



## The Potential of Silver Nanoparticles as Antibacterial and Antibiofilm Agents in Bacteria that Cause Periodontal Disease — A Literature Review

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### Abstract

**Background:** Periodontal disease is a chronic inflammatory disease that is closely related to the activity of biofilm-forming pathogenic bacteria, such as *Porphyromonas gingivalis*, *Tannerella forsythia*, and *Treponema denticola*. Conventional therapies using antibiotics often face limitations in the form of bacterial resistance and side effects. Silver nanoparticles (AgNPs) are reported to have effective antibacterial and antibiofilm activity against a wide range of pathogenic microorganisms. **Objective:** This literature review aims to examine the potential of silver nanoparticles as antibacterial agents and antibiotics against bacteria that cause periodontal disease. **Methods:** Literature search was conducted through PubMed, Scopus, and Google Scholar scientific databases with relevant keywords. **Results:** The results of the study showed that AgNPs are able to inhibit the growth of periodontal bacteria through cell membrane damage, increased membrane permeability, disruption of intracellular metabolic processes, and inhibition of biofilm formation and maturation. Based on these findings, silver nanoparticles have the potential to be developed as an alternative or adjuvant therapy in the control of periodontal infections. **Conclusion:** However, further research is needed regarding safety and its clinical application.

### Keywords:

Silver nanoparticles;  
Antibacterial; Antibiofilm;  
Periodontal disease; Periodontal  
bacteria

## INTRODUCTION

Periodontal disease is one of the most common and complex oral health problems, characterized by inflammation of the tooth's support tissue due to infection with pathogenic microorganisms (Araújo, 2023; Barik et al., 2025). Gram-negative anaerobic bacteria, such as *Porphyromonas gingivalis*, *Tannerella forsythia*, and *Treponema denticola* Known as "red complex bacteria," it has an important role in the pathogenesis of periodontitis (Casals et al., 2025). The microbial activity triggers an excessive immune response, leading to the destruction of periodontal tissue, resorption of alveolar bones, and eventually tooth loss (Chegini et al., 2024; Cui et al., 2025).

Treatment of periodontal disease today includes mechanical therapies such as scaling and root planing, accompanied by the use of topical or systemic antimicrobial agents (Elsayed et al., 2020). However, the emergence of bacterial resistance to antibiotics as well as the limitation of drug penetration into the biofilm are major challenges in the effectiveness of conventional therapies (Hosny et al., 2025; Khalid et al., 2024; Khan et al., 2021). Therefore, an alternative approach is needed that is able to efficiently suppress microbial activity without causing significant side effects.

One of the innovations that has attracted attention in the field of dentistry is the use of metal nanoparticles, especially silver nanoparticles (AgNPs), which have strong antibacterial and antibiofilm properties (Mohanta & Mohanta, 2020; Muteeb et al., 2023; Nasiri et al., 2023). Silver nanoparticles work through a variety of mechanisms, including bacterial cell membrane

damage, the production of reactive free radicals (ROS), as well as interactions with intracellular DNA and proteins that inhibit cell replication and metabolism (Pachghare et al., 2025; Radu et al., 2024; Rebersak & Schara, 2025). Their very small size allows AgNPs to penetrate the biofilm and reach the bacteria in the deepest layers, thereby increasing the effectiveness of antimicrobials.

In the context of periodontal disease, the application of AgNPs shows great potential to inhibit the growth and colonization of pathogenic bacteria, both through direct application to the periodontal pouch and through restorative materials and modified dental devices. This literature review aims to explore the mechanism of action, effectiveness, and potential clinical applications of silver nanoparticles in inhibiting the microbial activity that causes periodontal disease (Yin et al., 2025; Zi et al., 2025).

