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REVIEW ARTICLE

# Silver Nanoparticles in Denture Base Material

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## ABSTRACT

Silver nanoparticles (AgNPs) have been synthesized and incorporated into several dental materials, since their small size provides great effects at low filler level. These nanoparticles have been applied in dentistry, in order to prevent microbial adhesion or to improve the various physical and mechanical properties of dental materials. This review aims to discuss the current progress in this field, highlighting aspects regarding AgNPs incorporation into polymethyl methacrylate based resins and its influence on its antimicrobial properties, thermal properties, and other mechanical properties.



**Keywords:** Antimicrobial, Flexural, Polymethyl methacrylate, Silver nanoparticles, Thermal, Viscoelastic.

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## INTRODUCTION

Polymethyl methacrylate (PMMA) based resins are widely used in dentistry for different purposes, such as removable base plates, functional appliances, and denture bases. The majority of prosthetic acrylic resins consist of PMMA and additional copolymers. Autopolymerizing acrylic resins have the advantage of rapid and easy handling.

Nanotechnology broadly refers to a field of applied science and technology whose unifying theme is the control of matter on the atomic and molecular scale. Nanoscience involves the study of materials on the nanoscale between 1 and 100 nm approximately.


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Silver ions ($Ag^+$) 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. Silver has many advantages except being antimicrobial, it has low toxicity, good biocompatibility with human cells, long-term antibacterial activity due to sustained ion release, and low bacterial resistance.[1]

With the advent of nanotechnology, silver nanoparticles (AgNPs) have been synthesized and they have shown potent antimicrobial properties. Silver nanoparticles have demonstrated unique interactions with bacteria and fungi species. Silver nanoparticles are smaller in size and hence, they possess physical, chemical, and biological properties that are distinctive from those presented by traditional bulk materials. Smaller particles and larger surface area provide potent antibacterial effects at a low filler level, diminishing Ag particle concentration necessary for its efficacy and avoiding negative influence on mechanical properties.[1]

Recently, more attention has been directed toward the incorporation of AgNPs into PMMA to improve its properties. In this review, we discuss AgNPs incorporation into acrylic resin denture base materials and highlight aspects regarding antimicrobial activity, viscoelastic, thermal, and mechanical properties of these modified materials.

## ANTIMICROBIAL EFFECT OF AgNPs

Dentures, mostly constructed by PMMA resin, have their inner surface incredibly rough, and this roughness allied to other factors (Poor hygiene, xerostomy, and HIV infection) contributes to the emergence of denture stomatitis. This pathology, characterized by red focal area, mostly localized in palatal mucosa is present in 50 to 70% of denture wearers, and it is frequently associated with *Candida* species colonization. These fungi colonize denture surfaces forming a biofilm which acts as a key factor to development of denture stomatitis.[1]

The treatment of denture stomatitis is based on topical or systemic antifungal drugs. However, this infection is often persistent since antifungal resistance has been reported in *Candida* biofilms. Another problem related to denture stomatitis is that most denture wearers are geriatric patients and it becomes difficult for them to keep the denture clean due to their limited manual dexterity and cognitive impairment.

Silver nanoparticles have been incorporated into polymers used for denture base and tissue conditioners.

Acosta-Torres et al[2] developed a PMMA containing 1 µg/mL of AgNPs and they compared this new compound to unmodified PMMA. They observed that PMMA-AgNPs specimen showed significantly less *Candida albicans* adherence compared to PMMA, showing the antifungal potential of AgNPs incorporated to acrylic resin. They also evaluated the activity of mouse fibroblasts and human lymphocytes, and it has been shown that PMMA-AgNP compound does not present cytotoxicity or genotoxicity. These results suggest that the novel acrylic resin incorporated with AgNPs could be developed as a denture base.

