AN INVESTIGATION INTO THE ANTIMICROBIAL EFFECTIVENESS OF GOLD NANOPARTICLES AND LASERS AGAINST VARIOUS BACTERIAL STRAINS†

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1. Abstract

As a catalyst, AuNPs are one of many NPs that have found application in gene therapy, medical therapy, and biological diagnostic methods, as well as NPs used in gene therapy. An in vitro study was conducted to assess the effectiveness of gold nanoparticles (AuNPs) and gold nanopar-ticle–low-level-laser-combined therapy against bacterial isolates. The bacterial growth rate and medium inhibitory concentrations of AuNPs were determined at five concentrations (25, 50, 75, 100, 150, and 200 g/mL). After treatment with gold nanoparticles, bacterial growth was found to be slightly reduced. Also, gold nanoparticles were tested for their influence on Staphylococcus aureus biofilms. The amount of biofilm that can be formed was reduced by different concentra-tions of AuNPs when compared to a control without nanoparticles. A combination of low-level lasers and AuNPs produced an improved cytotoxic effect against Escherichia coli and Staphylo-coccus aureus, indicating that the combination of low-level lasers enhanced AuNPs' antibacterial activity. As a result of this work, we were able to explore the effectiveness of gold nanoparticles and the AuNP-laser-induced therapeutic approach (at different energy densities of lasers and dif-ferent concentrations of AuNPs) as antibacterial agents against some pathogenic bacterial strains with gold nanoparticles.

2. Results

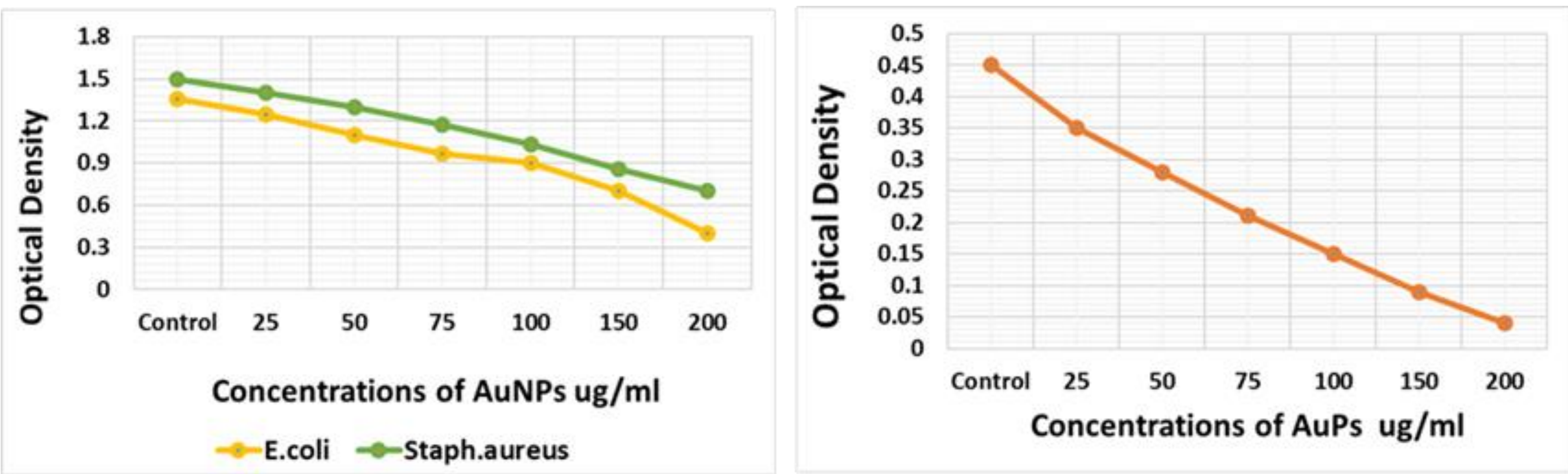

Figure 1: (a) Impact of Various AuNP Concentrations on Bacterial Isolate Growth. (b) Im-pact of Various AuNP Concentrations on the Development of Staph aureus Biofilms.

