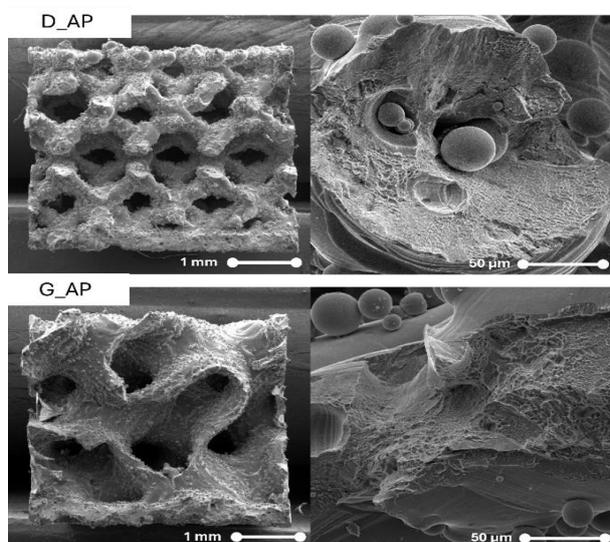


Fig. 5 Fracture surfaces of LPBF-fabricated porous structures with diamond and gyroid geometries in their as-printed states: D_AP: diamond structure in as-printed state; G_AP: gyroid structure in as-printed state

By contrast, the gyroid exhibited smoother fracture surfaces, reflecting more uniform stress pathways, but also a tendency towards localised collapse once critical deformation was reached.

As a research study discovered [34], the main distinctions between these structures also lie in their failure mechanisms. The diamond lattice is prone to abrupt failure due to the sudden buckling of struts, while the gyroid lattice demonstrates a more gradual failure through the steady collapse of its curved walls. Therefore, the type of printed structure chosen has a significant influence on its mechanical behaviour and overall performance. Even though a thorough mechanistic analysis lies beyond the scope of this study, the observations underscore the paramount necessity to adapt post-processing strategies, such as HIP, to the geometry and loading conditions of printed scaffolds.

4 Conclusion

Both Ti-6Al-4V Diamond and Gyroid lattice designs are popular for biomedical implants and engineering applications. However, they differ in terms of mechanical behaviour, manufacturability and biological performance.

- The LPBF-fabricated Diamond and Gyroid TPMS structures exhibited a martensitic microstructure containing micro-pores within the lattice struts.
- The hardness values of the porous structures were comparable to or higher than those of the bulk material, indicating preserved local strength.

- Compression tests showed that the gyroid structure had a significantly higher compressive yield strength (CYS = 162 MPa) than the diamond structure (CYS = 81 MPa). Furthermore, the gyroid structure achieved a notably higher ultimate bending stress (UBS \approx 261 MPa) than the diamond structure (UBS \approx 164 MPa), demonstrating its superior load-bearing capacity under compressive and bending stress.
- The structural design, for example the thickness and geometry of the struts, plays a decisive role in determining the mechanical response, underlining the need for application-specific optimisation. The superior performance of the gyroid structure under both testing conditions suggests that it is highly suitable for high-load biomedical implants, as its properties approach the optimal range for load-bearing bone ingrowth. Given the observed martensitic microstructure and the presence of micro-pores, future post-processing strategies such as hot isostatic pressing (HIP) are recommended to transform the microstructure into the equilibrium $\alpha + \beta$ phase, thereby improving toughness and fatigue resistance for long-term implant stability.

Acknowledgement

This publication was supported by the project "Mechanical Engineering of Biological and Bioinspired Systems", funded as project No. CZ.02.01.01/00/22_008/0004634 by Programme Johannes Amos Comenius, call Excellent Research. It was also supported by the Ministry of Health of the Czech Republic in cooperation with the Czech Health Research Council under project No. NW25-08-00044. The grant of Specific university research – grant No. A1_FCHT_2025_011 is also acknowledged.