In a study performed by Monteiro et al,[3] AgNPs were incorporated in a commercial acrylic resin in different concentrations (0.05, 0.5, and 5% of AgNPs by mass). The authors evaluated the denture base resin through morphological analysis to check the distribution and dispersion of these particles in the polymer by testing the silver release in deionized water at different time periods. The authors concluded that the lower the volume of this AgNPs suspension, the lower the distribution and higher the dispersion of the nanoparticles in the PMMA matrix. Furthermore, silver was not detected by the detection limit of the atomic absorption spectrophotometer used in this study, even after 120 days of storage in deionized water, suggesting that AgNPs are incorporated in the PMMA denture resin to attain an effective antimicrobial material to help control common oral infections in complete denture wearers.

Nam et al[4] performed an *in vitro* study to determine whether the modified denture acrylic combined with different concentration of AgNPs (0 wt%, 1.0 wt%, 5.0 wt%, 10.0 wt%, 20.0 wt% and 30.0%) exhibits antifungal activity against *C. albicans*. They concluded that modified denture base acrylic resin combined with AgNPs at 20 wt% displayed antifungal properties.

Monteiro et al[5] evaluated the antifungal efficacy of AgNPs in combination with nystatin (NYT) or chlorhexidine digluconate (CHG) against *C. albicans* and *C. glabrata* biofilms. They concluded that the AgNPs combined with either NYT or CHG demonstrated synergistic antibiofilm activity, and this activity was dependent on the species and the drug concentrations used, suggesting that AgNPs in combination with NYT or chlorhexidine may have clinical implications in the treatment of denture stomatitis.

Similarly, Li et al[6] evaluated the effect of denture base resin containing AgNPs on *C. albicans* adhesion and biofilms formation. The results of their study suggested that the bioactivity and biomass of *C. albicans* biofilms successively decreased with increasing Nano silver solution concentration. Denture bases with higher concentration of AgNPs (5%) exhibited anti-adhesion activity to *C. albicans*.

According to a study conducted by Abdulkareem and Hatim,[7] it was concluded that samples prepared from microwave PMMA powder is a biocompatible material and AgNPs demonstrated good level of biocompatibility when added to microwave treated and untreated PMMA powder.

Nam[8] has incorporated AgNPs into a commercial tissue conditioner, in the following concentrations: 0.1, 0.5, 1.0, 2.0, and 3.0%. Their inhibitory effect was evaluated against *Staphylococcus aureus*, *Streptococcus mutans*, and *C. albicans* after 24 and 72 hours. The authors have reported that the modified tissue conditioner presented antimicrobial properties even at lower concentrations, i.e., 0.1% (for *S. mutans* and *S. aureus*) and 0.5% (for *C. albicans*).

## THERMAL PROPERTIES OF SILVER NANOPARTICLES

Appropriate esthetics and desirable characteristics of acrylic resin make this material a good candidate for prosthodontic applications. This material presents excellent esthetic properties, it has adequate strength, low water sorption, low solubility, and low thermal conductivity and is free from toxicity. However, it has limitations including a high thermal expansion coefficient, low thermal conductivity, a low elasticity coefficient, low impact strength, and low resistance to fatigue.[9]

Several researchers have demonstrated that PMMA can show good fatigue behavior and impact strength when it is reinforced by carbon fibers (CF). Polyethylene and sapphire fibers seem to enhance the physical properties of acrylic resin. Furthermore, physical and mechanical properties of acrylic resin, such as flexural modulus, can also be improved using metal fibers. For instance, the incorporation of silver, copper, and/or aluminum in the form of powder into the resin was found to improve its thermal conductivity, polymerization shrinkage, and water sorption. Recently, autopolymerizing PMMA resin was reinforced with silane-treated glass fibers which increased the strength of the resin. Therefore, numerous studies have been conducted to study the physical and mechanical properties of these materials.[9]

Rad et al[9] compared the thermal conductivity, compressive strength, and tensile strength of the acrylic base of complete dentures with those of acrylic reinforced with nanosilver. Results of this study suggested that the mean thermal conductivity and compressive strength of PMMA reinforced with nanosilver were significantly higher than the unmodified PMMA ($p < 0.05$). Hence, adding these particles to the palatal portion of the maxillary denture base is highly recommended.

