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Research Article

Enhancement of the Antibacterial Efficiency of Silver Nanoparticles against Gram-Positive and Gram-Negative Bacteria Using Blue Laser Light

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Silver nanoparticles (Ag-NPs) possess excellent antibacterial properties and are considered to be an alternative material for treating antibiotic-resistant bacteria. The present study was aimed at enhancing the antibacterial efficiency of Ag-NPs using visible laser light against *Escherichia coli* and *Staphylococcus aureus in vitro*. Four concentrations of Ag-NPs (12.5, 25, 50, and 100 μg/ml), synthesized by the chemical reduction method, were utilized to conduct the antibacterial activity of prepared Ag-NPs. The antibacterial efficiencies of photoactivated Ag-NPs against both bacteria were determined by survival assay after exposure to laser irradiation. The mechanism of interactions between Ag-NPs and the bacterial cell membranes was then evaluated via scanning electron microscopy (SEM) and reactive oxygen species analysis to study the cytotoxic action of photoactivated Ag-NPs against both bacterial species. Results showed that the laser-activated Ag-NP treatment reduced the surviving population to 14% of the control in the *E. coli* population, while the survival in the *S. aureus* population was reduced to 28% of the control upon 10 min exposure time at the concentration of 50 μg/ml. However, *S. aureus* showed lower sensitivity after photoactivation compared to *E. coli*. Moreover, the effects depended on the concentration of Ag-NPs and exposure time to laser light. SEM images of treated bacterial cells indicated that substantial morphological changes occurred in cell membranes after treatment. The results suggested that Ag-NPs in the presence of visible light exhibit strong antibacterial activity which could be used to inactivate harmful and pathogenic microorganisms.

1. Introduction

Silver nanoparticles (Ag-NPs) have been used as antibacterial, antifungal, antiviral, anti-inflammatory, and anti-antiangiogenic due to their unique properties such as physical, chemical, and biological properties [1]. These previous studies demonstrated that the antibacterial activity of Ag-NPs is dependent on their size and specific surface area, with smaller particles showing the better antibacterial activities [2, 3]. This difference in efficacy based on sizes is related to their large surface area to volume ratio, which allows efficient binding with the bacterial surface. Recently, researchers have discovered how to activate the bactericidal effect of Ag-NPs using laser irradiation [4, 5], thus offering a promising development in the fight against antibacterial resistance. The size of metal particles (NPs) also correlates with their optical properties, which have been extensively studied and found to depend on their size, shape, composition, and dielectric surrounding medium [6]. These unique optical properties of metal NPs are closely associated with the localized surface plasmon resonance (LSPR) effect, in which free electrons oscillate collectively on the metal surface when irradiated with certain light energies, causing wavelength-dependent absorption and scattering [7].

Ag-NPs can potentially be engineered as drug delivery tools due to their strong interaction with light. Hence,