Availability of data

***The data are accessible through the Zenodo repository:
<https://doi.org/10.5281/zenodo.17898548>.***

References

- [1] MARIN, E., LANZUTTI, A. (2024). Biomedical Applications of Titanium Alloys: A Comprehensive Review. In: *Materials (Basel)*, Vol. 17, No. 1, Article 114. MDPI, Switzerland. ISSN 1996-1944.
- [2] SHAH, F. A., TROBOS, M., THOMSEN, P., PALMQUIST, A. (2016). Commercially pure titanium (cp-Ti) versus titanium alloy (Ti6Al4V) materials as bone anchored implants — Is one truly better than the other? In: *Materials Science and Engineering: C*, Vol. 62, pp. 960 – 966. Elsevier, Netherlands. ISSN 0928-4931.
- [3] BARTOLOMEU, F., GASIK, M., SILVA, F. S., MIRANDA, G. (2022). Mechanical Properties of Ti6Al4V Fabricated by Laser Powder Bed Fusion: A Review Focused on the Processing and Microstructural Parameters Influence on the Final Properties. In: *Metals (Basel)*, Vol. 12, No. 6, Article 986. MDPI, Switzerland. ISSN 2075-4701.
- [4] CAO, S., ZOU, Y., LIM, C. V. S., WU, X. (2021). Review of laser powder bed fusion (LPBF) fabricated Ti-6Al-4V: process, post-process treatment, microstructure, and property. In: *Laser Additive Manufacturing*, Vol. 1, Article 020. Wiley, UK. ISSN 2752-3363.
- [5] CAO, S., ZOU, Y., LIM, C. V. S., WU, X. (2021). Review of laser powder bed fusion (LPBF) fabricated Ti-6Al-4V: process, post-process treatment, microstructure, and property. In: *Laser Additive Manufacturing*, Vol. 1, Article 020. Wiley, UK. ISSN 2752-3363.
- [6] GAO, X.-S., ZHAO, Y., WANG, M., LIU, Z., LIU, C. (2022). Parametric Design of Hip Implant With Gradient Porous Structure. In: *Frontiers in Bioengineering and Biotechnology*, Vol. 10, Article 850184. Frontiers Media, Switzerland. ISSN 2296-4185.
- [7] VERMA, R., CHAKRAVARTY, A., SRIVASTAVA, V., KUMAR, A. (2022). Low elastic modulus and highly porous triply periodic minimal surfaces architected implant for orthopedic applications. In: *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine*, Vol. 236, No. 8, pp. 1045 – 1055. SAGE Publications, UK. ISSN 0954-4119.
- [8] SIREGAR, I., SAEDON, J., SHARIMAN ADENAN, M. (2025). Milling Performance of Selective Laser Melted Ti6Al4V: A Taguchi Approach for Surface Roughness Optimization. In: *Manufacturing Technology*, Vol. 25, No. 2, pp. 230 – 238. J. E. Purkyně University in Ústí nad Labem, Czech Republic. ISSN 1213-2489.