Among emerging nanotherapeutic agents, silver nanoparticles (AgNPs) have attracted substantial attention because of their broad-spectrum antibacterial activity, antibiofilm properties, and versatile physicochemical behaviour. Their small size and large surface-area-to-volume ratio enable intimate interaction with bacterial cell walls, while their antimicrobial action has been linked to membrane disruption, generation of reactive oxygen species, protein dysfunction, and interference with DNA replication (Kulanthaivel & Mishra, 2021; Modi et al., 2023). In addition, AgNPs may penetrate deeper biofilm layers more effectively than many conventional agents, making them particularly attractive for managing periodontal pathogens embedded in mature subgingival biofilms

Recent studies indexed in PubMed and related scholarly databases provide growing evidence for this potential. Zhang and Lo reported that polymer-functionalized AgNPs, especially PVP-coated formulations, enhanced antibacterial and antibiofilm activity against *P. gingivalis* while maintaining cellular compatibility at the minimum inhibitory concentration level. Likewise, Hedayatipناه and colleagues showed that propolis-mediated green-synthesized AgNPs significantly reduced *P. gingivalis* biofilm formation in a dose-dependent manner, indicating that both nanoparticle engineering and synthesis method can meaningfully affect antimicrobial performance. These findings suggest that AgNP efficacy is not uniform but depends on formulation characteristics that deserve systematic analysis.

Other recent investigations have further expanded the evidence base by comparing AgNPs with established periodontal antimicrobials. Krishnappan et al. found that neem-infused silver nanoparticles demonstrated stronger antibacterial activity than chlorhexidine against red-complex pathogens in selected *in vitro* measurements, while Kadam et al. reported that AgNP gel showed clinical and microbiological effects comparable to tetracycline gel as an adjunctive therapy in chronic periodontitis patients. In your uploaded manuscript, these studies are already listed among the core evidence base, which is useful because they indicate that AgNPs may have translational relevance not only in laboratory models but also in adjunctive periodontal treatment settings

Despite these promising findings, the current literature still shows several important gaps. First, many studies remain *in vitro* and focus on single strains rather than multispecies biofilms that better represent the periodontal ecosystem. Second, study designs vary considerably in nanoparticle size, coating, synthesis route, concentration, comparator agents, and outcome measures, making direct comparison difficult. Third, although antibacterial and antibiofilm

effects are increasingly reported, issues of cytotoxicity, long-term biocompatibility, dosage standardization, and clinical delivery systems remain insufficiently resolved. This means that the evidence is encouraging but still fragmented, and a focused literature review is needed to synthesize what is already known while clarifying what has not yet been adequately addressed.

The urgency of this research therefore lies in the need to bridge the gap between laboratory promise and clinically meaningful periodontal innovation. As the global burden of severe periodontitis continues to affect over one billion people and conventional therapies face persistent challenges related to biofilm resistance and antimicrobial limitations, evaluating AgNPs as an alternative or adjunctive strategy is both scientifically relevant and clinically important. A review focused specifically on periodontal pathogens can help determine whether AgNP-based interventions are merely experimental antimicrobial materials or whether they represent a realistic pathway toward next-generation periodontal therapy.

The novelty of this study lies in its integrative focus on silver nanoparticles specifically as both antibacterial and antibiofilm agents against bacteria implicated in periodontal disease, rather than discussing nanotechnology in dentistry in general. Accordingly, this research aims to analyze the mechanisms of action, summarize the most relevant recent findings, identify the research gap, and evaluate the potential clinical applicability of AgNPs in controlling periodontal pathogens. The expected contribution of the study is to provide a clearer conceptual and evidence-based foundation for future biomaterial development, translational testing, and clinical periodontal innovation. In practical terms, the study is expected to benefit researchers by mapping unresolved questions, assist clinicians by highlighting promising adjunctive therapies, and support the development of safer and more effective antimicrobial approaches for managing periodontitis.

## RESEARCH METHOD

This study was a *narrative literature review* that aims to review and synthesize scientific findings related to the potential of silver nanoparticles (AgNPs) as antibacterial agents and antibiofilms against bacteria that cause periodontal disease. Literature searches were conducted systematically on the electronic databases PubMed, ScienceDirect, and Google Scholar. Keywords used include: "*silver nanoparticles*" AND "*periodontal disease*", "*silver nanoparticles*" AND "*antibacterial*", as well as "*silver nanoparticles*" AND "*periodontal bacteria*". The search process is limited to articles published in the 2019–2024 range. Inclusion criteria include *original research articles*, in English, available in full *text*, discussing the antibacterial and/or antibiofilm activity of silver nanoparticles against periodontal bacteria or oral biofilms, and using *in vitro*, *in vivo*, or clinical trial designs.

