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Review Article

# Application of plant extract synthesised silver nanoparticles in dentistry – A narrative review

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## Abstract

Dental caries and periodontitis are the major dental diseases affiliated with pain, tooth loss, and systemic infections throughout the world. Traditionally, such diseases are dealt with curative measures that are costly and unreachable for low-income regions. The green synthesis of AgNPs from plant extracts poses a highly promising eco-friendly approach in this regard and has substantial potential for dental care applications. This review, therefore, highlights the benefits of plant extract-pre-synthesized AgNPs as an antimicrobial, cost-effective, and eco-friendly process for their preparation. AgNPs have good compatibility and can be added in various dental products like toothpaste, mouth rinses, and dental sealants and provide proper dental caries prevention and periodontal management. They have also found potential uses in the fields of endodontics and prosthodontics through increased antimicrobial activities and regeneration of tissues. Despite the obstacles created to stability and standardization, work in that area has been brought under further research processing. This review enhances the potential of AgNPs for revolutionizing dental care through innovative and cost-effective solutions.

**Keywords:** Dental caries, Green synthesis, Periodontitis, Plant extracts, Silver nanoparticles

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## 1. Introduction

Oral diseases, like dental caries and periodontitis, pose an enormous health burden around the world with pain and discomfort, tooth loss, and deformity at all ages.[1] Dental caries, or the gradual deterioration of enamel, dentin, and cementum, is the most common noncommunicable illness worldwide, affecting 60-90% of schoolchildren and virtually all adults.[2] It remains the largest cause of tooth loss in children and young adults, as well as root decay in the elderly.[2] Similarly, periodontal disease, which damages the supporting structures of teeth, affects about 10% of the world's population and was the sixth most frequent health problem from 1990 to 2010.[3] Without proper treatment, these conditions cause severe morbidity and can cause systemic disorders like infective endocarditis, diabetes, and pneumonia.[4]

Both dental caries and periodontitis are primarily caused by polymicrobial communities evident in dental biofilms. These biofilms, or plaques, support harmful microbes that elude the host's immune system, causing the evolution of oral illnesses.[5] Prevention and management strategies, including the use of antimicrobial agents, remineralization products, mechanical plaque removal, and restorative procedures such as fillings and implants, are critical to minimizing the impact of these diseases.[6] However, the financial burden associated with oral disease treatment is significant, particularly in low- and middle-income nations where treatment may not be affordable.[7] As a result, interest in developing cost-effective and sustainable oral hygiene products has risen, with the

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World Health Organization (WHO) advocating for the investigation of safe, inexpensive alternatives.[8]

One of the emerging areas includes green-synthesized silver nanoparticles (AgNPs) for application in dental care products. Silver nanoparticles have been widely used in medicinal applications due to their antibacterial properties.[9,10] Silver may be manufactured at the nanoscale using nanotechnology, resulting in a greater surface area-to-volume ratio and improved antibacterial action.[11] This is particularly relevant in combating oral pathogens like Streptococcus mutans and Lactobacillus, which form acidic biofilms responsible for tooth decay and demineralization.[10] While traditional restorative materials like composites and ceramics repair damaged teeth, secondary caries often develop due to bacterial accumulation around the restoration. Silver nanoparticles, with their broad-spectrum antimicrobial activity, may prevent such complications and improve overall oral health.[9,10]

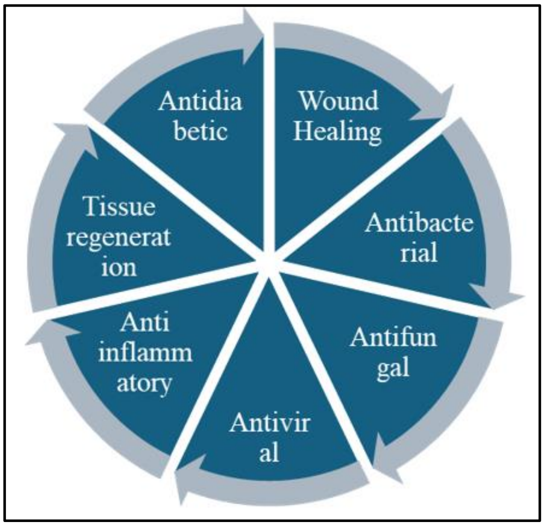


**Figure 1:** Significance of silver nanoparticles

This review focuses on the use of silver nanoparticles made from plant extracts in dentistry, investigating their potential as an economical and environmentally responsible means of treating and preventing oral disorders.