- [9] MORAN, T. P., CARRIÓN, P. E., LEE, S., BROWN, D., RAGHAVAN, B., WILLIAMS, C. B. (2022). Hot Isostatic Pressing for Fatigue Critical Additively Manufactured Ti-6Al-4V. In: *Materials (Basel)*, Vol. 15, No. 6, Article 2051. MDPI, Switzerland. ISSN 1996-1944.
- [10] KOLAROVSKI, B., FICSOR, S., FRANK, D., KATONA, K., SOOS, B., TURZÓ, K. (2024). Unlocking the potential: laser surface modifications for titanium dental implants. In: *Lasers in Medical Science*, Vol. 39, Article 162. Springer, Germany. ISSN 0268-8921.
- [11] WANG, C., ZHAO, Y., YANG, F., ZHANG, X., ZHOU, Y. (2020). Effect of pore size on bone ingrowth into porous titanium implants fabricated by additive manufacturing: an in vivo experiment. In: *ACS Omega*, Vol. 5, No. 44, pp. 28531 – 28539. American Chemical Society, USA. ISSN 2470-1343.
- [12] STRAKOVÁ, M., KUBÁSEK, J., DIVÍN, J., PINC, J., VOJTĚCH, D. (2025). Effect of hot isostatic pressing on the microstructure and mechanical properties of porous Ti-6Al-4V alloy manufactured by laser powder bed fusion. In: *Material Science in Additive Manufacturing*, Vol. 3, Article 055. Science Target, UK. ISSN 2754-0826.
- [13] QIU, C., ADKINS, N. J. E., ATTALLAH, M. M. (2013). Microstructure and tensile properties of selectively laser-melted and of HIPed laser-melted Ti-6Al-4V. In: *Materials Science and Engineering: A*, Vol. 578, pp. 230 – 239. Elsevier, Netherlands. ISSN 0921-5093.
- [14] NAGHAVI, S. A., TAMADDON, M., MARGHOUB, A., WANG, K., BABAMIRI, B. B., HAZELI, K., XU, W., LU, X., SUN, C., WANG, L., MOAZEN, M., LI, D., LIU, C. (2022). Mechanical Characterisation and Numerical Modelling of TPMS-Based Gyroid and Diamond Ti6Al4V Scaffolds for Bone Implants: An Integrated Approach for Translational Consideration. In: *Bioengineering (Basel)*, Vol. 9, No. 10, Article 504. MDPI, Switzerland. ISSN 2306-5354.
- [15] GADO, M., ALKETAN, O., AZIZ, M., ABU AL-RUB, R., OOKAWARA, S. (2024). Triply Periodic Minimal Surface Structures: Design, Fabrication, 3D Printing Techniques, State-of-the-Art Studies, and Prospective Thermal Applications for Efficient Energy Utilization. In: *Energy Technology*, Vol. 12, No. 5, Article 2400177. Wiley-VCH, Germany. ISSN 2194-4288.
- [16] FENG, J., FAN, J., YAO, X. (2022). Triply periodic minimal surface (TPMS) porous structures: From multi-scale design, precise additive manufacturing to multidisciplinary applications. In: *International Journal of Extreme Manufacturing*, Vol. 4, No. 3, Article 032004. IOP Publishing, UK. ISSN 2631-7990.
- [17] DOWNING, D., MEDVEDEV, A. E., TINO, R., JONES, A., MACONACHIE, T., BRANDT, M., LEARY, M. (2025). Evaluation of mechanical properties and energy absorption of Ti-6Al-4V gyroid structures produced by PBF-LB. In: *Progress in Additive Manufacturing*, Vol. 10, No. 11, pp. 9249 – 9270. Springer, Switzerland. ISSN 2363-9512.
- [18] FOUISOVÁ, M., VOJTĚCH, D., KUBÁSEK, J., JABLONSKÁ, E., FOJT, J. (2017). Promising characteristics of gradient porosity Ti-6Al-4V alloy prepared by SLM process. In: *Journal of the Mechanical Behavior of Biomedical Materials*, Vol. 69, pp. 368 – 376. Elsevier, Netherlands. ISSN 1751-6161.
- [19] ALJABERI, M. H. K., AGHDAM, M. M., GOUDARZI, T., AL-WAILY, M. (2024). Compressive Behavior of Novel Additively Manufactured Ti-6Al-4V Lattice Structures: Experimental and Numerical Studies. In: *Materials (Basel)*, Vol. 17, No. 15, Article 3691. MDPI, Switzerland. ISSN 1996-1944.
- [20] BARTOLOMEU, F., GASIK, M., SILVA, F. S., MIRANDA, G. (2022). Mechanical Properties of Ti6Al4V Fabricated by Laser Powder Bed Fusion: A Review Focused on the Processing and Microstructural Parameters Influence on the Final Properties. In: *Metals (Basel)*, Vol. 12, No. 6, Article 986. MDPI, Switzerland. ISSN 2075-4701.
- [21] VILARÓ, T., COLIN, C., BARTOUT, J.-D. (2011). As-fabricated and heat-treated microstructures of Ti-6Al-4V processed by selective laser melting. In: *Metallurgical and Materials Transactions A*, Vol. 42, No. 10, pp. 3190 – 3199. Springer, Germany. ISSN 1073-5623.
- [22] TIMERCAN, A., SHEREMET'YEV, V., BRAILOVSKI, V. (2021). Mechanical properties and fluid permeability of gyroid and diamond lattice structures for intervertebral devices: Functional requirements and comparative analysis. In: *Science and Technology of Advanced Materials*, Vol. 22, No. 1, pp. 285 – 300. Taylor & Francis, UK. ISSN 1468-6996.

