Review Article

Antimicrobial Efficacy of Dental Materials Modified with Biosynthesized Silver Nanoparticles: A Review

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ABSTRACT

Background: Silver metal alloy has been used by dentists for more than 150 years in hundreds of millions of patients. It is the most thoroughly researched and tested of all the dental materials. Its antimicrobial property is attributed to sustained ion release. With advent of nanotechnology increased number of research on dental material containing Silver nanoparticles have proven the antimicrobial efficacy of the same. However the reduction of the Silver metal salts with chemicals pose a threat on the environment in the long term. Hence there is a growing trend towards green or biosynthesis of the Silver nanoparticles using microbe mediated or plant mediated reduction process. **Aim:** This paper reviews the antimicrobial efficacy of the silver nanoparticles which were biosynthesized in prevention of dental infections when used with materials used in dentistry. **Methodology:** The literature search was performed in PubMed using the Silver nanoparticles, biosynthesized, green synthesis, antimicrobial effect, dentistry. Only full text articles from 2013 to 2023 were considered. **Results:** The search retrieved 16 articles which were screened per exclusion criteria of removing duplicate studies, six articles were selected for review. **Conclusion:** Biosynthesized Silver nanoparticles are proven to be effective against Gram Positive, Gram Negative causing dental infections when used in conjunction with conventional dental materials.

Keywords: Silver nanoparticles, Biosynthesis, Green synthesis, Antimicrobial effect, Dental materials, Streptococcus mutans, Staphylococcus aureus

Nanotechnology is defined as the manipulation of matter with at least one dimension sized from 1 to 100 nanometers for industrial purposes [1]. Due to the recent advancements in nanotechnology, the use of these nano-molecules or atoms is not limited to industry but has led to an emergence in nanometals that are biomimetic, therapeutic, and custom-made. One such nanometal of interest which has gained popularity in the recent decades is silver nanoparticle. Due to a large surface-to-volume ratio, silver nanoparticles (AgNp) exhibit remarkable antimicrobial activity, even at a low concentration [2]. In addition to this, it has been proven that they are less cytotoxic, have lower immunological response, and are also available at a low cost [3].

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The aforementioned properties of silver nanoparticles and their antimicrobial effect make them an essential ingredient of choice in a wide array of dental materials. They can be incorporated into acrylic resins for the fabrication of removable dentures in prosthetic treatment, composite resinfor direct restoration in restorative treatment, irrigating solution, and obturation material in endodontic treatment, adhesive materials in orthodontic treatment, membrane for guided tissue regeneration in periodontal treatment, and titanium coating in dental implant treatment [4]. Increasing awareness of green chemistry and other biological processes has led to a desire to develop an eco-friendly approach to the synthesis of nanoparticles. Many studies have also focused on the investigation of the reduction mechanism using plant extract [5-9].

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In addition, the other major reason for the development of biosynthesis of nanoparticles is the need for environmentally benign processes [10]. There is a large body of references on the preparation of metal nanoparticles using some chemicals such as hydrazine, sodium borohydride (NaBH4), and dimethylformamide (DMF) that have been considered to have some environmental and biological risks [11]. Keeping the recent emerging trends in the biosynthesis of AgNP, different studies have been done testing the efficacy of these biosynthesized AgNp in combination with different dental materials against the most common causative Gram-positive and Gram-negative bacteria. This literature review was conducted to determine the antimicrobial effect of these biosynthesized AgNP when combined with conventional dental materials used in dentistry.

METHODS

The literature search was performed in PubMed using the following Medical Subject Heading (MesH) keywords, silver nanoparticles, biosynthesized, green synthesis, antimicrobial effect, and dentistry. The inclusion criteria were original articles published in the last 10 years from 2013 to 2023. The articles should have been written in English and should include clinical trials of in vivo studies or in vitro studies that investigated the antimicrobial effects of biosynthesized silver nanoparticles when used in conjunction with dental materials. The exclusion criteria were scientific articles that were not available or could not be accessed in full text and duplicate articles. The inclusion criteria were the use of only biosynthesized silver nanoparticles in conjunction with dental materials used in routine dental procedures.

RESULTS

In the search, a total of 16 articles were detected from the electronic database MEDLINE (Pubmed). After eliminating duplicates, a total of 12 studies were identified. After screening the full text of the remaining 12 articles, 6 were excluded because they did not meet the inclusion criteria. Finally, 6 articles were included in the review **(Figure 1).** The results of the studies reviewed are presented in **(Table 1)** [12-17]. Out of the six articles, three articles have used microbial mediated method of biosynthesis of silver nanoparticles [12-14]. However, these microbes were also extracted from plant sources. The remaining three articles have used the reduction of plant extracts to synthesize silver nanoparticles. All the articles included in the study have conducted characterization of the silver nanoparticles. The minimum inhibitory concentration (MIC) test was performed in all six articles to assess the antimicrobial activity of the silver nanoparticles.