Exclusion criteria include articles in the form of reviews, systematic reviews, meta-analysis, articles that are not relevant to the topic of periodontal disease, and studies that do not specifically evaluate the antibacterial or antibiofilm activity of silver nanoparticles. Some articles were issued based on certain considerations, namely articles that did not meet the inclusion criteria and did not specifically address the application of the addition of silver nanoparticles as an antimicrobial agent. After the selection and review process, as many as 9 articles that met the criteria were obtained.

## RESULTS AND DISCUSSION

After conducting a literature search and adjusting to the inclusion and exclusion criteria, as many as 10 articles that met these criteria were obtained. Table 1 presents a summary of the findings from the selected studies.

**Table 1. Summary of Previous Studies on the Antibacterial and Antibiofilm Activity of Silver Nanoparticles Against Periodontal Bacteria**

Author	Title	Study Design	Bacteria	Results
PA Hernández-Venegas, et al. (2023)	“Bactericidal Activity of Silver Nanoparticles on Oral Biofilms Related to Patients with and without Periodontal Disease”	A total of 60 clinical biofilms were collected: 30 from patients with periodontitis (PD) and 30 from healthy patients (without PD). AgNP is synthesized in two different average sizes: $\sim 5.4 \pm 1.3$ nm and $\sim 17.5 \pm 3.4$ nm.	<i>Porphyromonas gingivalis</i> , <i>Treponema denticola</i> , dan <i>Tannerella forsythia</i>	AgNP exhibits strong bactericidal activity against clinical oral biofilms
H.N. Faris et al. (2024)	“The Effect of Silver Nanoparticles Manufactured by Lactobacillus Bacteria on Some Bacterial Isolates Causing Gingivitis”	In vitro: synthesis of AgNP (silver nanoparticles) using <i>Lactobacillus bulgaricus</i> bacteria from clinical isolates and testing its antibacterial activity in the laboratory.	<i>Staphylococcus aureus</i> , <i>Streptococcus mutans</i>	AgNP synthesized by <i>L. bulgaricus</i> showed fairly strong antibacterial activity against <i>S. aureus</i> and <i>S. mutans</i> based on disc diffusion assays.
Pooja Kadamet al.(2020)	Efficacy of silver nanoparticles in chronic periodontitis patients: a clinico-microbiological study	60 periodontal sites (pockets) from patients with chronic periodontitis were selected and randomly divided into 3 groups	Bacterium anaerobic subgingiva	Group A (AgNP) and Group B (tetracycline) are not significantly different from each other — meaning that AgNP gel is almost as effective as tetracycline gel as an adjunct local therapy.

<b>Morad Hedayatipannah et al. (2023)</b>	Green synthesis of silver nanoparticles and evaluation of their effects on the <i>Porphyromonas gingivalis</i> bacterial biofilm formation	In vitro, laboratory studies, focus on the formation of bacterial biofilms. Silver nanoparticles (AgNPs) are synthesized by the green synthesis method using propolis as a reducing agent.	<i>Porphyromonas gingivalis</i> strain IR-TUMS/BPG5	AgNPs significantly decreased the biofilm formation of <i>P. gingivalis</i> compared to controls. The inhibitory effect is dose-dependent: the higher the concentration of AgNP (0.1 → 0.3 → 0.5 %), the lower the biofilm density (OD).
<b>B Barik et al. (2024)</b>	Sustainable synthesis of silver nanoparticles from <i>Azadirachta indica</i> : antimicrobial, antioxidant and <i>in silico</i> analysis for periodontal treatment	In vitro studies (laboratory experimental) combined with <i>in silico</i> analysis (molecular docking and ADME) to evaluate the therapeutic potential of green synthetic silver nanoparticles (AgNP) against periodontal infections.	<i>Porphyromonas gingivalis</i> , <i>Treponema denticola</i> , <i>Staphylococcus aureus</i>	AgNP exhibits strong antibacterial activity against <i>P. gingivalis</i> , <i>T. denticola</i> , and <i>S. aureus</i> . The largest inhibition zones are found at a concentration of 75 µg/mL: <i>P. gingivalis</i> : ~ 25 mm <i>T. denticola</i> : ~26 mm <i>S. aureus</i> : ~ 24 mm
<b>Shatha Subhi ALHarthi et al. (2021)</b>	Myrrh mixed with silver nanoparticles demonstrates superior antimicrobial activity against <i>Porphyromonas gingivalis</i> compared to myrrh and silver nanoparticles alone	In vitro study with 4 conditions, namely: Placebo (distilled water), myrrh from <i>Commiphora myrrha extract</i> , Silver nanoparticles (SN) only (AgNP suspension), Myrrh + silver	<i>Porphyromonas gingivalis</i> (ATCC® 33277™)	The mixture of myrrh + AgNP (MSN) showed better antimicrobial activity than myrrh alone especially after 48 hours of incubation.