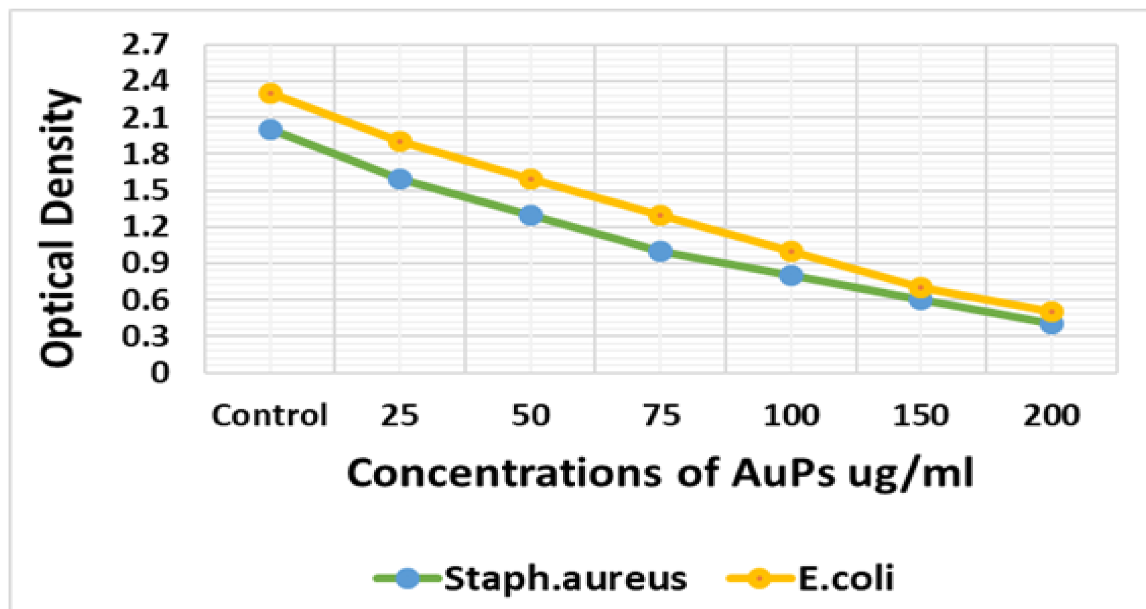

Figure 2: Bacterial Growth Response to Different AuNP Concentrations Combined with 20-Minute Laser Irradiation

2. Discussion

Since nanoparticles differ from their bulk counterparts in unique and innovative ways, nanomethods have gained international attention. Several studies have reported the anti-bacterial activity of different nanoparticles against important Gram-positive and Gram-negative pathogens, including S. aureus and E. coli [10]. However, Chatterjee et al. [24] ob-served that the growth curves of E. coli isolates showed no significant changes when ex-posed to varying concentrations of AuNPs (25, 50, 75, and 100 µg/mL). These findings suggest that gold nanoparticles, under the tested conditions, exhibit a harmless effect on E. coli growth. As a result, it can be used in biological applications where cytotoxicity is un-likely.

With MICs ranging from 20 to 40 µg/mL, AuNPs' bactericidal efficacy varies against many pathogenic types of Gram-negative bacteria, including Salmonella typhi, Pseudo-monas aeruginosa, E. coli, and Klebsiella pneumoniae. This could be because larger bac-terial cell walls slow down the pace at which these nanoparticles diffuse through them (at lower concentrations), which in turn lessens the effectiveness of gold nanoparticles as an-tibacterial agents [1]. In both Gram-positive and Gram-negative bacteria, AuNPs have been shown to cluster on and react with the cell membranes, inhibiting bacterial protein synthesis and preventing cell membrane synthesis [25]. Shi et al. [17] reported that in the absence of gold nanoparticles, bacterial biofilm formation increased rapidly within the first 12 hours. In contrast, the presence of nanoparticles suppressed this rise as early as 6 hours, with a more pronounced reduction in bacterial density observed between 6 and 12 hours. These results indicate that nanoparticles are highly effective in preventing bacterial colonization within biofilms.

Furthermore, several studies have shown that radiation absorbed by chromophores can induce molecular conformational changes, leading to the generation of free radicals and reactive oxygen species. These reactive species disrupt the structural integrity of bac-terial and fungal membranes, accounting for the bactericidal effects of laser irradiation [26]. Importantly, one study demonstrated that the antibacterial activity of AuNPs is en-hanced—by at least one-fold—when combined with laser light. This synergistic photo-thermal effect is attributed to the unique optical properties of colloidal gold nanoparticles, which exhibit a strong absorption band at 524 nm corresponding to surface plasmon res-onance (SPR) oscillations. The kinetic energy of AuNPs rises when exposed to a resonant laser emission line [27].

The resulting photothermal action can be used to quickly and efficiently destroy bac-terial cells. The duration of the bacterial cells' exposure determines how well AuNPs work as antibacterials when enhanced by lasers. A prior study that examined the antibacterial impact of AuNPs-laser and found that photothermal degeneration enhanced this effect in a combined manner, confirmed these findings. AuNPs-laser causes a rapid loss of bacte-rial cell membrane integrity [28].

3. Conclusion

It has been discovered that AuNPs are a crucial and successful advancement in med-ication delivery. Additionally, when compared to antibiotics, they function as a non-toxic and non-dangerous antimicrobial agent, indicating their functional effectiveness. Because the low level laser boosts the antibacterial action of AuNPs by at least one fold, this study concludes that AuNPs combined with laser exposure could be used as restricted effective antibacterials.