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Review:

Applications of silver nanoparticles in pediatric dentistry

Anil Kumar Patil[1], Anpam Saha[2], Mahesh Nunna[3], Jaya Chandra Bhumireddy[4]

Correspondence author: dr.jayachandra2509@gmail.com

Dr. Jaya Chandra Bhumireddy

Department of Pediatric and Preventive Dentistry, Government Dental College and Hospital, Kadapa, Andhra Pradesh, India

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Abstract

Nanotechnologies are fields that are growing all the time. At the heart of these fields is the creation and use of substances and structures on the nanoscale level. Because biofilms stop the growth of nanoparticles and oxides and stop bacteria from breaking down their food, they are used a lot in the field of dentistry. Silver nanoparticles, also called AgNPs, are solids that have no dimensions and come in many different shapes. Since ancient times, people have known that silver kills germs. Over the course of medical history, silver-based compounds have been used to treat a wide range of illnesses. Adding AgNPs to dental composites could improve both the materials' mechanical qualities and their ability to kill bacteria. The use of AgNPs in dental materials has led to a big change in patients' oral health, which has led to their widespread use. The goal of this study is to give an overview of the research that has already been done on AgNPs, including any relevant uses in the area of pediatric dentistry.

Keywords: Pediatric Dentistry, Silver Nanoparticles (AgNPs), Nanoscience, Oral Health

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Introduction

Metallic silver (Ag) has been used in the field of youth dentistry for a long time because it can stop the growth of microorganisms. Before it was found that bacteria caused infections, silver-based chemicals were used to treat a wide range of illnesses, such as ulcers, burns, and the healing of wounds in the teeth of young children and teens. This was done before people knew that germs were what made people sick. Ag has a lot of useful properties, and one of them is strong "antimicrobial (AM)" action against a wide range of infections [1]. Over the past few decades, antibiotics have become less efficient as the number of germs that are resistant to them has grown. Because of this, there must be bactericides that can cure bacterial diseases in kids and teens [2].

word "Nano" comes from the Greek word "Nanom," which means a dwarf or someone who is very short. This phrase refers to particles that are between one and one hundred nanometers in size and have between 20 and 15,000 silver atoms. Scientists in the field of biomedicine have known for a long time that AgNPs can kill bacteria, fungus, and plasmodium. On the other hand, the AB effect can be changed by the amount and speed of the ionic Ag release. Due to their nanoscale size and relatively large outer area, AgNPs could come into direct contact with germs, change their basic structure, and cause cell damage in children's teeth [3]. Synthesis can be done in many ways, including physically, chemically, and biologically [4],which means that nanoparticles can be made in a wide range of sizes and shapes. It is well known that Streptococcus mutans, the main bacterium that causes cavities in kids' teeth, is immune to AgNPs' AB and anti-adherence properties. AgNPs with sizes between 1 and 10 nm were very good at stopping "S. Mutans bacteria" from sticking together and doing AB [5]. There are a lot of different types of bacteria, and each type has its own wall structure. "Gram-positive bacteria (GPB) and Gram-negative bacteria (GNB)" can be put into different groups in a number of ways. The thickness of the cell wall and the presence or absence of an extracellular lipid layer are the two main ways to tell them apart. Even though GPB doesn't have a lipid membrane on the outside, the peptidoglycan layer that makes up its cell walls is about 30 nm thick. GNB bacteria still have a membrane made of lipopolysaccharides that is surrounded by a much thinner layer of peptidoglycan (2–3 nm) [6]. The lipopolysaccharide membrane is surrounded by this layer. Therapeutic oral health care to infants, children, and adolescents, including those with unique medical requirements. In pediatric Dentistryof the most often employed nanoparticles due to their mechanisms of AM activities. The size of the NPs affects their ability to kill germs in children's teeth. Smaller particles (1 to 10 nm) have a significant AB effect because they contact more microbial cells [7]. The “silver ions (AgI)” target many sites in the bacteria, causing structural and morphological alterations [8-13].