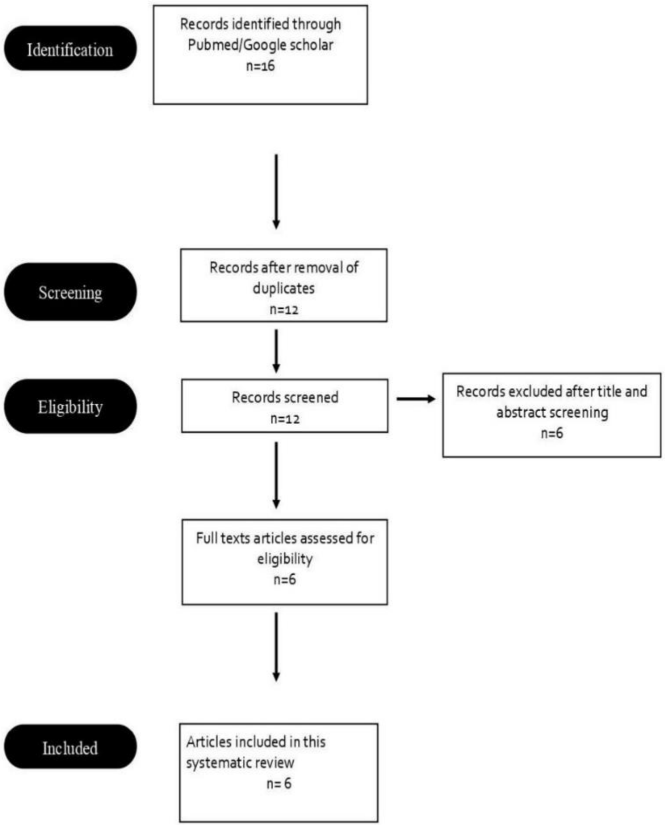

Figure 1: Search strategy for selecting studies in systematic review

Table 1: Studies included in systematic review

Authors	Source of biosynthesised AgNP	Method of characterization	Size of AgNP	Microorganism of study	Antimicrobial test
Tuba Baygar et al (2019) [12]	Microbial mediated synthesis of AgNPs, *Streptomyces griseorubens*	SEM & EDS	5-20nm	Candida albicans(a fungi), Escherichia coli (a gram-negative bacteria) and *Staphylococcus aureus* (a gram-positive bacteria)	Agar Diffusion test
Halkai K, et al (2017) [13]	Microbial mediated synthesis of AgNPs, using Fusarium semitectum isolated from *Withania Somnifera*	UV-Vis, TEM, SAED & FTIR	10 nm-20 nm	*P. gingivalis*	Agar Diffusion test
Halkai K, et al (2018) [14]	Microbial mediated synthesis of AgNPs, using Fusarium semitectum isolated from *Withania somnifera*	UV, TEM & FTIR	10 nm-20 nm	*P. gingivalis, Bacillus pumilus, and Enterococcus faecalis.*	Broth dilution method

Enan E, *et al* (2021) [15]	Cupressus macrocarpa extract as a reducing agent	UV-Vis, TEM & XRD	13.5–25.8 nm	*Streptococcus mutans* & *Staphylococcus aureus*	Kirby-Bauer method
Rodrigues M, et al (2020) [16]	Commercial green tea extract (Camelia Sinensis)	XRD	10.64nm	*Streptococcus mutans*	MIC test
Gad El-Rab et al (2021) [17]	Rosmarinus officinalis L. extract	UV-Vis, TEM, XRD, FTIR	ROE-AgNP 8.7 ±0.57 to 15.9 ± 1.15 nm	*Streptococcus mutans*	MIC test

List of Abbreviations: AgNp: Silver Nanoparticles, NaBH4: sodium borohydride, DMF: dimethylformamide, SEM: Scanning Electron Microscopy, EDS: Energy Dispersive X-ray Spectroscopy, TEM: Transmission Electron Microscopy, SAED: Selected Area Electron Diffraction Analysis, FTIR: Fourier Transform Infrared Spectroscopy, CHX: Chlorhexidine, XRD: X-ray diffraction analysis, MIC: Minimal inhibitory concentration test, ml: Milliliter, µg: Microgram, TEM: Transmission electron microscopy, UV: Ultraviolet spectroscopy.