			nanoparticles (MSN) mixed with AgNP		
<b>Meng Zhang and Edward C. M. Lo (2022)</b>	Compare the physicochemical and biological properties of engineered polymer-functionalized silver nanoparticles against <i>Porphyromonas gingivalis</i>	Experimental in vitro studies. The aim is to compare the physicochemical properties and biological effects of AgNP (silver nanoparticles) equipped with different types of polymers.	<i>Porphyromonas gingivalis</i>	Among all polymers tested, PVP was the most effective for enhancing the antibacterial and antibiofilm properties of AgNP against <i>P. gingivalis</i> , while maintaining cellular compatibility at the MIC level	
<b>Srinivasan Krishnappan et al. (2024)</b>	Comparative Evaluation of Antimicrobial Efficacy of Silver Nanoparticles Infused with <i>Azadirachta indica</i> Extract and Chlorhexidine Against Red-complex Pathogens	In vitro studies with comparisons between three "treatment groups": Group I: 99% ethanol extract from neem leaves ( <i>Azadirachta indica</i> ) Group II: Nim-infused silver nanoparticles (NAgNPs) — silver nanoparticles synthesized with neem extracts. Group III: Chlorhexidine (CHX), as an antimicrobial "gold standard" control.	<i>Red complex pathogens</i>	Silver nanoparticles synthesized with neem extract have better antibacterial activity against red-complex pathogens compared to chlorhexidine, in some measurements	
<b>Carolina Holguín-Meráz et al. (2024)</b>	Antibacterial Effect of Silver Nanoparticles against Oral Biofilms in Subjects with Motor and	An experimental in vitro study used clinical oral biofilm collected from patients (n = 37; ages 10–27 years) with and without motor &	<i>Streptococcus mutans</i> <i>Prevotella intermedia</i> <i>Tannerella forsythia</i> <i>Treponema denticola</i> <i>Porphyromonas gingivalis</i> <i>Fusobacterium nucleatum</i> <i>Streptococcus sobrinus</i>	biofilms from patients with MID, AgNPs show better efficacy (MIC range AgNPs ≈ 18.1–51.4 µg/mL) than	

Intellectual Disabilities	intellectual impairment (MID). Samples were obtained by mechanical sweep of the sulcus/gingival line and cultured prior to testing.	<i>Aggregatibacter actinomycetemcomitans</i>	CHX ( $\approx$ 58.5–87.8 $\mu\text{g/mL}$ )
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Source: Compiled from various studies indexed in PubMed, Scopus, and Google Scholar (2020–2024)

## Discussion

Various studies assessing the effectiveness of silver nanoparticles (AgNPs) show consistency that these nanoparticles have great potential as antimicrobial and antibiofilm agents in periodontal disease. AgNPs, whether produced through chemical methods, green synthesis using plants such as *Azadirachta indica*, or modified with polymers or combined with herbal ingredients such as myrrh, are generally able to reduce the viability of periodontal bacteria and significantly inhibit the formation of biofilms. This ability is especially seen in the main pathogens of red complexes, such as *Porphyromonas gingivalis*, *Tannerella forsythia*, and *Treponema denticola*, which are the most virulent bacteria in the pathogenesis of periodontitis. The high effectiveness of these AgNPs is largely attributed to their small particle size, which facilitates penetration into the biofilm matrix, interaction with bacterial cell membranes, as well as the production of reactive oxygen species (ROS) that cause cellular damage.

