Review Article

Silver Nanoparticles and Its Applications in Dentistry – A Review

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Abstract

Oral cavity is a gateway to the entire body and protection of this gateway is a major goal in dentistry. Plaque biofilm is a major cause of the majority of dental diseases and although various biomaterials have been applied for their cure, limitations pertaining to the material properties prevent achievement of desired outcomes. Nanoparticle applications have become useful tools for various dental applications in endodontics, periodontics, restorative dentistry, orthodontics and oral cancers. Of these, silver nanoparticles (AgNPs) have been used in medicine and dentistry due to its antimicrobial properties. AgNPs have been incorporated into biomaterials in order to prevent or reduce biofilm formation. Due to greater surface to volume ratio and small particle size, they possess excellent antimicrobial action without affecting the mechanical properties of the material. This unique property of AgNPs makes these materials as fillers of choice in different biomaterials whereby they play a vital role in improving the properties. This review aims to discuss the influence of addition of AgNPs to various biomaterials used in different dental applications.

Keywords: Antimicrobial, nanotechnology, silver nanoparticles

Introduction

Nanotechnology is defined as the design, characterization and application of structures, devices and systems by controlling shape and size at a nanometer scale (1 nm to 100 nm).[1] Among various nanoparticles, silver nanoparticles have been one of the most popular objects of study in the recent decades. Silver (Ag) ions or salts are known to have a wide antimicrobial effect and they have been used for years, in different fields in medicine, including wound dressings, catheters, and prostheses. Besides being a potent antimicrobial, Ag has many advantages, such as low toxicity and good biocompatibility with human cells, long-term antibacterial activity, due to sustained ion release, and low bacterial resistance. In dentistry, silver nanoparticles are used to develop antibacterial materials to improve the quality of the dental appliance for a better treatment outcome.[2] They can be incorporated to acrylic resins for fabrication of removable dentures in prosthetic treatment, composite resin for 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.[3,4] This article provides an overview of the antibacterial use of silver nanoparticles in dentistry, highlighting their antimicrobial mechanism, applications and safety in clinical treatment.

Mechanism of Action

Silver ions are capable of acting on different structures of the bacterial cell. Primarily, these ions seem to adhere to the cell wall and cytoplasmic membrane through electrostatic attraction and affinity to sulfur proteins, thus enhancing the permeability of the membrane and also leading to disruption of these structures.[5] In Gram-negative bacteria, porins in the outer membrane are also involved in the uptake of AgNPs. Bacterial molecules that can be damaged by AgNPs include DNA, proteins, and lipids. AgNPs also stimulate oxidative stress response causing bacterial cell destruction and increase dephosphorylation of tyrosine residues on bacterial peptide

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substrates, inhibiting bacterial growth and viability. Cell membrane disruption and DNA modification through reactive oxygen species (ROS) as the principal agent were also described in the literature.[6,7]

Characterization of Silver Nanoparticles

One important step for the development of AgNPs containing materials is their characterization. Many studies have analyzed the Ag dispersion, through transmission electron microscopy. This technique allows visualizing how AgNPs spread into the tested material, as well as to verify the particle size. According to Cheng *et al.*, NAg particles of ~3 nm were clearly visible and well dispersed throughout the polymer matrix.[6,8] These results were confirmed in a subsequent study, in which authors reported NAg sizes ranging from 2 mm to 5 nm. This very small size allows NAg penetration on dentinal tubules, which can represent the possibility of inactivating residual bacteria on dentine. Another important feature to be analyzed is the minimum inhibitory concentration (MIC) of AgNPs. MIC is defined as the lowest concentration of antimicrobial agent at which 90% growth is observed in the medium.[9]

Clinical Applications for Silver Nanoparticles in Dentistry

Prosthetic treatment

Acrylic resin is commonly used to fabricate removable dentures. Opportunistic oral pathogens can colonize acrylic materials, causing dental infections, such as denture stomatitis. Silver nanoparticles can be added to acrylic resin to inhibit the growth of such bacteria as *Streptococcus mutans*, *Escherichia coli,* and *Staphylococcus aureus*.[10,11]