## 2. Review of Literature

A comprehensive search strategy was implemented to investigate the application of plant extract-synthesized silver nanoparticles in dentistry. Initially, 115 records were identified through database searches, including sources like Google Scholar, PubMed, and Science Direct. After the removal of duplicates, 76 unique records remained for screening. 53 full-text articles were evaluated for eligibility after 23 records were eliminated throughout the screening process. In the end, 30 papers that concentrated on the pertinent uses and advantages of silver nanoparticles produced from plant extracts in dental procedures were included in the review. Figure 2 shows a representation of this.

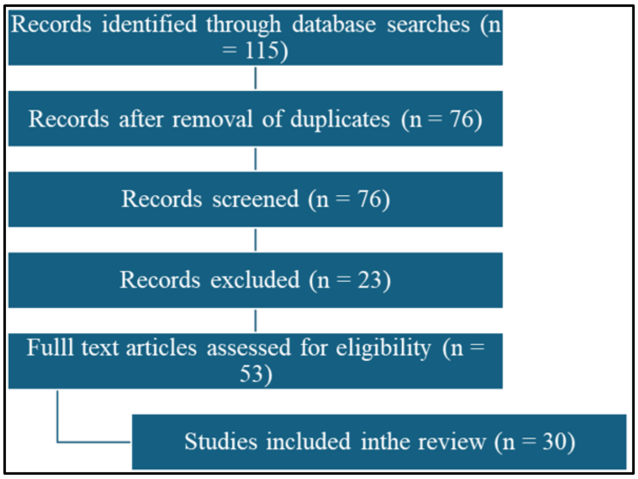


**Figure 2:** PRISMA flow diagram for the study

## 3. Silver Nanoparticle Chemistry and Synthesis

Different techniques are used to create silver nanoparticles (AgNPs), and each one is controlled by particular chemical principles that affect the nanoparticles' stability, size, and shape. Usually, chemical reductants like sodium borohydride or citrate, which also serve as stabilizing agents, are used to reduce silver ions ($Ag^+$) into elemental silver ($Ag^0$) in order to create AgNPs.[11] A number of variables, such as pH, reaction temperature, precursor concentration, and the molar ratio of stabilizers to precursors, affect the nucleation and development of these nanoparticles. Brust et al.'s widely used method for thiol-stabilized AgNPs illustrates this, where $Ag^+$ undergoes reduction in an aqueous medium, followed by controlled nucleation into colloidal particles. [11] Weaker reductants like citrate, used in the Turkevich method, ensure better control over particle size and shape by moderating the reduction rate. Furthermore, biological methods harness plant or microbial agents to reduce silver ions, offering a greener, low-cost alternative that minimizes toxicity and environmental impact.[12]

Silver nanoparticle (AgNP) synthesis for dental applications involves several methodologies, each with distinct advantages. Hanif et al. utilized physical synthesis techniques such as evaporation, condensation, and laser ablation, which produce large quantities of pure AgNPs without the use of harmful chemicals, thus making them environmentally friendly.[13] According to Yang et al., biosynthesis uses natural sources such as Azadirachta indica and Allium cepa and offers a low-cost, effective, one-step process with controllable nanoparticle size, stability, and efficacy.[14] Barot et al. concentrated on chemical synthesis employing wet chemical techniques, which offer the benefits of low cost and high yield.[15] In the meanwhile, Bacali et al. investigated physicochemical synthesis using irradiation techniques, which offer scalability, environmental friendliness, and broad biodiversity, making it a viable method for producing AgNP on a large scale.[16] Each of these methods contributes uniquely to advancing silver nanoparticle synthesis for safe and effective dental applications.