Studies using clinical biofilms, including in patients with periodontitis as well as individuals with motor and intellectual limitations, have shown that AgNPs can inhibit the growth of multispecies biofilms with results that are equal to or even exceed standard antimicrobial agents such as chlorhexidine (CHX). Some studies have even reported that in mature biofilms, especially those derived from periodontitis patients, AgNPs provide a stronger antibiofilm response than CHX, indicating their ability to penetrate more resistant biofilm structures. Certain formulations such as AgNP-myrrh or polymer-functionalized AgNPs show increased stability, bioactivity, and better antibacterial potential, thus reinforcing the benefits of using these nanoparticles in the context of periodontal therapy.

Clinical findings also support the potential of AgNPs as adjuvants in the treatment of periodontitis. Its use as subgingival irrigation or as an adjunct to scaling and root planing (SRP) therapy has been shown to provide significant improvements in clinical indicators such as a decrease in periodontal pocket depth, plaque index, and number of anaerobic bacterial colonies. Natural ingredient-based formulations, particularly green-synthesized AgNPs using neems, provide the added benefit of improved biocompatibility and antioxidant activity that supports periodontal tissue healing.

Overall, the results of this entire study lead to the conclusion that AgNPs are very promising antimicrobial and antibiofilm agents in the management of periodontal disease. With multiple mechanisms of action, ability to target red complex bacteria, and effectiveness against biofilms that are difficult to treat with conventional therapies, AgNPs have the potential to be

an important alternative or companion in modern periodontal therapy. The integration of this nanoparticle technology opens up opportunities for the development of therapeutic approaches that are more effective, more biocompatible, and better able to overcome bacterial resistance in periodontal biofilm environments.

## CONCLUSION

The reviewed literature collectively demonstrates that silver nanoparticles (AgNPs) hold significant potential as antibacterial and antibiofilm agents in the management of periodontal disease. AgNPs exhibit consistent antimicrobial efficacy against the primary periodontal pathogens, particularly the red complex bacteria *Porphyromonas gingivalis*, *Tannerella forsythia*, and *Treponema denticola* as well as other anaerobic species implicated in the progression of periodontitis. This efficacy is maintained across varying synthesis methods, including chemical, biological, and green synthesis approaches using plant extracts such as *Azadirachta indica*, as well as combination formulations such as AgNP-myrhh composites and polymer-functionalised AgNPs. Beyond inhibiting planktonic bacterial growth, AgNPs effectively disrupt biofilm formation, maturation, and structural integrity through their small particle size, reactive surface properties, and capacity to generate reactive oxygen species (ROS), which collectively enable penetration of the biofilm matrix and destabilisation of microbial communities that are otherwise resistant to conventional therapies. Several studies have further demonstrated that AgNPs surpass chlorhexidine (CHX) in antibacterial potency, particularly against multispecies biofilms and clinical isolates from patients with chronic periodontitis. From a clinical standpoint, the application of AgNPs as adjunctive periodontal therapy whether as subgingival irrigants or topical agents yields measurable improvements in periodontal parameters, including reductions in probing pocket depth, plaque index, and anaerobic bacterial load, while green synthesis formulations additionally confer antioxidant activity and favourable biocompatibility. Taken together, these findings confirm that AgNPs are promising therapeutic candidates offering multiple complementary mechanisms of action — antibacterial, antibiofilm, antioxidant, and enhanced biopenetration that are well-suited to addressing the complex and polymicrobial pathogenesis of periodontitis, positioning them as a viable adjunct or alternative to conventional antimicrobial agents with a reduced risk of adverse effects and greater efficacy against resistant biofilms. Nevertheless, the existing evidence remains predominantly *in vitro* and short-term, and future research should therefore prioritise well-designed randomised controlled clinical trials to establish standardised AgNP dosing protocols, long-term biosafety profiles, and the comparative clinical efficacy of AgNPs against established periodontal therapeutics. Further investigation into the optimal physicochemical parameters of AgNPs including particle size, surface functionalisation, and synthesis method as determinants of antimicrobial and antibiofilm performance in periodontal biofilm models would also strengthen the translational foundation necessary for the integration of AgNP-based nanotechnology into routine periodontal therapy.

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