Implantology

The coating of implants has been a strategy to hamper bacterial adhesion to their surfaces and also to stimulate osseointegration and fibroblast proliferation. AgNPs together with other antibiotics have been tested in coating formulations, showing favorable results regarding antimicrobial activity.[12] AgNPs were used in combination with tantalum nitride for the coating of titanium substrates. The composites with a silver concentration of 21.4 wt% presented significant antibacterial effect against *S. aureus*.[13]

Orthodontic treatment

Patients undergoing orthodontic therapy are more prone for white spot or caries formation. Due to its antimicrobial action, AgNPs have been used in orthodontics either to prevent demineralization of enamel or adhesion of microorganisms. These have been used as coating on orthodontic brackets and in cements or adhesives to improve bond strengths and prevent caries or whitespot formation.[5,9]

Periodontics

The action of silver nanoparticles is not restricted to microorganisms that cause dental caries but can also be active for other cells and tissues of the oral cavity. Thus, some studies have demonstrated the action of AgNPs on human gingival fibroblasts and human oral keratinocytes. The strategy of capping silver nanoparticles can improve biocompatibility by creating surface functionalization.[2] Ten nm nanoparticles capped with lipoic acid or polyethylene glycol decreased the cytotoxic effects against human gingival fibroblasts at nontoxic concentrations (<50 μg/mL) and showed marked antimicrobial potential, inhibiting methicillin-resistant *Staphylococcus epidermidis* and *S. mutans* strain biofilms.[3]

Pediatric dentistry

Glass ionomer cement (GIC) has many uses in pediatric dentistry and is known by its fluoride release and storage capacity. This release makes this cement an anti-caries agent, as fluoride inhibits bacterial enzyme enolase.[14] However, this material needs to be replenished with fluoride from time to time to maintain its anti-caries effect. In this context, the impregnation of GIC with longer-lasting antimicrobial agents would make this cement more effective in combating oral diseases. The association between GIC and AgNP generated a biomaterial with antimicrobial action against Gram-positive and Gram-negative bacteria [5,6]. The authors believe that the antimicrobial action occurs through the release of silver ions, which causes an oxidative dissolution in the cement matrix, inhibiting dental caries and preventing the development of oral biofilms.

Endodontic materials

Successful root canal treatment depends on elimination of bacteria; materials used in its treatment should be able to eradicate these bacteria to better the outcome of endodontically treated teeth. Gutta-percha is the most preferred filling material in root canal therapy. Shantiaee *et al*., 2011 developed gutta-percha with nanosilver coating and tested their microleakage in obturated teeth. Although the results were comparable to normal gutta percha, nanosilver coated showed marginally less leakage than control.[7,15]

Porcelain for crown and bridges

Fujieda *et al*., 2012 studied the effect of silver and platinum nanoparticles on fracture resistance of porcelain. Fracture toughness and young's modulus increased with addition of both nanoparticles. They also investigated the influence of AgNPs on the behavior of subcritical crack growth of porcelains by postindentation method. The study discovered that with increased concentration of AgNPs, the fatigue parameter increased.[9]

Toxicity of AgNPs

Although the use of AgNPs improves the performance of dental materials, proactive approximations might also be introduced to establish safe conditions for the use of AgNPs in dentistry. The toxicity of AgNPs was demonstrated to be directly related to the activity of free Ag + ions released in the medium. Another concern exists about the capability of AgNPs to cross the blood − brain barrier through transsynaptic transport, with final accumulation in the brain. *In vitro* studies showed that AgNPs could induce a reduction in mitochondrial function in many contexts, such as in murine neuroblastoma cells, hepatic cells, human skin carcinoma, and human epidermal keratinocytes. In addition, *in vivo* studies showed the influence of these AgNPs on oxidative stress processes, thrombosis, myocardial infarction, and inflammation.[2]

Conclusion

Incorporating silver nanoparticles into dental materials may enhance the mechanical features and antibacterial properties of the dental materials. Although the mechanism of silver nanoparticles' antibacterial effects is not yet fully understood, many researchers believe that silver nanoparticles can continually release silver ions to kill microbes. An increasing number of dental materials with silver nanoparticles are being developed for prosthetic, restorative, endodontic, orthodontic, periodontal, and implant treatment. Some laboratory studies reported that silver nanoparticles have cytotoxic effects on human cells. However, the clinical significance of the potential toxicity of silver nanoparticles remains unknown. Further studies are essential because clinical evidence is still limited.

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Conflicts of interest

There are no conflicts of interest.

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