Review Article

The Effects of Silver Nanoparticles on Treated Dental Caries: A systematic Review

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Abstract

Background: Due to their powerful antimicrobial activity against a wide range of microorganisms, Silver nanoparticles have been successfully implanted in numerous fields. In dentistry, AgNP implants can be used for prophylaxis, disinfection, and infection prevention in the oral cavity.
Objective: Screening the roles of Silver nanoparticles towards dental caries
Methods: In this paper systematic review investigating for usage of AgNPs dentistry depending on PubMed, Google scholar and Scopus databases resulting on 75 open access articles.
Results: The results found involvement of Silver nanoparticles in various fields of dentistry and having a potent activity towards microbes. These papers can serve as a guide for developing clinical application protocols for both permanent and temporary dentitions, which have different structures, and the behavior of formulations containing Silver nanoparticles can produce different results.
Conclusion: Silver nanoparticles could be used as a potential method in dentistry in a variety of implantations. Furthermore, current understanding of the precise dimensions, concentrations, antimicrobial mechanisms, and toxicological properties of nano-Silver compounds is insufficient to make conclusive statements about their clinical utility.
Key word: Silver nanoparticle, dental caries, antimicrobial activity

Introduction

Streptococcus mutans and Lactobacillus are the main pathogens responsible for dental caries, which is a disease brought on by a particular biofilm that produces acid. Dental caries starts with demineralization on the enamel surface, which is represented by a white and opaque color. Dental caries is still a costly, widespread issue that has a negative impact on both children's and adults' health and quality of life, despite recent advancements in dental care (1). Recent years have seen a significant increase in the use of nanotechnology in dentistry, demonstrating novel techniques for the prevention and treatment of caries, managing plaque-related biofilms, and remineralizing primary dental caries, including formulations of Silver nanoparticles (AgNPs) with antimicrobial properties against a variety of microorganisms (2). Silver nanoparticles (AgNps) are Silver particles with sizes ranging from 1 to 100 nanometers. Silver nanoparticles have unique features and have a broad range of potential utility in health, electronics, cosmetics, and a variety of other industries (3). The release of cationic Silver and its oxidative potential is a key to AgNPs mechanism of action (4). Since the inclusion of antimicrobial chemicals in dental biomaterials has been a technique taken by certain researchers, AgNPs have emerged as a promising compound to be employed in dentistry (5). However, commercial usage of AgNPs in dentistry is still in its early stages, with just three products containing AgNPs on the market: dental adhesive (NanoCare Gold DNT™), Novaron AG300 (Toagosei Co Ltd., Tokyo, Japan), and sealer (GuttaFlow™ Coltène-Whaledent) (6-8). Despite efforts and advancements in caries management, caries still has a significant impact on a lot of patients. The goal of any intervention or treatment should be to stop tooth decay. In order to prevent caries, it can be challenging to alter the environment at high-risk locations. By lowering tooth demineralization, calcium and phosphate ions can aid in the prevention of dental caries. Remineralization or demineralization depends on the amount of these ions present in the saliva [9]. The current research's goal is to better understand and screening the roles of Silver nanoparticles towards dental caries

Materials and Methods

According to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, this systematic literature review was carried out [10]. The set questions for the review included: Is it true that dental restorative materials' antibacterial and antimicrobial properties improve when nanoparticles are added? Also, could dental caries be treated with Silver nanoparticles? The study conducted between 1st August and 30th November 2021

Inclusion Standards: studies examining the antimicrobial and antibacterial properties of bacteria treated with nanoparticles that cause dental caries. An extensive manual search of pertinent content reviews and references from the included literature was done in order to find potential studies that satisfied the criteria for inclusion. Two authors independently screened and extracted the literature in accordance with the inclusion criteria, which included research articles and studies written in English.

Exclusion Criteria: Literature reviews, systematic reviews, case studies, and editorials are all excluded. Studies that lack an appropriate control group that would allow assessment of the impact of incorporating nanoparticles on the antibacterial capacity of the material

Search Strategy

The databases of Scopus, Google Scholar, and PubMed were electronically searched. Following are the search terms that were used: (dental* or dentistry or orthodontics or nanoparticle in dental) and (adhesive* or cement* or composite* or resin*) and (nanoparticle* or Silver nanoparticle) and (antibact* or antibact* or antimicro* or antimicro* or antibiofilm* or antiinfect* or antiinfect* or bactericidal* or bacteriostatic*) from 2011 to 2020.

