Multifunctional porous scaffold combining bioactivity and electrical features for bone tissue regeneration

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Bone defects remain a major healthcare challenge, as grafts and implants face complications, such as donor morbidity, immune rejection and lack of bioactivity [1]. To overcome these limitations, bone tissue engineering proposes multifunctional scaffolds that mimic both the structural and electrophysiological environment of the bone [1]. This work aims the development of a chitosan-based scaffold reinforced with nano-hydroxyapatite, carbon-sepiolite (CARSEP) and zinc oxide (ZnO) nanoparticles, aiming to combine biocompatibility, osteoconductivity, conductivity, piezoelectric stimulation and antibacterial activity.

Three scaffold formulations were prepared: 1) Chitosan (3.5% w/v), nHA (60:40 w/w with Ch) and CARSEP (0.50% w/v) suspension frozen and freeze-dried (named “Control"), 2) obtained using similar formulation of the Control sample but containing ZnO nanoparticles (3% w/w) added to chitosan solution for uniform dispersion (called “A1”), 3) Control scaffold impregnated with a ZnO suspension (3% w/v) under voltage, then refrozen and freeze-dried to enhance nanoparticle alignment and integration (here in “A2”).

The scaffolds were characterized to evaluate their potential for bone regeneration. The XRD shows signals representative of crystalline nHA within an amorphous chitosan matrix and ZnO characteristic peaks appears only in A1 and A2 scaffolds, with A2 displaying a slight increase of the ratio I(002)/I(101). Relatively to the structure–property response: A1 shows higher porosity (79% vs Control 67% and A2 70%), the highest compressive strength (≈ 0.20 MPa) and the most stable degradation. All groups present slim, centered P-E loops ($|Pr| \leq 1.6\times10^{-5}$ μC/cm^{-2}; Pmax ≈ $9.45/9.49\times10^{-4}$), confirming similar lossy, non-ferroelectric dielectrics. Under shaker loading, voltage was detected on only one electrode in A1 and A2, so bulk piezoelectricity cannot be claimed (likely interfacial charging). *In vitro* tests were performed. Cell viability of Saos-2 cells was enhanced in A1, showing a stable growth from day 3 to 14.

In conclusion, it was developed multiphasic chitosan/nHA-CARSEP-ZnO scaffolds integrating bioactivity, conductivity and dielectricity to enable adjustable electromechanical signals for bone repair. The A1 shows the best porosity-strength-viability balance, highlighting a practical path toward the next generation of bone tissue engineering.

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References

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