Transactions on Additive Manufacturing Meets Medicine
Trans. AMMM, 2026, Vol. 8, No 1, Suppl. 1, Article ID 2764, 1 Page

Abstract

3D-printing of an electroactive niobate-based ceramic for potential bone-tissue regeneration: Fabrication and piezoelectric response

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In large bone defects, advanced scaffold designs are imperative to support osteoconductivity, osteoinductivity, and vascularized bone regeneration. 3D-printed ceramic implants exhibit high structural and mechanical similarity to native bone tissue. Today, lithography-based ceramic manufacturing (LCM) is widely used for 3D printing of ceramic scaffolds. The potential advantages of LCM technology include the development of customized ceramic structures with high resolution and favorable mechanical properties. However, providing biological activity remains a major challenge.

Bone is known to exhibit piezoelectric behavior, suggesting that biomaterials with similar properties are desirable to improve the regenerative outcomes. Niobate (Nb)-based ceramics such as potassium sodium niobate (KNN) and lithium-substituted KNN (LNKN) have demonstrated efficient piezoelectric properties for orthopedic applications. Their Nb, potassium, and sodium contents have been associated with anti-inflammatory and osteogenic responses [1]. Additionally, the Li content of the LNKN is expected to further enhance the quality and stability of the piezoelectric response and improve the biomineralization and osteogenic differentiation of the bone cells [2, 3].

This study is pioneering research on the 3D printing of LNKN structures for bone tissue regeneration using DLP technology. At the first step, we optimized LNKN loading of the slurry by examining the rheological features. Then, a series of simple to complex structures, including discs, cuboids, and benchmarks, have been printed to adjust the cure depth and the energy exposure. Different sintering times and temperatures were, then, evaluated to obtain optimal phase purity, mechanical strength, and structural features. Finally, the collected data were utilized to develop high-precision gyroid structures. We demonstrated that LNKN-based gyroids can achieve the desired porosity, mechanical strength, and piezoelectricity, highlighting their potential as suitable biomaterials for critical-sized bone defect repair.

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. Research funding: This study is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)—SFB 1270/3,4-299150580.

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DOI: 10.18416/AMMM.2026.26062764