Pediatric dentistry is an age-defined specialty that offers primary and comprehensive preventative and therapeutic oral health care to infants, children, and adolescents, including those with unique medical requirements. In pediatric dentistry, AgNPs are one of the most often employed nanoparticles due to their mechanisms of AM activities. The size of the NPs affects their ability to kill germs in children's teeth. Smaller particles (1 to 10 nm) have a significant AB effect because they contact more microbial cells [7]. The “silver ions (AgI)” target many sites in the bacteria, causing structural and morphological alterations [8-13].

Applications of AgNPs in pediatric dentistry

Due to its potent AB action against various microbes, AgNPs have been effectively employed in several fields. In pediatric dentistry, AgNP may be used for prophylaxis, sanitation, and infection prevention in the oral cavity.

Synthesis of AgNPs

Because metallic NPs have considerable surface energy, AgNPs are synthesized using a forerunner (often Ag nitrate), a reducing agent that converts AgI from “Ag^+ to Ag^0”, and a stabilizer that prevents nanoparticle formation. As a result, AgNP production might be chemically, physically, or biologically. AgNP is created by chemically reducing Ag^{+1} to Ag^0. The “reduction agents and stabilizers” utilized, including such “sodium citrate, ascorbate, sodium borohydride, elemental hydrogen, polyol process, Tollen’s reagent, N, N-dimethylformamide, and poly (ethylene glycol)-block copolymers," serve as a representation of the differences across chemical processes. “Thiols, amines, acids, alcohols, and polymeric substances like chitosan [14, 15, 16] and polymethylmethacrylate” [19, 20, 21] have all been used as protective agents. These substances prevent the agglomeration and sedimentation of dispersive NPs by stabilizing them throughout the manufacturing process and defending NPs that may bind to or absorb on nanoparticle surfaces. Thermal synthesis, spray pyrolysis, and UV light are all used in physical synthesis [23].

Discussion

Other researchers have discovered an unusual synthesis by directly sputtering a metal into anhydrous glycerol. Toxic reducing agents like sodium borohydride and the discharge of AgNPs into the environment have raised concerns. As a result, efforts are being made to develop inexpensive synthesis procedures and environmentally responsible techniques that do not involve using hazardous chemicals. In contrast to “chemical and physical syntheses, biological synthesis” emerges as a viable alternative and an effort to simplify the process. It employs eukaryotic creatures like fungi and plants and prokaryotic species like bacteria as possible reducing agents [25, 26].

Different AgNPs Types Used in Pediatric Dentistry

Similar to other silver-containing compounds, AgNPs' biological activity in children and adolescents is driven by the "redox reactions" that arise from Ag's delayed release in the presence of water. Additionally, the size and shape of NPs affect their ability to inhibit the proliferation of bacteria, fungi, and viruses; sizes less than 10 nm have the most substantial AM effects [18]. The diverse nano-ionic origins of NPs may be used to explain the variety in sizes and forms. In pediatric dentistry, AgNPs are utilized in combination with components such as “Chitalac-Ag [22], AgNP-methyl polymethylmethacrylate [28], amorphous calcium AgNP-phosphate [29], and fluorides (Nano Ag Fluoride) [30]”. The dental care of children might use AgNPs or Ag plasma [31].

AgNP Action Mechanisms

AgNPs are commonly linked to AB and antioxidant properties. AgNPs' effect is mainly connected to their nanoscale, modifying the AgI release degree and interfering with exterior energy. NPs have strong AB properties compared to other AM treatments owing to their substantial exterior region, allowing for significant interaction with microbes [32].

In the past, AgNPs have shown therapeutic effects in children's dental care against various diseases, including bacteria, fungi, and viruses. Even “multi-resistant bacteria” are vulnerable to AgNPs, indicating that the processes that resist commercial antibiotics in these strains have no defensive action in Pediatric dental when treated to NPs.