In order to find studies not found during the initial search, the electronic search was supplemented by a manual search among the reference lists of all the articles found. There were no limitations placed on the language or the year of publication.

Data Extraction Author, publication year, study type, study groups, sample size, bonding material type, bonding material assessment, storage conditions, antibacterial tests used, conclusions, and study quality were all recorded for each article under review. After evaluation, the studies' risk of bias for these domains was categorized as low, high, or unclear.

The characteristics of each study were carefully recorded after reading the entire text. This made it easier to decide on the study's structure, setting, and funding sources, as well as the preparation of the test samples and test microbes. Additionally, the type of intervention, comparator, timing of the evaluation, assessment procedures, sample size, statistical analysis, and study results were carefully examined.

Results

Literature Search

The search strategy was initially used to find 75 papers in the database, and 41 papers were selected based on, among other things, the title, abstract, and keywords. Final screening involved reading the full text of 34 papers (Figure 1). and the classification of the studies is shown in the flow chart below.

The treatment of dental caries with formulations containing nanoscaled Silver particles (AgNPs) represents the most recent clinical advancement in cariology. There are, however, a very small number of studies on this subject, and we discuss a clinical trial below that looked at the effects of Silver nanoparticle solution or powder on caries arrest, particularly when it occurred in the primary teeth of preschoolers.

The majority of studies discovered that Silver nanomaterials are antibacterial, primarily against Streptococcus mutans by preventing their growth, biofilm, adhesions, and metabolism. Other studies looked into the antibacterial properties of Silver nanomaterials against cariogenic bacteria. It's crucial to take into account the findings of a prior study that combined AgNPs with hypochloride, a dental sanitizer, to produce highly antibacterial activity against E. feaclis.

Studies that used oral microcosms and others that used monospecies bacteria, including Staphylococcus, Streptococcus, Lactobacillus, Enterococcus, Pseudomonas, and E. coli, were conducted. Only three studies were conducted in vivo, and the majority of studies evaluated bactericidal abilities in vitro. Despite the antimicrobial activity of AgNPs toward bacteria and fungus, higher activity toward bacteria with concentrations of 0.1% and 0.5% and toward fungus with concentrations of 0.5%, in addition one study indicated the ability of AgNPs to inhibit adhesion of fungus but no effects on metabolism and growth and toxic effects to fungus. 5-12.5 g/ml of AgNPs are the ideal concentration to use.