- [23] SUN, Y., WANG, Y., DONG, B., ZHANG, S., LI, J., XU, L., LI, D., YANG, Q. (2025). Understanding the relationship between pore structure and properties of triply periodic minimal surface bone scaffolds. In: *Journal of Materials Science: Materials in Medicine*, Vol. 36, No. 1, Article 6. Springer, Germany. ISSN 0957-4530.
- [24] GE, J., HUANG, J., LEI, Y., O'REILLY, P., AHMED, M., ZHANG, C., YAN, X., YIN, S. (2020). Microstructural features and compressive properties of SLM Ti6Al4V lattice structures. In: *Surface and Coatings Technology*, Vol. 403, Article 126419. Elsevier, Netherlands. ISSN 0257-8972.
- [25] SICHANI, H. R., ATAPOUR, M., ASHRAFIZADEH, F., GALATI, M., SABOORI, A. (2024). Mechanical, electrochemical and permeability behaviour of Ti6Al-4V scaffolds fabricated by electron beam powder bed fusion for orthopedic implant applications: The role of cell type and cell size. In: *Journal of Materials Research and Technology*, Vol. 28, pp. 3240 – 3257. Elsevier, Netherlands. ISSN 2238-7854.
- [26] HUDÁK, R., SCHNITZER, M., KRÁLOVÁ, Z. O., GOREJOVÁ, R., MITRÍK, L., RAJČUKOVÁ, V., TÓTH, T., KOVAČEVIĆ, M., RIZNIČ, M., ORINA KOVÁ, R., ŽIVČÁK, J. (2021). Additive Manufacturing of Porous Ti6Al4V Alloy: Geometry Analysis and Mechanical Properties Testing. In: *Applied Sciences (Basel)*, Vol. 11, No. 6, Article 2611. MDPI, Switzerland. ISSN 2076-3417.
- [27] KOJU, N., NIRLA, S., FOTOVVATI, B. (2022). Additively Manufactured Porous Ti-6Al-4V for Bone Implants: A Review. In: *Metals (Basel)*, Vol. 12, No. 3, Article 441. MDPI, Switzerland. ISSN 2075-4701.
- [28] LI, S. J., XU, Q. S., WANG, Z., HOU, W. T., HAO, Y. L., YANG, R., MURR, L. E. (2014). Influence of cell shape on mechanical properties of Ti-6Al-4V meshes fabricated by electron beam melting method. In: *Acta Biomaterialia*, Vol. 10, No. 10, pp. 4537 – 4547. Elsevier, Netherlands. ISSN 1742-7061.
- [29] ZHAO, S., LI, S. J., HOU, W. T., HAO, Y. L., YANG, R., MISRA, R. D. K. (2016). The influence of cell morphology on the compressive fatigue behavior of Ti-6Al-4V meshes fabricated by electron beam melting. In: *Journal of the Mechanical Behavior of Biomedical Materials*, Vol. 59, pp. 251 – 264. Elsevier, Netherlands. ISSN 1751-6161.
- [30] LIU, F., MAO, Z., ZHANG, P., ZHANG, D., JIANG, J., MA, Z. (2018). Functionally graded porous scaffolds in multiple patterns: New design method, physical and mechanical properties. In: *Materials & Design*, Vol. 160, pp. 849 – 860. Elsevier, Netherlands. ISSN 0264-1275.
- [31] BANDYOPADHYAY, A., MITRA, I., AVILA, J. D., UPADHYAYULA, M., BOSE, S. (2023). Porous metal implants: Processing, properties, and challenges. In: *International Journal of Extreme Manufacturing*, Vol. 5, No. 3, Article 032014. IOP Publishing, UK. ISSN 2631-7990.
- [32] MAHMUD, A., HUYNH, T., ZHOU, L., HYER, H., MEHTA, A., IMHOLTE, D. D., WOOLSTENHULME, N. E., WACHS, D. M., SOHN, Y. (2021). Mechanical Behavior Assessment of Ti-6Al-4V ELI Alloy Produced by Laser Powder Bed Fusion. In: *Metals (Basel)*, Vol. 11, No. 4, Article 626. MDPI, Switzerland. ISSN 2075-4701.
- [33] LI, X., WANG, C., ZHANG, W., LI, Y. (2009). Properties of a porous Ti-6Al-4V implant with a low stiffness for biomedical application. In: *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine*, Vol. 223, No. 2, pp. 173 – 178. SAGE Publications, London. ISSN 0954-4119.
- [34] ANATOLIE, T., SHEREMET'YEV, V., BRAILOVSKI, V. (2021). Mechanical properties and fluid permeability of gyroid and diamond lattice structures for intervertebral devices: Functional requirements and comparative analysis. In: *Science and Technology of Advanced Materials*, Vol. 22, pp. 735 – 748. Taylor & Francis, UK. ISSN 1468-6996.