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SILVER NANOPARTICLES: A NEW PERSPECTIVE IN ENDODNTIC THERAPY

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ABSTRACT

Silver has been in use in medicine since time immemorial because of its antimicrobial properties. But due to the emergence of antibiotics the use of silver has been declined. Several pathogenic bacteria have developed resistance against various antibiotics. This has led to reemergence of silver. Recently nano science and nanotechnology are gaining tremendous popularity. The small size of nanoparticles provides larger surface area and hence increases the effectiveness of nanoparticles. Silver nanoparticles are used in medical and dental applications ranging from silver based wound dressings, silver coated medicinal devices like catheters, endotrachial tubes, bone cements, in gels, lotions, cosmetics, in dental restorative materials, endodontic cements, dental implants caries inhibitory agents, and in prosthesis. The purpose of this article is to discuss briefly the potential role of silver nano particles in endodontic therapy.

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Silver nanoparticles; Root Canal disinfectant; root canal irrigation; Antimicrobial agent; Nano Sealer

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INTRODUCTION

For thousands of years, silver has been used in medicines as an antimicrobial agent. The use of silver as an antibacterial agent lessened with the discovery of antibiotics. The evolution of antibiotic-resistant pathogens has brought a revival in silver-based applications.[1] The use of silver nanoparticles as antimicrobial has become very popular. Silver has been widely used in medical and life-care polymers and exhibits antimicrobial action against gram positive, gram negative bacteria and fungi. This has stimulated incorporation of antimicrobials into dental materials such as silver, silver ions and silver nanoparticles (AgNPs). Some researchers used silver nanoparticles in dental restorative and endodontic materials to make them antimicrobial.

"Nano" is a Greek word synonymous to dwarf, meaning extremely small. Nanoparticles are clusters of atoms in the size range of 1-100nm. Nanotechnology modulates metals into their nanosize. This drastically changes the chemical, physical and optical properties of metals. Nanoparticles have been introduced as materials with good potential to be extensively used in biological and medical applications. Inorganic nanoparticles and their nano-composites are used as good antibacterial agents.[2] As per Humberto HH**,** particle size, size distribution, shape and surface chemistry of silver nanoparticles determine their performance and they determine in vivo distribution, biological fate, toxicity and the targeting ability of nanoparticle systems. [3] The small size and large surface area of the nano-particles can lead to particle-particle aggregation, making physical handling of nanoparticles difficult in liquid and dry forms. This aggregation may lead to the loss of properties associated with the nanoscale nature of the particles. Agglomeration and particle sizes of AgNPs are responsible for cytotoxicity. Smaller AgNPs (3 nm) are more cytotoxic than larger particles (25 nm) at a concentration of 10 µg/mL.[4] For better efficacy size, shape and morphology are important. Recent advances in Nanotechnology help in modulation of size and shape of nanoparticles.

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Antimicrobial actions of silver nanoparticles

The mechanism of the inhibitory action of AgNps on microbes is still not fully understood. Recently, it has been suggested that the antimicrobial mechanism of AgNps may also be related to membrane damage due to free radicals that are derived from the surface of the nanoparticles. This bactericidal activity also appears to be dependent on the size, shape and concentration of the AgNps. Silver nanoparticles bind to sulfur- containing proteins in biological molecules, resulting in pore formation in cell membrane or defect in cell membrane through the formation of reactive oxygen species (ROS) in the vicinity of bacterial cell membrane causing cell permeability and death.[5] As per other researchers it interacts with phosphorus- containing compounds such as DNA and various cellular enzymes such as cytochrome oxidase, NADH- succunate- dyhydroginase that affects cell division process and leading to cell death.[6] Both mechanisms depend on Ag release. Researchers have studied silver nanocomposites with antimicrobial, antifungal, antiviral applications in the medical field. But as compared to other fields application of silver nanoparticles in dentistry is less.

APPLICATIONS OF SILVER NANOPARTICLES IN DENTISTRY

Main intention of incorporation AgNPs into dental materials is to avoid or at least to decrease the biofilm formation and microbial colonization.[7] Silver nanoparticles are used in dental prostheses, implantology and restorative dentistry.[8,9,10,11,12,] Recently it is under research for its potential use in endodontic materials.