DISCUSSION

Metal nanoparticles have been used in a wide-ranging application in various fields. Specifically, as shapes, sizes, and compositions of metallic nanomaterials are significantly linked to their physical, chemical, and optical properties, technologies based on nanoscale materials have been exploited in a variety of fields from chemistry to medicine [18, 19]. Recently, silver nanoparticles (AgNPs) have been investigated extensively due to their superior physical, chemical, and biological characteristics, and their superiority stems mainly from the size, shape, composition, crystallinity, and structure of AgNPs compared to their bulk forms [20]. There are mainly three methods of synthesizing these metal nanoparticles, physical, chemical/photochemical, and biosynthesis/green synthesis [21]. The chemical method is the most common method which includes the synthesis of metallic nanoparticles as a colloidal dispersion in aqueous solution or organic solvent by reducing their metal salts. The other method that is discussed in this article is the biogenic (green chemistry) metal NP synthesis method that employs biological entities, such as microorganisms and plant extracts. Quite a few bacteria have shown the potential to synthesize AgNPs intracellularly, wherein intracellular components serve as both reducing and stabilizing agents [12, 21].

Tuba Bayger et al have used this microbial-mediated biological synthesis of AgNP using cell-free extract of Streptomyces griseorubens. The resultant AgNP was characterized and was found to be spherical and crystalline particles with a 5–20 nm average size. The authors then coated non-absorbable silk surgical sutures with the biosynthesised AgNP. This antimicrobial activity of this Bio-AgNP was compared with non-coated suture material which served as the control group against Candida albicans (a fungus), Escherichia coli (a gram-negative bacteria), and Staphylococcus aureus (a gram-positive bacteria) using a standard agar plate method. In their study, the authors found that the biosynthesised AgNP showed zones of adhesion for fungi, Gram-positive, and Gram-negative bacteria but the highest zone of inhibition was seen for Candida albicans which is a fungi followed by Staphylococcus aureus (a Gram-positive bacteria), and Escherichia coli (a Gram-negative bacteria) respectively. Two other studies that used this method of synthesizing Bio-AgNP used Fusarium semitectum isolated from Withania somnifera also tested the antimicrobial properties of the resultant extract were tested against Porphyromonas gingivalis, Bacillus pumilus, and Enterococcus faecalis at different concentrations [13,14].

The results of these studies show that AgNPs are effective against both Gram-positive and Gram-negative microorganisms with minimum effective concentration values of 30 µg/ml Bio-AgNp against P. gingivalis and E. faecalis and 20 µg/ml Bio-AgNp against B. pumilus. This however differed from the findings of a study conducted by Tuba Bayger et al. [12] who reported the least inhibition zone for Gram-negative bacteria as the concentration of AgNPs required for its inhibition was more. The other three studies used plant extracts as reducing agents of Silver nitrate particles [14-16]. The resultant Bio-AgNP was tested in conjugation with different restorative and esthetic cements. It was found that irrespective of the derivative plant, the antimicrobial properties of the biosynthesized AgNP were statistically significant against different Gram-positive bacteria (Streptococcus mutant and Staphylococcus aureus).

The factors deciding the antimicrobial efficacy of these Bio-AGNP were found to be particle size, shape, and concentration. According to three studies, the effective size of the AgNP particles was determined to be between 10-20 nm against both Gram-positive and Gram-negative bacteria, as well as, fungi. However, according to the study conducted by Tuba Baygar et al, the effective size at which antimicrobial activity was reported was as low as 5 nm. This was the only study reporting antimicrobial efficacy at a concentration lower than 10nm. A study conducted by Sanaa M. F. Gad El-Rab et al also reported antibacterial efficacy when the size of nanoparticles started from 8.7 ± 0.57nm but that can be attributed to the fact that it was used along with Cefuroxime and the effective minimum concentration level was also higher at 25 µg/mL.

CONCLUSION

To conclude, incorporation of biosynthesized metal nanoparticles in dental materials has been shown effective against the common disease causative microbes in the intraoral cavity. Study shows that both plant-extracted and microbe-extracted silver nanoparticles have promising antimicrobial effects against Gram-positive, Gram-negative, and fungal microbes. The antimicrobial activity of these biosynthesized silver nanoparticles is dependent on the size, shape, and concentration of the nanoparticles. Silver nanoparticles were found to be most effective when between the sizes of 10-20 nm when spherical in shape and uniformly distributed in the dental aesthetic, restorative cement. The concentrations at which they showed maximum efficacy were 80 µl and 100 µl which was found to be comparative with 0.2% and 2% of chlorhexidine mouthwash. Although these studies suggest that environmental concentrations of AgNPs affect microbial biomass with a low impact on their diversity, further research needs to be addressed in order to determine the cytotoxic effects they could produce on human cells.

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