Nanoscience Technology in Pediatric dentistry

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**Abstract**

Nanoscience and nanotechnology represent burgeoning disciplines focused on the creation and utilization of materials and structures at the nanoscale. In dentistry, metallic nanoparticles and metal oxides are widely employed due to their ability to disrupt bacterial metabolism and inhibit biofilm development. Silver nanoparticles (AgNPs), a category of zero-dimensional materials with unique shapes, exhibit significant antimicrobial properties through mechanisms such as ion release, oxidative stress induction, and non-oxidative pathways. The antimicrobial properties of metallic silver have been recognized since ancient times, and over the years, various silver-containing compounds have been utilized to address numerous medical issues. The integration of silver nanoparticles into dental materials has the potential to improve both the mechanical characteristics and antibacterial efficacy of these materials. Consequently, there is a growing trend in the development of dental products that incorporate silver nanoparticles, thereby enhancing the overall oral health of patients. This paper seeks to review existing literature regarding the specific properties of silver nanoparticles and their applications in pediatric dentistry.

**Key Words**: Nanoscience, nanotechnology, nanoscale, nanoparticles (AgNPs) and silver.

**Introduction**

Silver nanoparticles have been recognized for centuries for their diverse biomedical uses, including antibacterial, antifungal, and anti-plasmodial properties. The antibacterial efficacy, however, is influenced by the concentration and rate of ionic silver release. Due to their nanoscale size and potentially extensive surface area, silver nanoparticles can interact directly with bacteria, inducing structural alterations that ultimately result in cell death. Furthermore, silver nanoparticles exhibit notable antibacterial and anti-adherence effects against Streptococcus mutans, the primary pathogen associated with dental caries, particularly those sized between 1-10 nm. Bacterial species vary in their membrane structures and are generally classified as Gram-positive or Gram-negative. The distinguishing characteristics include the thickness of the cell wall and the presence of an outer lipid membrane. Gram-positive bacteria have a cell wall composed of a peptidoglycan layer approximately 30 nm thick, while Gram-negative bacteria possess a thinner peptidoglycan layer (around 2-3 nm) encased by a lipopolysaccharide membrane. In the realm of dentistry, silver nanoparticles are among the most commonly utilized nanomaterials due to their antimicrobial properties, which are size-dependent. Particles measuring 1-10 nm exhibit a significant antibacterial effect owing to their increased surface area for interaction with microbial cells. Silver ions target various sites within the bacterial cell, leading to morphological and structural changes. [1-3]

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Mechanisms of Antimicrobial Action. Target Site Mechanisms of Antimicrobial Action Interaction of Silver Nanoparticles with Peptidoglycan Cell Wall Silver ions, due to their high reactivity, engage with and adhere to the negatively charged bacterial cell wall, modifying its permeability and resulting in cellular damage. Gram-negative bacteria possess a thin peptidoglycan layer, which is enveloped by an outer membrane composed of lipoproteins, phospholipids, and lipopolysaccharides. This outer lipid layer serves to facilitate selective permeability for specific substances. The bacterial membrane is rich in sulfur-containing proteins. Given that silver has a strong tendency to react with sulfur and phosphorus compounds, biologically active silver ions attach to the outer membrane, inducing alterations in membrane structure and increasing permeability. Some research indicates a mutual electrostatic attraction between the negatively charged bacterial cell and the positively charged silver ions. [4-7]

In gram-positive bacteria, the thick cellular wall may hinder the penetration of silver nanoparticles. The bactericidal efficacy of silver nanoparticles is influenced by their size and concentration, with nanoparticles measuring 1-10 nm exhibiting optimal interaction with the bacterial surface. Effect on Plasma Membrane In addition to their capacity to release silver ions, nanoparticles can also induce cell lysis. Nanoparticles smaller than 10 nm are particularly reactive due to their increased surface area for interaction with bacterial cells. These nanoscale particles can infiltrate the cell membrane, instigating structural alterations within the bacterial casing and obstructing the absorption of phosphate compounds, which are vital for numerous biological processes in bacteria, including energy metabolism, membrane integrity, genetic material inheritance, and intracellular signaling. Ionic silver interacts with thiol group compounds found in respiratory enzymes within the bacterial cell. [8-10]

