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THEME Inguinal hernia

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Piezoelectric-Driven 'Muscle Charging' to Promote Regeneration and Repair of Abdominal Wall Defects

Aim: Currently, abdominal wall defect repair primarily depends on implant materials, yet no single material satisfies all optimal criteria. Thus, the development of biomimetic composites that promote endogenous tissue regeneration is essential. The high sensitivity of muscle-tendon tissues to electrical stimulation, coupled with the ability of piezoelectric materials to convert mechanical forces into electrical fields, offers promising potential for enhancing repair.

Material & Methods: Electrospinning technology was used to fabricate chitin-based electrospun piezoelectric scaffolds with aligned structures. The physicochemical properties of the scaffolds were first evaluated, followed by in vitro cell experiments to assess their biological functions, including the promotion of muscle stem cell proliferation and differentiation. High-throughput sequencing was employed to investigate the potential mechanisms. Finally, in vivo animal experiments were conducted to explore the relationship between piezoelectric catalysis and abdominal wall defect regeneration.

Results: The results showed that chitin electrospun scaffolds with aligned structures exhibited excellent piezoelectric effects, and the microcurrent generated by mechanical deformation enhanced the expression of genes and proteins related to muscle stem cell regeneration and differentiation. Sequencing results indicated the enrichment of calcium signaling pathways. Further in vitro experiments confirmed that the piezoelectric material upregulated the Ca^{2+}-CaN-NFAT signaling pathway, enhancing the expression of muscle differentiation-related genes such as CCN2 and MyoD. In vivo experiments further validated the scaffolds' ability to promote abdominal wall defect regeneration.

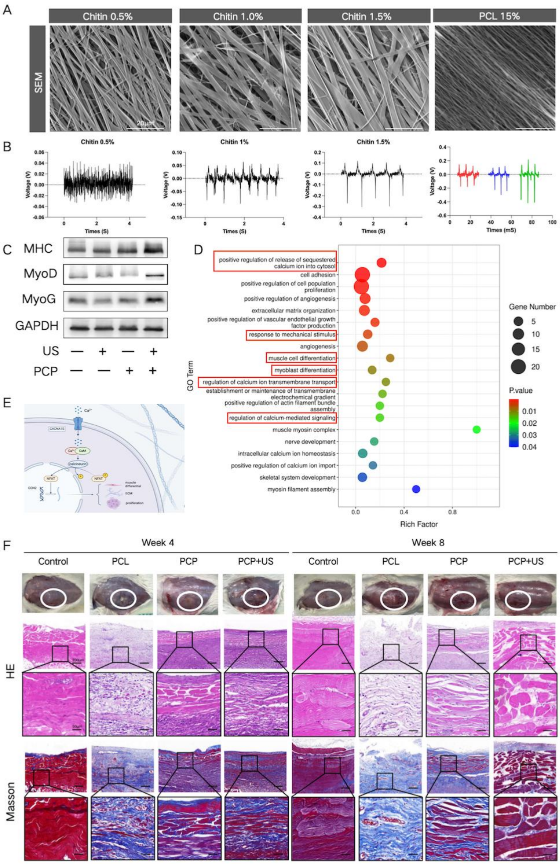

Figure. (A) SEM images of electrospun scaffolds, (B) Piezoelectric properties of the electrospun scaffolds, (C) Expression of muscle differentiation-related proteins, (D) Gene Ontology (GO) enrichment analysis of sequencing data, (E) Potential mechanistic pathways, (F) In vivo rat experiments.

Conclusions: Chitin-based electrospun piezoelectric scaffolds with aligned structures effectively promote regeneration and repair of abdominal wall defects through piezoelectric catalysis.