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Abstract

Printed highly bio-tolerant Ti/Nb/Ta alloys - Combination of elasticity and strength

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Feldfunktion geändert

Titanium alloys are state-of-the art implant materials featuring good biocompatibility. Unfortunately, they have a high Young's modulus of 108 –115 GPa, which contrasts with the better elasticity of the human bones, having a Young's modulus < 25 GPa. This mismatch increases the risk of stress-shielding and can lead to of implant rejection [1,2]. In addition, the use of only non-toxic and non-allergenic elements is beneficial for the osseointegration of the implant. Ti/Nb/Ta (TNT) alloys, consisting exclusively of biocompatible elements, offer the favorable combination of high elasticity (Young's modulus: 49-76 GPa) and strength (UTS: 649-802 MPa) and thus represent suitable alternatives.

The present work focuses on the development of highly bio-tolerant TNT alloys and their additive manufacturing (AM) and gives an overview of their performance in mechanical, in-vitro and in-vivo tests. Extensive studies on LB-PBF parameters confirmed the excellent processability of TNT alloy powders resulting in optical densities of the 3D-manufactured parts > 99,97% [3]. Compression and tensile tests of the printed material demonstrated high elasticity and ductility of the TNT samples combined with appropriate strength in 0°, 45° or 90° build orientations [4].

For application in spinal implants, static and dynamic tests were conducted according to ASTM F2077, comparing hipped Ti-6Al-4V (Ti64) cages with as-printed TNT cages. A post-process thermal treatment of the TNT parts was not required, since they possessed full density and excellent ductility with no signs for internal stresses.

Biocompatibility studies were conducted in-vitro using standard disc specimens elaborating the interaction of TNT and Ti64 with human cells. TNT alloys thereby proved excellent and superior biocompatibility [4]. The results of the in-vitro tests were confirmed by sheep trials with additively manufactured implants using the same lattice structure [5]. The significant higher bone ingrowth of TNT printed implants (i.e. Ti-35Nb-6Ta) compared to Ti64 confirmed the superior biocompatibility of this material. Histopathologically, all implants demonstrated good local tolerance, with no evidence of local irritation or safety concerns.

Author's statement

Conflict of interest: M. Stenzel and M. Weinmann are employees of Taniobis GmbH; O. Morgan and N. Kuek are employees of Alloyed Ltd. Ethical approval: The UK Home Office Project License (PPL: PP8459576) governing this study directly specified the regulated procedures required on this project, severity limits and possible adverse effects on the animals. The regulations conform to the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (Strasbourg, Council of Europe), and achieves the standard of care required by the US Department of Health and Human Services Guide for the Care and the Use of Laboratory Animals.

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