The utilization of silver nanoparticles in pediatric dentistry has demonstrated significant antibacterial properties, effectively preventing dental caries in children. Prior studies have indicated their strong anti-cariogenic effects against Streptococcus mutans in laboratory settings. The virulence of silver nanoparticles is 25 times higher than that of other agents such as chlorhexidine, and they also exhibit antifungal and antiviral properties. Consequently, various formulations containing silver nanoparticles are beneficial in averting serious conditions like Early Childhood Caries (ECC) and Rampant Caries, primarily due to their capacity to penetrate and disrupt the biofilm matrix. [11-13]

Recent developments have introduced silver nanofluoride (NSF), which combines silver nanoparticles with fluoride. In vitro tests have assessed its effectiveness against cariogenic pathogens and its cytotoxicity, revealing a minimum inhibitory concentration (MIC) of 33.54 μg/ml and a minimum bactericidal concentration (MBC) of 50.32 μg/ml, comparable to Silver diamine fluoride (SDF), although enamel staining was not analyzed in this study. Additionally, a formulation incorporating silver nanoparticles, fluoride, and chitosan was tested. A single application of this customized varnish on dental caries was monitored at intervals of seven days, five months, and twelve months. At the seven-day mark, 81% of the samples exhibited arrested cavities; by the five-month evaluation, 72.7% showed signs of halted carious lesions, and after twelve months, 66.7% of the affected teeth remained stable, with no dark or black stains noted on the enamel.

In a similar study, silver nanoparticles were incorporated into a commercially available fluoride varnish to assess their effectiveness in remineralizing primary teeth affected by white spot lesions. [14-16]

Anterior primary teeth were selected for the study following evaluation with the DIAGNOdent laser wand. A formulation of silver nanoparticle powder combined with fluoride varnish was created at a concentration of 0.1% wt. Each quadrant of the mouth received treatment, with one tooth coated in the experimental varnish and the corresponding opposing quadrant receiving the standard control fluoride varnish. This treatment was administered weekly over a three-week period. Follow-up assessments were conducted using the DIAGNOdent after three months to measure remineralization changes. The results indicated that the remineralization rate was superior to that observed with plain water when treated with silver nanoparticles. Furthermore, another study investigated the effectiveness of pit and fissure sealants enhanced with silver nanoparticles. [17]

The microleakage of this experimental sealant was compared to that of conventional sealants in first permanent molars. The conventional sealant exhibited an average microleakage of 30.6%, while the sealant containing silver nanoparticles showed a microleakage of 33.6%. Notably, a significant reduction in fluorescence was observed in the group using the silver nanoparticle sealant. The adhesion of the pit and fissure sealants containing silver nanoparticles revealed an average difference exceeding 25% between the two groups, with the silver nanoparticle group demonstrating a faster reduction in fluorescence. This finding suggests that the teeth were more likely to remineralize when subjected to demineralization caused by microorganisms. [18]

Glass ionomer cement (GIC) integrated with silver nanoparticles is characterized by the presence of poly acrylic acid (PAA), a key component of traditional GIC. In an aqueous environment, PAA generates polyacrylate anions (PA−) alongside uncoordinated carboxylate ions (COO−), which can effectively bind to metallic cations such as silver salts (Ag+). A study focused on the antimicrobial properties and compressive strength of GIC containing silver nanoparticles detailed a tailored one-step synthesis of nanosilver within a long-chain PAA aqueous solution, followed by the photo-reduction of Ag+ ions into silver nanoparticles. This method was proposed to enhance the material's properties while preserving the fundamental structure of the cement. [18]

The increased concentration of silver within this specialized cement (NanoAg-GIC) resulted in a 32% extension of the setting time and demonstrated significant inhibition zones against Escherichia coli, suggesting that Ag+ ions were capable of diffusing into the surrounding material. Additionally, the metabolic activity of Streptococcus mutans was also influenced by the NanoAg-GIC. In orthodontic contexts, studies were conducted to evaluate composite resins containing silver nanoparticles for their effectiveness in mitigating white spot lesions near orthodontic brackets. In the comparative analysis, TiO2 nanoparticles were utilized. A light-cure orthodontic resin was infused with 0.5% (w/w) nano-silver particles (Ag, 99.99%, 20 nm) through thorough mixing to achieve a consistent distribution of the nanoparticles. Orthodontic brackets were affixed to the buccal surfaces of extracted teeth, which were then subjected to a cariogenic model. [19]

**Conclusion**

Overnight cultures of Streptococcus mutans (ATCC #35668) and Lactobacillus casei (ATCC #39392) were prepared in a dextrose-free trypticase soy broth, enriched with 5% sucrose (TSBS), and incubated at 37°C for use as the inoculum.

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