One of the most significant modes of action of AgNPs is the formation of “reactive oxygen species (ROS)” and "Hydroxyl radicals cause oxidative damage." However, it also shatters nucleic acids, interferes with the respiratory chain, damages cell walls and membranes deplete intracellular ATP levels, and interacts with the respiratory chain. The size, shape, and target species of the NPs affect this action method differently in children's dentistry. This study focused on the AB action mechanism against GPB and GNB and the antifungal action mechanism against Candida albicans. Studies have indicated that GNB acts predominantly on the outer surface, causing the leaking of cell components, with “Escherichia coli” serving as a typical species [33]. AgNPs have also been shown to deactivate the respiratory chain dehydrogenases once within the cell, which prevents the growth and respiration of the cell.

Additionally, these NPs have the potential to interact with membrane proteins and phospholipids, leading to alterations in the permeability and breakdown of the plasma membrane. Reactive oxygen is primarily in charge of oxidizing lipids in E. coli. After being exposed to AgNPs, E. coli fragmented, according to electron microscopy investigations. GNB has shown no resistance to the dental effects of silver in children. The peptidoglycan cell wall structure affects how differently AgNPs interact with GPB and GNB. “E.coli and S. aureus," used as model organisms for research on GPB, were used to compare inhibition. It was shown that GNB is more readily inhibited than GPB [34]. Additionally, the respiratory chain's protein composition and membrane permeability in GPB alter, and ROS is produced. GPB experience oxidative stress that is more sudden than GNB. High ROS concentrations trigger the proteolytic pathway and lipid oxidation, which cause protein breakdown, much as in GNB. Nevertheless, lipid oxidation in “S. aureus” is brought on by the hydroxyl radical. Similar to GNB microorganisms, GPB also experiences changes in membrane potential and DNA deterioration. Comparing the mechanisms of action of AgNPs in bacteria and fungus reveals that only eukaryotic cells can aggregate NPs into bigger particles [35]. It has been shown that in Candida species, AgNPs harmful activity is connected to both the ROS-mediated route, which causes defective “mitochondrial apoptosis, and the ROS-independent mechanism," which results in similar cell failure which is comparable to how AB agents work, AgNP also interferes with the potential, integrity, fluidity, proliferation, and cell cycle of Candida species. Furthermore, the synthesis process influences the behavior of AgNPs in children's teeth, with biogenesis yielding superior results. [36].

AgNPs-containing glass ionomer cement (GIC)

GIC, well-known for its fluoride release and storage capabilities, is used in numerous pediatric dental procedures. Restorative cement, including liner/base materials or luting cement, are two glass ionomer cement utilized on children and adolescents.[37] This release turns this cement into an "anti-caries agent as fluoride" prevents the enzyme enolase from functioning. To preserve its anti-caries action, this substance must sometimes get fluoride replenishment. In this situation, GIC would be more beneficial in preventing children's oral illnesses if it were impregnated with AM chemicals that lasted longer. A biomaterial having AB properties against both GPB and GNB was produced via the interaction of GIC with AgNPs. According to the authors, the oxidative disintegration in the cement matrix caused by the release of AgI, which inhibits adolescent tooth caries and prevents dental biofilm growth, causes the AM effect. When these materials are combined, mechanical properties like commercial GIC are presented [38]. In contrast, another research contends that this union lowers GIC rigidity and is "cytotoxic." However, when twelve nm AgNPs were evaluated with GIC, odontoblastic lineage cells were unaffected by their cytotoxicity. Additionally, AgNP immobilization in "Halloysite Nanotubes (HNT/Ag)" and its integration into a unique investigational oral resin combined suppress the development of "S. mutans without cytotoxicity" [39]. Researchers have integrated AgNPs into a "resin matrix" composed of "bisphenol A-glycidyl methacrylate/triethylene glycol dimethacrylate (BISGMA/TEGDMA)," which is used in the repair of enduring dentitions using "chitosan polymers." They discovered AB activity against "S. mitis" and demonstrated that covering restorative materials with this polymer reduces AM activity. AgNP's combination with composite resins did not affect the material's little infiltration [40]. The kind of polymerization these nanocomposites underwent impacts their ultimate mechanical characteristics. Compared to commercial resins, using " photopolymerization " to create resins containing AgNPs did not enhance their mechanical qualities. The surface wetting and cohesive failures of dentin adhesives in combination with AgNPs increased [41]. In pediatric dental, AgNP inclusion increased the AB activity's durability when "self-etching adhesives and S. mutans" were examined. AM activity was shown without impairing the adhesive's ability to become resin. For urgent AM requirements, it may be used. AgNP-based two-step adhesive systems performed better regarding shear strength than AgNP-based self-etchers [42]. Regarding AB activity and the "self-etching adhesive" conversion amount, AgNP powder outperformed alcoholic AgNP solution. Incorporating AgNP into disinfectants generated biocompatible, non-cytotoxic commercial solutions (Nanocare Gold) [32].