## 4. Biocompatibility of Silver Nanoparticles

Because of their low toxicity, compatibility with the digestive system, and immune-stimulating properties, biocompatible dental materials—such as silver nanoparticles made from plant extract have been developed to protect oral keratinocytes and mucosal tissues.[17] However, nanomaterials can become harmful as their size decreases from 100 nm to 1 nm, and their behaviour changes when fragmented.[17] Predicting human reactions to nanomaterials is challenging because they behave differently in farmed cells compared to living organisms.[18] Furthermore, ethical, economic, and health concerns regarding nanomaterials have covered scientific advancements, leading to public uncertainty.

## 5. Clinical Applications of Nanoparticles in Dentistry

### *5.1. Endodontics*

Based on their unique antibacterial properties, plant extract-based silver nanoparticles have demonstrated significant potential in dentistry. These nanoparticles, according to Thangavelu et al., enhance adhesive elasticity when filling nano-flaws and possess a faster setting time than conventional sealers that are often hampered by stiffness, poor solubility, and limited biochemical affinity to dental tissues.[19] Combining calcium hydroxide with silver nanoparticles (AgNPs) has been investigated to improve the efficacy of intra-canal medications against Enterococcus faecalis. When compared to calcium hydroxide and chlorhexidine, this combination showed greater antibacterial activity; the highest effects were shown in the first week of use. However, the antibacterial efficacy of AgNPs significantly reduced after one month, indicating that while they serve as powerful short-term agents against E. faecalis, their long-term effectiveness may be limited.[20,21]

Furthermore, Afkhami et al. reported better antibacterial and cytotoxic properties of AgNPs compared to 2.5% sodium hypochlorite (NaOCl). These nanoparticles have further increased potential in their innovative use with ethanol and sodium hydroxide in AgNP-based irrigants.[20] Ethanol reduces the surface tension which makes the nanoparticles enter the dentin's lateral canals and tubules, while sodium hydroxide helps in breaking up pulp tissue and removal of smear layer, resulting in deeper penetration by AgNPs. AgNPs exhibited bactericidal activity against Staphylococcus aureus and Enterococcus faecalis that was comparable to 5.25% NaOCl.[21]

Besinis et al. (2017) also reported that AgNPs, when used as surface modifications on titanium alloy implants, greatly prevent the formation of bacterial biofilms.[22] Such studies highlight the potential and flexibility of plant extract-synthesized AgNPs in several dental applications, including root canal irrigation and preventing the formation of dental implants' biofilm.

### *5.2. Preventive sentistry*

AgNPs synthesized from plant extracts have exhibited promise for enhancing dental materials, especially in sustaining the antibacterial durability of self-etching adhesives. Vence et al. emphasized that the AgNPs dramatically inhibit Streptococcus mutans without causing resin adhesion to deteriorate.[23] Fatemeh et al. revealed that the two-step adhesive systems based on AgNP showed better shear strength values than conventional self-etching systems.[24] Ethanol reduces surface tension, helping nanoparticles reach the dentinal lateral canals and the tubules, and sodium hydroxide helps break down the pulpal tissue, and remove smear layers, enabling deeper penetration of AgNPs. AgNPs exhibited bactericidal effects against Staphylococcus aureus and Enterococcus faecalis like 5.25% NaOCl.[25] In addition, biocompatible and non-cytotoxic products such as Nanocare Gold containing AgNPs blended with disinfectants have been reported by Salas-López et al.[26] Additionally, Ali et al. compared AgNP-based sealants with traditional sealants, reporting similar micro-leakage but faster fluorescence loss in AgNP-based sealants.[27] These findings emphasize AgNPs' role in advancing dental materials, with Jonaidi-Jafari et al. suggesting that silver nanofluoride (NSF) is an economical, bacteriostatic alternative for infection prevention.[28]