Ghafari et al[10] did a similar study in which they added 0.2 and 2 wt% silver nanoparticle measuring 10 to 100 nm to the conventional acrylic denture base powder and evaluated its thermal conductivity. They concluded that the thermal conductivity of the reinforced resin was higher than that of the conventional resin and by increasing the amount of nanoparticles in the acrylic powder, the thermal conductivity increased.

Al-Noori et al[11] evaluated the thermal diffusivity of nano sized additives ($Al_2O_3$, ZnO and Ag) with different concentrations (0.25, 0.5, 1 and 2%) by weight on flexible denture base material. The results of their study showed that the 0.25, 0.5, 1 and 2% of each additives significantly increased the thermal diffusivity of flexible denture base material than control group because of the nano sized particles which might have acted as fillers and increased the thermal diffusivity of the material.

## PHYSICAL PROPERTIES OF SILVER NANOPARTICLES

An ideal denture base material is that which possesses biocompatibility with the oral tissues, excellent esthetics, superior mechanical properties like modulus of elasticity, impact strength, flexural strength, bond strength, ability to repair, and dimensional accuracy.

Clinical failures of complete or partial denture prosthesis caused from PMMA are most likely in the form of fracture either due to fatigue or impact forces of mastication.

Flexural fatigue of dentures as evidenced by midline fracture is due to the stress concentration around the micro cracks formed in the material due to continuous applications of small forces. Similarly, repetitive nature of masticatory load results in the propagation of cracks which weakens the denture base and finally results in fracture.

Several researches have tried to improve the physical and mechanical properties of the denture base material.[12]

Al-Noori[13] stated that the tensile strength of acrylic resin is typically not more than 50 megapascal (MPa), but the elastic modulus is low and the flexural modulus is in the region of 2200 to 2500 MPa. Therefore, the lack of strength and the toughness of acrylic resin dentures is a serious problem and this can result in fractures of upto 10% of dentures within 3 years of service.

Mahross and Baaroudi[12] investigated the viscoelastic properties of acrylic denture base material incorporated with AgNPs according to the concentration (1, 2 and 5%). The results of this study showed that 5% nanoparticles of silver had significantly highest mean storage modulus E′ and loss tangent values followed by 2% AgNPs ($p < 0.05$). For 1% silver nanoparticle incorporation, there were no statistically significant differences in storage modulus E′, loss modulus E″, and loss tangent with other groups, suggesting that the AgNP incorporation within the acrylic resin denture base material can improve its viscoelastic properties.

Ghaaffari and Hamedi-rad[14] studied the effect of AgNPs on the tensile strength of PMMA. They concluded that by adding AgNPs by 5 wt% decreased the tensile strength of the acrylic resin.

Sodagar et al[15] investigated the effect of AgNPs on the flexural strength of two types of PMMA (Selecta Plus and Rapid Repair). The authors inferred that Rapid repair without AgNPs showed the highest flexural strength. Addition of 0.05% AgNPs to rapid repair significantly decreased its flexural strength while, continuing the addition upto 0.2% increased it nearly up to its primary level. In contrast, addition of AgNPs to Selecta Plus increased its flexural strength but addition of 0.05% nano AgNPs was more effective than 0.2%. Thus, the authors concluded that the effect of AgNPs on flexural strength of PMMA depends on several factors including the type of acrylics and the concentration of AgNPs.

## CONCLUSION

In this review, the effect of AgNPs, when incorporated into PMMA, was investigated. Several studies have shown the antimicrobial effect of AgNPs when incorporated into acrylic resins and their use for treating common oral infections like denture stomatitis and other antifungal and antibacterial infections. Furthermore, nanoparticles can be modified to improve the thermal and mechanical properties of various acrylic denture base resin materials. Moreover, further studies are needed to investigate the Ag ion release and long term properties of AgNPs incorporated acrylic resin denture base materials. We encourage fellow researchers to study and elucidate the best ways of silver incorporation in dental materials and detail the possible negative influence of its addition in dental materials.

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