A Hierarchical Biomimetic Coating Mitigates Bending-Accelerated Corrosion and Enhances Osteogenesis of Biodegradable Zn Membranes for Guided Bone Regeneration

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Abstract:
Repairing complex alveolar bone defects via guided bone regeneration remains challenging, requiring membranes with robust mechanics, structural stability, and controlled degradation. We engineered a hierarchical biomimetic silk fibroin/laponite (SF/LAP) coating on Zn membranes to enhance mechanical performance, achieve bending-adaptive degradation, and promote osteogenesis. The coating's laminated "brick-and-mortar" architecture resists bending-induced cracking and creates tortuous ion-diffusion pathways, imparting bending-resistant corrosion resistance. It also modulates the osteogenic microenvironment by suppressing burst Zn^{2+} release while enabling sustained release of osteogenic Li^{+} and Si^{4+} ions from LAP. The optimized coating with 10 wt% LAP (SL10) reduced the in vivo degradation rate under bending to 15.03 $\mu m \cdot yr^{-1}$, far lower than bare Zn and SF-coated membranes. In a rat cranial defect model, SL10-coated membranes significantly enhanced bone regeneration and defect closure without systemic toxicity. This hierarchical biomimetic coating strategy simultaneously confers stress-adaptive degradation control and pro-osteogenic functionality, offering a translatable approach for biodegradable Zn-based membranes in guided bone regeneration and other load-bearing orthopedic applications.