Fissure and pit sealants (FPS)

In another study, the effectiveness of FPS with additional AgNPs was assessed. In the first permanent molars, the microleakage of this innovative sealant was compared to that of standard sealants. The conventional sealant revealed a mean microleakage of 30.6%, whereas the sealant with AgNPs displayed 33.3%. In addition, the AgNPs sealant group showed a significant decrease in fluorescence. The adherence to FPS using AgNPs varied across groups by an average of more than 25 percent. The AgNPs group tended to lose fluorescence more rapidly. This demonstrated that when the microbe induced demineralization, the children's teeth tended to remineralize [43, 44].

Discussion

The prevalence of dental caries in children has decreased in many nations in recent years. Caries remain a significant public health concern. Approximately twenty-five percent of children and adolescents aged five to seventeen years are responsible for 80% of dental caries in permanent dentition [46]. Most of these goods aim to remove "S. mutans" using therapeutic or preventive methods once the carious lesion has healed. These resources include "mouthwashes, fluoride varnish, fluoride foods, toothpaste, gels, laser treatment, and pit and fissure sealants.

Fissure sealants" are frequently used as a preventative strategy in various nations. FS has significantly lowered the incidence of tooth cavities. FPS, which are mechanically retained resins applied to the enamel's surface to cover the tooth's anatomical "defects," have successfully prevented tooth decay in molars. In children aged six and nine who attended public schools, [45] assessed the efficacy of "sealant retention" and caries prevention with and without primer and bond below the FS Most people in our demographic wait for periodic updates, and dental health education needs improvement. By inhibiting the "respiratory chain's enzymatic systems and changing DNA synthesis," silver has significant antibacterial effects that are dependent on superficial contact.[47] evaluated the use and efficacy of applying sealants to children's first and second permanent molars in private dental clinics by using an insurance claim database. Five years after receiving "sealant," results for beneficial outcomes were compared between children who received it and those who did not. "Occlusal caries incidence and sealant usage" were both lower than anticipated. Additionally, five years later, teeth were only 50% more likely than un-sealed molars to have hadexterior repaired. Bactericidal activities against "S. mutans" have been demonstrated for "silver diamine fluoride and silver nitrate." However, their application has been restricted due to tooth pigmentation brought on by high concentrations of Ag precipitation, which can also induce soft tissue frustration due to deep AgIdiffusion into the dentin [48].

Conclusions

AgNPs' strong AB effect and high volume-to-surface ratio are what are driving biological applications. Materials containing AgNPs have demonstrated strong AB effects in pediatric dentistry. These metallic nanoparticles produce AgI, which prevents planktonic bacterial cell attachment and biofilm formation. Composite resins, root canal fillings, glass ionomer cement, and pit and fissure sealants have been observed to limit microbial development and improve physical properties when combined with AgNPs. AgNPs prevent microbial colonization. The review also highlights the need for long-term clinical studies with AgNPs in pediatric dentistry.

The Authors

Dr. Anil Kumar Patil

Anil Kumar Patil Department of Pediatric and Preventive Dentistry. Aditya Dental College, Beed, Maharashtra, India

Dr. Anupam Saha

Anpam Saha Pediatric Dentistry, Sairam Dental Hospital, Calcutta 700012, West Bengal, India

Dr. Mahesh Nunna

Mahesh Nunna Department of Pediatric and Preventive Dentistry, Government Dental College and Hospital, Kadapa, Andhra Pradesh, India.

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