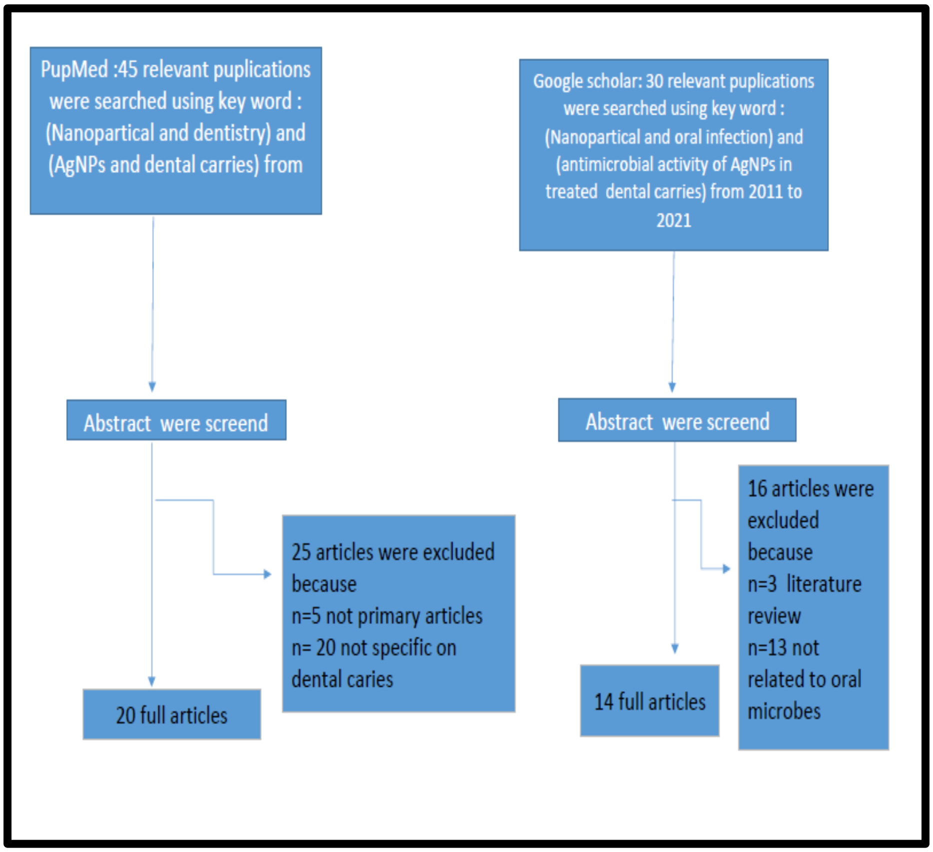

Figure 1. Flow-charts of the literature search and study selection

Table 1. Description of previous studies with its characteristics and findings

Name	Objective	Microbes	Finding
Nam, 2011 Korea [11]	Determine the tissue conditioner's antimicrobial activity in vitro against various microbial strains.	*Staphylococcus aureus, Streptococcus mutans Candida albicans*.	The minimal bactericidal effect of 0.1% AgNPs added to tissue conditioner against S. aureus and S. mutans strains, and 0.5% against fungal strains, was observed.
Acosta-Torres et al., 2012 Mexico [12]	looked at the safety of a new nano dental material with antifungal characteristics.	*C. albicans*	the results reveal that PMMA –Silver nanoparticle discs inhibit C. albicans adhesion while having no effect on metabolism or proliferation. They also don't appear to be genotoxic to cells.
Cabal, et al., 2012 Spain [13]	Streptococcus oralis in vitro biofilm's viability as a result of soda-lime-glass-nAg coating	*S. oralis*	Glass-nAg prevents the growth of biofilms in S. oralis strains, which may be useful for materials like dental implants that need to have a long-lasting antibacterial effect on their surfaces.
Besinis et al, 2014 USA [14]	Compared to the dental disinfectant chlorhexidine, Silver, titanium dioxide, and silica dioxide nanoparticles	*S. mutans*	The traditional chlorhexidine disinfectant used in dentistry was less effective against S. mutans than Ag NPs and AgNO3.
Zhu et al., 2015 China [15]	in vitro antimicrobial and compatible properties of AgNPs using the commonly suspected oral pathogens	*Fusobacterium nucleatum* and *S. aureus*	results demonstrated that good bactericidal activity could be obtained with very small quantities of