### *5.3. Dental implants*

Dental implants are favoured over removable prostheses due to their reliability, yet peri-implant infections caused by biofilm buildup can lead to failure. Fu et al. emphasized that titanium implants, while biocompatible, require antibacterial coatings to prevent such infections.[29] AgNPs were deposited on titanium surfaces using a unique silver plasma immersion ion implantation technique, which successfully inhibited Escherichia coli and Staphylococcus aureus while encouraging osteoblast growth. Niska et al. highlighted that AgNPs' physicochemical properties influence surface cytotoxicity, making them potential for dental applications. Additionally, carboxymethyl cellulose-capped AgNPs were shown to inhibit Gram-negative bacteria, which are responsible for most periodontal infections.[30]

### *5.4. Orthodontics*

Due to insufficient self-cleaning and acidogenic oral flora, orthodontic patients frequently develop cavities and white spot lesions as a result of plaque buildup around brackets. Caries may develop as a result of this demineralization brought on by the biofilm. According to Ghorbanzadeh et al., silver nanoparticles (AgNPs) have the potential to dramatically lower tooth demineralization and bacterial adherence.[31] Because of their extended Ag+ ion release, resins containing AgNPs showed improved antibacterial qualities without compromising their mechanical qualities, which makes AgNPs biocompatible for use in orthodontics. Zafar et al. highlighted that AgNPs combined with hydroxyapatite (HA) in orthodontic adhesives further improved antibacterial efficacy, particularly with a 5% weight composition, which demonstrated the highest efficiency against cariogenic bacteria.[32] Moreover, this combination-maintained shear bond strength, proving that a 5% AgNPs/HA mixture is both antibacterial and mechanically stable for orthodontic applications. Alla et al. also emphasized AgNPs' potential as nano-vectors for gene transfer, which could enhance mandibular development. With these advantages, AgNPs present promising clinical applications that could improve orthodontic treatment outcomes while reducing associated costs.[33]

### *5.5. Paediatric dentistry*

Silver nanoparticles (AgNPs) were utilized in juvenile dentistry because of its antibacterial property, smaller size particles, and oral health establishment, and to minimize the biofilm formation. Although limited studies are conducted on the addition of AgNPs into composite resins and adhesive systems, Porter et al. reported that AgNPs enhance the mechanical and bactericidal properties of calcium silicate cements, including PC mixed with $ZrO2$ and MTA.[34] The inclusion of AgNPs significantly increased compression resistance in PC/$ZrO2$ mixes, likely because of a significant decrease in porosity. Makvandi et al. also reported that incorporation of AgNPs with MTA and PC/$ZrO2$ enhanced mechanical strength and provided enhanced antibacterial efficiency after an application period of 15 hours.[35] These findings depict that AgNPs can improve the mechanical characteristics of calcium silicate-based composites while reducing bacterial colonization. Moreover, composite resins and adhesives infused with AgNPs can prevent tooth decay significantly and inhibit biofilm deposition and may therefore be considered promising candidates for improving dental restorations in juvenile patients.

### *5.6. Anticancer treatment*

Oral squamous-cell carcinomas cause severe cosmetic issues in the mouth and face and have a significant impact on employment. Alternative medicines must be investigated because traditional treatments like chemotherapy and radiation disturb homeostasis and have a lot of negative side effects. Although nanoparticles, including AgNPs, have been applied in medicine and dentistry, their full potential in cancer treatment remains under investigation. AgNPs exhibit cytotoxicity through DNA damage and apoptosis, which makes them a promising anticancer agent. El-Batal and Ahmed observed that AgNPs inhibit cancer cell growth even at low doses, while combining AgNPs with natural compounds like berberine could enhance their anticancer efficacy.[36] Additionally, surface modifications of AgNPs offer targeted delivery to malignant cells, potentially enabling early cancer detection and reducing chemotherapy side effects by sparing healthy cells. These findings suggest that AgNPs, especially when combined with bioactive molecules, hold promise as a novel therapeutic approach in treating oral cancers.

## 6. Dental Biomaterials: Effect of Silver Nanoparticles

The dental field has shown a great deal of interest in silver nanoparticles (AgNPs) because of their strong antibacterial capabilities and biocompatibility. AgNPs have shown encouraging promise in improving oral health outcomes when incorporated into a variety of dental materials, especially when it comes to infections related to dental prosthesis, restorative materials, endodontics, periodontology, orthodontics, and even cancer treatment.

