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Letters to Editor

Innovative hybrid platforms for overcoming antimicrobial resistance in wound healing: The synergy of mesoporous nanostructures and antimicrobial peptides

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Multidrug-resistant (MDR) infections pose a growing global health crisis, threatening the efficacy of standard antibiotic therapy. In 2019 alone, bacterial antimicrobial resistance (AMR) was directly responsible for an estimated 1.27 million deaths worldwide [1]. Infected wounds, particularly those of a chronic or burn-related nature, often serve as reservoirs for resistant pathogens, thereby complicating treatment outcomes and delaying tissue regeneration. These antimicrobial resistance challenges in wound healing have been widely reported in recent studies, highlighting the urgent need for advanced antimicrobial strategies [2]. Nanotechnology has shown great promise in addressing the growing concern of antibiotic resistance. The adjustable characteristics of nanomaterials, particularly their surface functionalities, create design opportunities that can be optimized to enhance therapeutic impact while reducing toxicity to the host. Nanomaterials can exhibit various bactericidal mechanisms, including direct damage to the cell wall and/or membrane, the production of reactive oxygen species (ROS), the interruption of biofilm formation, the combating of intracellular bacteria, and the delivery of therapeutic agents [3].

The mesoporous nanocomposite catalyst Fe_3O_4@MCM-41 is a hybrid material composed of magnetic iron oxide nanoparticles encapsulated within a mesoporous silica matrix. This unique structure offers several advantages for use in targeted drug delivery systems, specifically in antibiotic therapy. The mesoporosity of the material enables high drug loading capacity, sustained release kinetics, and enhanced bioavailability of antibiotics. Additionally, the magnetic properties of Fe_3O_4 enable external manipulation and guidance of the catalyst to specific sites of infection by applying an external magnetic field. This precise targeting minimizes off-target effects, enhances therapeutic efficacy, and reduces systemic toxicity. Overall, the Fe_3O_4@MCM-41 nanocomposite catalyst offers a promising approach for improving the effectiveness and safety of antibiotic therapy in medical applications [4]. The attention towards antimicrobial peptides (AMPs) as innovative therapeutic molecules has grown steadily in recent times. Their versatility and ability to target a wide range of pathogens make them a promising candidate for the development of novel antimicrobial therapies.

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These peptides offer numerous benefits over traditionally used antibiotics owing to their potency, broad-spectrum efficacy, various natural sources, slow resistance development, low toxicity towards mammalian cells, and rapid killing activity. In addition, AMPs exhibit immunomodulatory, antioxidant, and anti-inflammatory properties, leading researchers to invest significant efforts in developing AMPs as marketable pharmaceuticals [5]. However, AMPs face challenges in clinical use, as host or bacterial proteases can degrade them, and sometimes exhibit off-target toxicity or poor stability. Embedding AMPs in nanocarriers can address these issues.

Encapsulation of AMPs in mesoporous nanocomposites protects them from enzymatic degradation in biological environments, thereby enhancing their activity. Controlled release from the nanocomposite ensures that therapeutic concentrations are maintained at the site of infection, thereby minimizing the need for frequent dosing and reducing off-target effects [6,7]. Furthermore, the magnetic component allows for the use of magnetic targeting and hyperthermia, which can further enhance antimicrobial activity by increasing local temperature and disrupting biofilms, while minimizing damage to surrounding healthy tissues [8].

In summary, mesoporous nanocomposites, especially those with magnetic cores, and antimicrobial peptides are two promising frontiers in the fight against MDR infections. Their combination can yield synergistic antimicrobial effects, helping to address problems encountered in the post-antibiotic era. However, to realize the anticipated capabilities of these materials, a significant amount of work and study is required, taking into account environmentally friendly manufacturing techniques, deliberate material choices, and comprehensive assessments of the body's long-term reactions.

Authors' contributions

HS: Conceptualization, Project administration, Supervision, Writing original draft, and editing. AH, AA: Data collection, writing original draft, and editing. MG: Validation, writing original draft, and editing. All authors read and approved the final version of the manuscript.

Conflict of interest

No potential conflict of interest was reported by the authors.

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