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Abstract

Porous zinc structures using molten metal jetting additive manufacturing

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The demand for bioresorbable, patient-specific implants has increased interest in additive manufacturing techniques that can process biodegradable metals. This work explores the use of Molten Metal Jetting (MMJ) for fabricating porous zinc scaffolds, aiming to develop customized degradable structures for biomedical applications. Zinc is a promising candidate due to its moderate degradation rate and essential biological relevance, yet its use with MMJ remains unexplored [1].

Previous studies have employed techniques such as powder bed fusion and wire-fed electron beam [2]. Most of these approaches rely on pre-designed porous architectures generated by computational modeling. In contrast, MMJ enables porosity control through the manipulation of droplet dynamics. In this study, a magnetohydrodynamic (MHD) actuation system is used to eject molten zinc droplets toward a moving substrate, facilitating the formation of complex three-dimensional (3D) structures [3]. Initial results indicate that low firing frequencies (50 Hz-100 Hz) influence pore size up to 20%, while increasing drop spacing influences porosity percentage by approximately 53%.

Printed structures were characterized using micro-computed tomography (µCT). Porosity values ranged from 3.5% to 12%, and pore size measured between 95 and 650 µm. These values meet the standards for natural bone in its cortical and trabecular pore sizes, and porosity percentage [4]. In vitro degradation testing was conducted in cell culture media over 72 hours using a dissolution machine. During this period, the pH decreased from 7.4 to 6.2 ± 0.3, and zinc ion release reached 5.6 ± 0.4 mg/L. This corresponds to a preliminary degradation rate of approximately 0.19 mm/year, which falls within the range considered suitable for supporting tissue regeneration in vivo [5]. SEM and EDS analyses confirmed the presence of localized corrosion and the formation of ZnO-rich surface layers.

These initial findings demonstrate that MMJ additive manufacturing can enable the fabrication of zinc scaffolds with tunable porosity. Future work will focus on optimizing jetting parameters to refine scaffold architecture and conducting a long-term degradation study. Zinc specimens with varying porous geometries will be evaluated to determine the influence of intrinsic porosity on the degradation rate.

Author's statement

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