Name	Objective	Microbes	Finding
			immobilized Ag NPs
Majeed S, Khanday 2016, India [16]	antibacterial effect of nanoparticles against bacteria isolated from dental plaque	*Lactobacillus* sp, *Strepto sp.* And *Staphylococcus*	Good antibacterial activity lone against the isolated bacterial pathogens from dental plaque and also enhances the efficacy of antibiotics quite remarkably
Niska et al., 2016 Poland [17]	Consider the antibacterial effects on a panel of oral pathogenic bacteria and bacterial biofilms as well as any potential cytotoxic effects on human gingival fibroblasts.	*Staphylococci* strains and *S. mutans*	if pharmacological activity and risk assessment are carefully carried out, the potential utility of AgNPs against oral anaerobic Gram-positive and Gram-negative bacterial infections and aerobic Staphylococci strains
Luna et al., 2016 Mexico [18]	find out if using AgNPs as a final irrigation agent in endodontics has a bactericidal effect.	*Enterococcus faecalis*	There was no discernible difference between sodium hypochlorite at 2.25% and AgNPs of 10 nm in their ability to eradicate E. faecalis.
Martínez-Robles et al., 2016 México [19]	AgNPs with bovine serum albumin (BSA) or chitosan (CS) coatings were prepared and the physical, chemical and microbiological properties of SNP were evaluated	*S. mutans*	Antimicrobial activity was demonstrated against S. mutans bacteria and serotypes by both types of coated AgNPs. Smaller particles and BSA coatings were associated with better inhibition.
Chladek et al, 2016 Poland [20]	Producing of AgNPs were introduced into two component system silicone based materials for The silicone based room temperature vulcanized (RTV) polymers	*S. mutans*	The addition of AgNPs to RTV-silicone increased the antimicrobial resistance against the common strain of Streptococcus.
Gligorijević et al., 2017 [21]	adding Different concentrations (2%, 5% and 10%) of AgNPsto the polymer components (powder) of cold polymerizing acrylate,	*S. aureus*	AgNPs in cold curing acrylic resin demonstrated antibacterial activity
Nam et al., 2017 Korea [22]	examined the effects of adding Silver AgNPs to Portland cement with a hydraulic calcium silicate base on the material's mechanical properties, antibacterial behavior, and biocompatibility as a new dental bone substitute.	*S.mutans* and *Streptococcus sobrinus*.	AgNPs could be a potential candidate for the cutting-edge dental biomaterial because the addition of AgNPs enhanced PC's bio-mechanical properties and enhanced its antibacterial activity.
Venugopal et al , 2017 Korea [23]	surface treating titanium microimplants with AgNPs to achieve antibacterial properties.	*S. mutans*, *Streptococcus sanguinis* and *Aggregatibacter acticetemcomitans*	Ti-BP-AgNP-modified titanium microimplants are a promising implantable biomaterial because they have excellent antibacterial qualities.
Hernández-Gómora et al., 2017 Mexico [24]	examined the elastomeric orthodontic modules decorated with AgNPs for their physical and antibacterial qualities..	*S. mutans*, *Lactobacillus casei*, *S.aureus* and *Escherichia coli*	The findings point to the material's potential to fight dental biofilm, which would reduce the likelihood of dental enamel demineralization and ensure its effectiveness in patients undergoing orthodontic treatment.
Besinis et al., 2017 UK [25]	In order to test the antimicrobial capabilities of the various nanomaterials and nanocoatings under investigation, one of the most prevalent pathogens linked to peri-implantitis and dental implant infections was used as a test subject.	Streptococcus sanguinis	The surface of titanium alloy implants treated with a dual-layered Silver + nHA coating is highly antibacterial against the oral pathogen S. sanguinis, inhibiting bacterial growth in the surrounding media and preventing biofilm formation on the implant surface.
Saafan et al., 2018 *Egypt* [26]	To evaluate S. mutans' resistance to the antibacterial effects of 650 nm diode laser, Methylene Blue (MB), and Ag NPs in biofilm-induced caries models.	*S. mutans*,	One of the most potent contemporary antimicrobial therapeutics in dentistry may be the combination of MB, 650 nm diode laser, and Ag NPs.

Name	Objective	Microbes	Finding
Paiva et al., 2018 Brazil [27]	develop polyacid formulations by the one-step photoreduction of AgNP in a polyacrylate solution of conventional glass ionomer cement (GIC), imparting antibacterial activity	*E. coli* and *S. mutans*	The production of highly bioactive water-based cements within clinically acceptable limits and with significant potential for dental and biomedical application was made possible by the one-step AgNP preparation in polyacrylate solution.
Yang et al., 2018 China [28]	antibacterial activities of AgNPs runoff from dental implants	*S.mutans*, *Porphyromonas gingival*	showed almost complete antibacterial activity, and the PLGA(Ag-Fe3O4) coating significantly maintained the antibacterial activity and prevented bacterial adhesion to the implant.
Yoshida et al., 2018 Japan [29]	develop an antibacterial mouthguard (MG) material using a masterbatch of AgNPs –embedded ethylene -vinyl acetate (EVA) copolymers	*S.sobrinus*, *P. gingivalis*, and *E. coli*	These results showed that this testing material could be clinically applicable as an antibacterial MG material
Fernandes et al., 2018 Brazil [30]	By adjusting the reducing agent of Silver nitrate (sodium borohydride or sodium citrate), the concentration of Silver (1% or 10%), and the CaGP forms (nano or microparticulated), it is possible to create nanocompounds that contain calcium glycerophosphate (CaGP) and AgNP. These compounds can then be characterized and tested for antimicrobial activity.	*C. albicans* and *S. mutans*	Both of the tested microorganisms were successfully neutralized by the sodium citrate-based nanocomposites and the anchorage of AgNP with CaGP.
León Francisco Espinosa-Cristóbal et al., 2018 Mexico [1]	to ascertain the S. mutans' adhesion to the surfaces of brackets and wires, and the inhibitory effect and antiadherence activity of AgNPs.	*S. mutans*	All AgNP samples prevented S. mutans from adhering, but smaller AgNPs had more effective inhibition than larger ones. S. mutans' adhesion was affected by the module's presence, but not AgNPs' activity. The AgNPs used in this study demonstrated effective antimicrobial and antiadherence properties against the bacteria S. mutans, indicating their high potential use in the management of WSLs in orthodontic treatments..
Schwass et al 2018 New Zealand [31]	In Vitro testing Colloidal AgNP Suspension ed against Monoculture Biofilms as Disinfectant for Treating Dental Caries	Streptococcus gordonii S. mutans Streptococcus mitis E. faecalis	By preventing in vitro biofilm formation for several Streptococcus spp. And E. faecalis, this AgNP formulation demonstrates potential for clinical application inhibiting biofilms
Barszczewska-Ry et al ., 2018 Poland [32]	mixing with AgNP bisphenol A glycerolate dimethacrylate (Bis-GMA) and triethylene glycol dimethacrylate (TEGDMA)		the higher the AgNP concentration, the lower the degree of conversion also, AgNP can have a strengthening
Munikamaiah et al., 2018 India [33]	Acrylic resins have been infused with Silver colloidal nanoparticles to produce antimicrobial properties.		Its flexural strength significantly increased in the specimens treated with the antimicrobial agent 0.5% Silver colloid al nanoparticles and subjected to lengthy curing cycles when compared to the control group, making it clinically suitable as a denture base material.