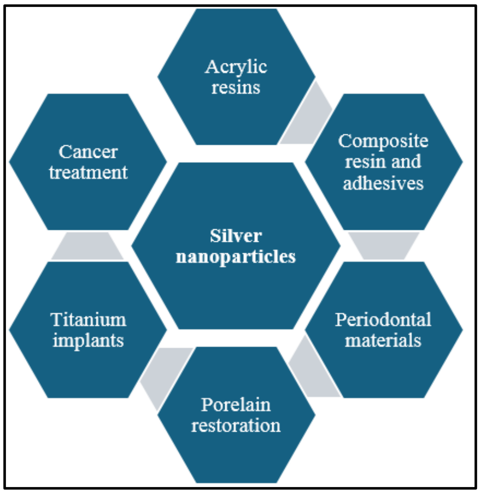


**Figure 3:** The use of AgNPs in dental bio materials.

### *6.1. Denture acrylic resin*

The production of partial and complete dentures to replace lost teeth frequently uses acrylic polymers made from poly(methyl methacrylate), or PMMA. Ginjupalli et al. highlight that these resins, with their rough surfaces, are particularly susceptible to microbial colonization, especially by Candida albicans, which can lead to opportunistic infections.[37] Despite the availability of various denture cleansers and mouthwashes designed to eliminate these microbes, Rodrigues et al. note that many of these products fall short of completely eradicating infections.[38]

### *6.2. Composite resins*

A study by Bhandi et al. reveals that traditional resin groups without silver nanoparticles exhibit superior impact strength compared to microwave resin groups containing 0.8 weight percent AgNPs, which demonstrate reduced impact resistance. [39] Moreover, Pajares-Chamorro et al. report that while heat polymerization groups achieve the highest glass transition temperatures, the incorporation of AgNPs tends to decrease these temperatures across both resin groups.[40]

Kirmanidou et al. postulate that the antibacterial power of silver nanoparticles (AgNPs) may be efficiently used by adding them into various dental materials, greatly lowering biofilm development and boosting oral health.[41] AgNPs' ability to pass through cell membranes due to their nanoscale size causes cellular damage and microbial inactivity as a result.

AgNPs' effects on the mechanical and antibacterial qualities of calcium silicate cement blocks—which are frequently used in dental applications—were examined by Sihivahanan et al.[42] Their findings showed that, following a 15-hour exposure period, the inclusion of AgNPs not only improved the mechanical characteristics of Portland cement (PC) and mineral trioxide aggregate (MTA), but also indicated strong bactericidal activity against test bacteria. Furthermore, AgNPs are able to effectively inhibit the growth of oral bacteria such as Streptococcus mutans, as Chen et al., noted. This offers a practical approach in preventing biofilm formation around restorations.[43]

### *6.3. Endodontic materials*

Successful endodontic treatments depend on the effective removal of the bacteria to enhance the prognosis of the tooth. Conventionally, gutta-percha has been the material of choice for root canal fillings, but recent studies by Ferreira et al have established that nanosilver-coated gutta-percha provides a potential substitute, which indicates less microleakage without compromising on functional properties.[44] The important challenge in endodontic treatment is efficient disinfection of the canal space, where specific areas of the canal space may not be accessible for such disinfecting instruments. Emerging study by Ren et al. recommended the use of nanoparticle irrigating systems for root canal lavage.[45]

### *6.4. Periodontology*

Oral biofilms, which are complex polymicrobial communities, are key factors associated with periodontal diseases and dental infections. The mechanical removal of these biofilms is essential to prevent further spread of periodontal disease and tooth loss; however, their structural robustness usually compromises the effectiveness of conventional antimicrobials. Hence, exploring alternative antibacterial approaches becomes crucial. Hamdy et al. reported that AgNPs can be well encapsulated by carboxymethyl cellulose and sodium alginate, thus protecting them from microbial degradation and enhancing their antibacterial activity.[46]

### *6.5. Orthodontic adhesives and cement*

The same authors reported that patients receiving orthodontic treatment suffer from an increased risk of developing white spot lesions and caries because of the aggregation of plaque on orthodontic brackets.[47] Silver nanoparticles (AgNPs) as an additive to orthodontic adhesives have thus become a prime approach that can delay bacterial adhesion and enamel demineralization. Research indicates that AgNPs can effectively inhibit bacterial growth while preserving the mechanical integrity of the adhesive material.

