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Commentary

Bioinspired nanocomposites for simultaneous antimicrobial action and tissue regeneration

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ABSTRACT

Bioinspired nanocomposites are a promising approach in biomedical engineering, combining antimicrobial properties and tissue regeneration capabilities. Mimicking natural extracellular matrices, they create an ideal environment for cell adhesion, growth, and differentiation, which accelerates tissue repair.

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Bioinspired nanocomposites often incorporate nanomaterials, including silver nanoparticles, zinc oxide, and antimicrobial peptides. These components break down bacterial membranes, generate reactive oxygen species, or interfere with microbial metabolic processes, providing broad-spectrum antimicrobial effects even against drug-resistant pathogens [1-3]. For example, zinc oxide/silver (ZnO/Ag) nanocomposites and peptide-functionalized nanomaterials demonstrated effective inhibition of Staphylococcus aureus and Escherichia coli, common causes of wound infections [4].

These nanocomposites are designed to imitate the extracellular matrix (ECM), supporting cell adhesion, proliferation, and differentiation, which are essential for tissue repair. Incorporating biopolymers like chitosan, gelatin, collagen, and alginate enhances biocompatibility and creates a scaffold for new tissue growth [1, 5-7]. Some systems, such as silica-based hydrogel nanocomposites, promote angiogenesis the development of new blood vessels and accelerate wound healing by increasing the activity of endothelial progenitor cells and encouraging growth factor expression [8].

The design of these materials is inspired by natural systems, either by mimicking the structure and function of biological tissues or by using biological synthesis methods. Recent advances have shown that these materials serve as barriers to microbes and promote bone and other tissue-specific differentiation, supporting tissue regeneration both in vitro and in vivo. Their combined antimicrobial and regenerative capabilities make bioinspired nanocomposites promising next-generation biomaterials for regenerative medicine [2, 9]. This approach results in materials that are more compatible with human tissues and can provide multiple functionalities, such as elasticity, mechanical strength, and controlled release of therapeutic agents [2].

Bioinspired nanocomposites are utilized in advanced wound dressings that not only guard against infection but also foster an ideal environment for tissue regeneration. Incorporating bioactive nanomaterials, such as antimicrobial peptides, metal oxides, or nano-silicates, gives these scaffolds strong antibacterial properties, which combat both Gram-positive and Gram-negative bacteria, thereby reducing the risk of implant infections. They also maintain high biocompatibility and mechanical strength for various tissue engineering applications, from bone to soft tissue [10, 11]. These dressings can be designed for the controlled release of antimicrobial agents and growth factors, further improving healing [12]. In bone regeneration, nanocomposites with osteoinductive and antimicrobial properties offer scaffolds that support bone cell growth while preventing implant-related infections [4, 13]. For skin repair, bionanocomposites made from natural polymers can be formed into films, hydrogels, or 3D-printed matrices that closely mimic native tissue structures [6].

Generally, Bioinspired nanocomposites present a promising frontier for biomedical implants and regenerative medicine, providing integrated solutions for infection control and tissue regeneration through innovative designs inspired by nature.

Author Contributions

Tengiz Tkebuchava: Conceptualization, Writing – original draft, Writing – review & editing. **Masoumeh Khamehchi:** Writing – original draft, Writing – review & editing. All authors read and approved the final version of manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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No data is available.

Ethical issues

The authors confirm full adherence to all ethical guidelines, including the prevention of plagiarism, data fabrication, and double publication.

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