Name	Objective	Microbes	Finding
Porenczuk et al, 2019 Poland [4]	Glass-ionomer cement (GIC), various bonding systems, an antimicrobial agent with Au and AgNPs, and combinations of these materials with the antimicrobial agent	S. mutans, S. salivarius and Lactobacillus acidophilus	The biocompatibility of the used materials was unaffected by the use of AgNPs in conjunction with other dental materials. In addition, all known bacteria species can be treated with antibacterial agents.
Espinosa-Cristóbal et al., 2019 Mexico [34]	cross-sectional research Using sterile wooden sticks and mechanical sweeping, dental plaque biofilm samples were collected from patients' mandibular molar interproximal sites at the gingival sulcus (subgingival level) and gingival margin (supragingival level).	*S. mutans*, *S. sobrinus*, *S. sanguinis*, *S. gordonii*, *S. oralis*, *P. gingivalis*, *T. forsythia*, and *P. intermedia*	Dental caries and periodontal disease could be controlled and prevented using the AgNPs as a potential antimicrobial agent.
Wu et al., 2019 China [35]	evaluate the inhibitory effect of reduced rapheme oxide-Silver nanoparticles (rGO/Ag) composite on the progression of artificial enamel caries biofilm model	*S. mutans*	As a novel composite material, rGO/Ag can be a promising antibacterial agent for caries prevention
Lampé et al., 2019 Hungary [36]	create and assess the antibacterial impact of Ag-NP coated Ti surfaces that, when used on the surface of dental implants, can aid in preventing such processes.	*S. aureus*	It is possible to create an AgNPs layer to give the implant surface antibacterial properties and to aid in preventing peri-implant inflammatory processes.
Choi, et al 2019 Korea [37]	various surface treatments have been developed to improve the antibacterial activity of titanium implant	*S. mutans* and *P. gingivalis*	It has been proven that the polydopamine and Silver coating on titanium's surface effectively slows the microbial growth that can result in the development of biofilm and the pathogenesis of gum disease in the mouth..
Rhshed et al., 2019 Egypt [38]	Examine how some oral bacterial pathogens are affected by the antibacterial activity of AgNPs nanoparticles.	*S. mutans*, *S aureus* and *E. faecalis*	Against three oral pathogens, AgNPs demonstrated good inhibitory effectiveness. These findings suggest a potential application for such bio-synthesised nanomaterial as an antibacterial agent in dental applications.
Omidkhoda, et al 2019 Iran [39]	Assess changes in working time, setting time, and surface detail reproduction as well as the antimicrobial effects of alginate combined with nanoSilver solution at concentrations of 500 ppm and 1000 ppm on common oral microorganisms..	*E.coli*, *S. aureus*, and *C. albicans*	Clinical evidence does not support the antimicrobial effect of Silver nanoparticles combined with alginate. However, there was little difference in the way it looked physically.
Guo et al., 2020 China [40]	In order to prevent infection and promote mineralization, a composite coating was created on a porous titanium surface. This coating was first created by depositing a poly-L-lysine (PLL)/sodium alginate (SA)/PLL self-assembled coating, then dopamine was added later..	*S. mutans* and S *aureus*	According to the antibacterial results, the composite coating killed or inhibited bacteria on the surface of the material as well as bacteria around it.
Zannella et al., 2020 Italy [41]	the production of a hybrid molecule composed of AgNPs and indolicidin, a well-known antibacterial peptide	*E. coli*, *P. aeruginosa*, and *S. aureus*.	A very low minimum inhibitory concentration (MIC) of 5 to 12.5 g/mL was required for the coated nanoparticles' antibacterial activity to significantly inhibit the growth of microorganisms.