### *6.6. Anticancer treatment*

Head and neck squamous cell carcinomas constitute a significant proportion of cancer diagnoses, often leading to severe functional and aesthetic complications. While conventional treatment modalities such as radiation and chemotherapy have demonstrated efficacy, they frequently entail considerable side effects, highlighting the need for innovative therapeutic approaches.

Silver nanoparticles (AgNPs) have emerged as potential anticancer agents, exhibiting the ability to induce cytotoxicity in cancer cells while preserving the viability of healthy cells. Combining AgNPs with naturally occurring substances, such berberine, has demonstrated potential in boosting anticancer effects, opening the door for the development of tailored cancer medicines, according to a study by Ahmed et al.[48]

## 7. Advantages of Plant Extract Synthesized Silver Nanoparticles

Plant extract-derived silver nanoparticles (AgNPs) have distinct benefits in biomedical and dental applications. These have excellent biocompatibility and safety profile, and less cytotoxic compared to chemically synthesized AgNPs because natural chemicals of a plant extract act as reducing and capping agents, thus being physiologically inert.[49] Additionally, the use of abundant raw materials allows for an economically viable green synthesis of AgNPs, involving considerable cost savings.[50] Furthermore, this sustainable method generates minimal hazardous waste and consumes less energy, aligning with green chemistry principles and reducing the ecological footprint associated with nanoparticle synthesis, thereby promoting environmental sustainability in dental practices.[51]

## 8. Challenges and Limitations

Plant extract-synthesized silver nanoparticles appear to be an effective alternative, with antimicrobial and anti-inflammatory properties, but several challenges, nevertheless, stand in the way of their practical application. For example, their stability and storage will have to be improved to ensure their effectiveness and safety for long-term use, as changing conditions can trigger the agglomeration of nanoparticles, which will decrease their bioactivity. Another complicating factor that jeopardizes reproducibility is standardization problems. Regulatory and safety concerns underline the need for deeper evaluations in relation to long-term health and environmental effects of AgNPs. If these challenges are to be ruled out, the successful integration of AgNPs into dental therapy must take place.

## 9. Future Directions

There are huge potentials for development of plant extract synthesized silver nanoparticles in dentistry in the future. The bulk of innovation is directed towards perfecting the synthesis techniques in creating advanced but eco-friendly methods that will increase AgNP production efficiency and scalability with high-quality standards. In addition, AgNPs have huge potentials for clinical application that can be explored beyond the present antimicrobial uses in the development of antimicrobial treatments and restorative materials that will help overcome the existing limitations, leading to suboptimal dental care outcomes. In the final analysis, efforts in research and development need to continue studying mechanisms, efficiency, and long-term safety of AgNPs. This continuous research serves an important role in validation and optimization of AgNPs integration into clinical practice and ensures that there will be efficacy and safety for further dental uses.

## 10. Conclusion

In conclusion, plant extract-synthesized silver nanoparticles may offer promising innovations in dental care with potent antimicrobial and anti-inflammatory properties, which might apply to almost all types of dental specialties. Their ability to fight cariogenic bacteria, biofilm inhibition, and enamel remineralization makes them very helpful in preventing or controlling dental caries and periodontal disease. Further, AgNPs have proved to increase durability and biocompatibility of dental prosthesis and implants, hence better patient outcomes in Prosthodontics and Implantology. With its potential in this regard, the progress of the same into practical applications has not been realized due to stability issues, standardization, and regulatory problems. Hence, continuous research and development of AgNPs for the optimization of synthesis, efficacy, and safety for their broad clinical use is going on. Future directions should focus on the advancing techniques of synthesis, new applications, and thorough evaluations to have sustainable and effective integration into dental practice.

## 11. Source of Funding

None.

## 12. Conflict of Interest

None.

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