Name	Objective	Microbes	Finding
Barot et al, 2020 India [42]	In order to compare the properties of corresponding composites containing conventional glass fillers, look into the impact of AgNPs immobilized Halloysite Nanotubes (HNT/Ag) fillers on the physicochemical, mechanical, and biological properties of novel experimental dental resin composites..	*S. mutans*	Dental resin composites made with Bis-GMA/TEGDMA and HNT/Ag have improved mechanical and biological properties.

According to earlier research, it was preferable to combine small amounts of AgNPs with PMMA, rapheme oxide-Silver nanoparticle, silicon, titanium, glycerolate, polyacrylate, porphyromonas, and diode laser to increase bacterial activity, increase flexural strength, and reduce conversion. By eliminating the microorganisms, this combination also increases the bactericidal activity of AgNPs, preventing dental caries and periodontal diseases.

Discussion

The effectiveness of Silver nanomaterials against cariogenic bacteria at both the minimum inhibitory concentration and the minimum bactericidal concentration varies significantly between studies [43-46]. The agar diffusion test showed that the inhibition zones on disks treated with Silver nanomaterial were larger than those on disks treated with water. Additionally, Silver nanomaterials' ability to prevent bacterial growth was shown by colony-forming unit counts. Additionally, they found that Silver nanomaterial-treated biofilm contained fewer bacteria than biofilm that had been treated with water. After applying Silver nanomaterials as opposed to after applying water, the bacteria in biofilm had significantly lower live-to-dead ratios [47, 48].

Silver nanomaterials also decreased the expression of the glucosyltransferases gene in the biofilm and decreased metabolic activity and lactic acid production. The antibacterial effect of smaller Silver nanoparticles has been proven to be stronger. In the meantime, materials' antibacterial properties were enhanced by the higher Silver nanoparticle concentration. Capping agents may also have an impact on how well Silver nanoparticles inhibit bacteria. [1]

Due largely to the antimicrobial potential of Silver ions, Silver has been used in dentistry since the 19th century for a variety of purposes. The nature of the stabilizing agent used in the formulation, which must permit constant interaction between the Silver nanoparticles and bacteria, is thought to affect the bactericidal activity and stability of Silver nanoparticles [49].

Studies have made use of cariogenic monospecies strains of the genera Streptococcus, Lactobacillus, Enterococcus, Pseudomonas, and Candida to show the antimicrobial action of Silver nanomaterials on microbial growth. The most frequently used bacteria in these studies is Streptococcus mutans. These are the cariogenic bacteria that are most frequently found in a carious lesion. Caries' onset and development have also been linked to streptococcus mutans. In the oral environment, bacteria collect to form biofilms in the extracellular matrix. By preventing agent transport, the biofilm can increase microorganism resistance to antimicrobial agents [48].

As an antimicrobial against S.mutans adhesion, growth, and subsequent biofilm formation in dentine lesions, in vitro evidence supports the use of Silver nanoparticles The use of AgNP-fluoride as a successful microbicidal in clinical settings is not sufficiently supported by the available data. The results and clinical relevance of these studies are constrained by the fact that only a few coronal dentine cariogenic microbes allow for conclusive inferences regarding the relative therapeutic efficacy of nano-Silver. The results, however, provide a useful framework for further investigation into other microbiota associated with dentinal caries [50].

Conclusion

In all studies, nanoparticles were found to have a strong antibacterial effect on oral pathogens; however, more research is needed to determine whether these particles are safe for use in mammalian cells.

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