Silver nanoparticles in conservative dentistry

'Dental caries is one of the most common infectious diseases, in which demineralization of hard tooth tissues occurs by the acid produced as a result of fermentation of carbohydrates by bacteria. In today's scenario restorations with composite resins have predominantly replaced dental amalgam restorations. But composite resin restorations is polymerization shrinkage, which produces gap between the restoration and tooth structure, leading to recurrent caries and the final failure of restoration. Silver nanoparticles have been considered as antibacterial components in dental resin composites. Composite resins containing zinc oxide and silver nanoparticles can significantly inhibit the growth of two important oral cavity microorganisms: Streptococcus mutans and Lactobacillus. [13] Patrícia Bolzan Agnelli das Neves et al evaluated physical properties and antibacterial activity of a light-activated composite modified with silver nanoparticles. . Discs were produced with unmodified resin (control group - CG) and modified resin with silver nanoparticles. It was concluded that the discs with silver nanoparticals were less conducive to biofilm growth, without compromising the strength in compression and surface roughness.[14] Cheng et al.[15] studied the effect of AgNPs incorporation, at different concentrations, to a composite resin, in order to investigate its mechanical properties and biofilm formation. In this study, composites were synthesized with AgNPs at 0.028, 0.042, 0.088, and 0.175%. Mechanical properties of composites with AgNPs at 0.028% and 0.042% were similar to those with no AgNPs. Besides that, counts of colony forming units (CFU) for total streptococci and S. mutans, using AgNPs at 0.042%, were 75% smaller than the control group without AgNPs. These data suggest that AgNPs incorporation to composite resins enables good mechanical properties and notable antimicrobial potential, even at low concentration. [16] To evaluate the influence of AgNPs incorporation on bond strength to dental substrate, Melo et al. [17] added AgNPs, at 0.1% by mass, to an adhesive system. The results have shown that AgNPs did not compromise the bond strength, at the same time that it decreased metabolic activity on biofilm, compared to control group without AgNPs. In this study it was also observed reduction of CFU for total microorganisms**.** The longevity of tooth restorations may increase and it helps in reduction of bacterial biofilms on teeth and restorations. It has been showed by many researchers that addition of AgNPs in specific concentration not affects mechanical properties and cytotoxicity of composite resins and adhesive systems**.[16]** The biocompatibility of AgNPs-containing restorative materials was studied by Zhang et al. [18] have studied the effects of AgNPs incorporation on human gingival fibroblast viability., at 0. 05% by mass, to a primer and an adhesive. It has been shown that AgNPs addition did not affect the cytotoxicity of primer and adhesive tested, evidencing the clinical applicability of this antimicrobial**.** Thus many studies showed that the antibacterial effects of AgNPs-containing restorative materials might decrease the development of recurrent caries.

Silver nanoparticles and endodontic materials

Bacteria are the main etiologic agent of pulpal infection and periradicular lesion formation. [16, 19, 20, 21] The microbiota of infected root canals is polymicrobial and is dominated by Gram-negative anaerobes. [22, 23] The residual bacteria in root canal are connected with significantly higher rates of treatment failure. [23] Since elimination of bacteria in root canals is the key to treatment success [24], endodontic materials should ideally provide some antimicrobial activity [25, 26], in order to improve the prognosis of endodontically treated teeth

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.[27] Various materials have been used as root canal fillings, among which gutta-percha is one of the most used. [28] This material has been proved to present slight antibacterial property, provided by the zinc oxide in its components; however, this does not provide to gutta-percha an effective bactericidal potential. [29,16] Shantiaee et al. [27] tested the biocompatibility of this new material, by comparing the cytotoxicity of nanosilver-coated gutta-percha and normal gutta-percha on mouse fibroblasts. In this study, after 24 hours, nanosilver-coated gutta-percha presented cytotoxicity similar to normal gutta-percha and, after one week, it reached the lowest level of cytotoxicity among the tested materials. Dianat and Ataie have introduced nanosilver gutta-percha, the standard gutta-percha that is coated with nanosilver particles . The nanosilver gutta-percha demonstrates significant antibacterial effect against Enterococcus (E.) faecalis, Staphylococcus (S.) aurous, Candida (C.) albicans and Escherichia (E.) coli.[30]

The applications of nanotechnology are not limited to filling materials but have been extended to endodontic applications. A bioceramic based nanomaterials (EndoSequence BC sealer) composed of calcium silicate, calcium phosphate, calcium hydroxide, zirconia and a thickening agent, has been developed recently. Nanoparticles have improved the handling and physical properties. During the hydration reaction in the root canal, a nanocomposites structure of calcium silicate and hydroxyapatite is formed. The hydration reaction and setting time is affected by the availability of water and setting time may be prolonged in overly dried canals. Nano sized particles facilitate delivery of material from 0.012 capillary needle and adopt to irregular dentin surfaces. It sets hard in a matter of a few hours providing excellent seal and dimensional stability. Upon setting, it forms of hydroxyapatite; providing biocompatible and bioactivity. The highly alkaline pH (12.8) gives antimicrobial properties as well Another example is a silicon based sealer (Gutta-Flow Sealer) with an addition of gutta-percha powder and silver nanoparticles. This material is available in the form of uni-dose capsule that can be mixed and injected.This nano-sealer has good biocompatibility, dimensionally stable and sets within half an hour. This material has been reported to improve the sealing capability and better resistance to bacterial penetration. For infection point of view, the antibacterial activity of endodontic sealers can be very beneficial. Recently, antibacterial quaternary ammonium polyethyleneimine (QPEI) nanoparticles have been incorporated into existing sealers such as AH plus, Epiphany and Guttaflow. [31]

Other important step in the endodontic treatment is the chemomechanical debridement of pulpal tissue and pathogenic bacteria. In this stage, irrigant solutions should be used, for dissolving tissue and disinfecting the root canal system. [32] For this purpose, sodium hypochlorite (NaOCl) has been used for more than 70 years, and it remains as one of the most common solutions. [33] However, if NaOCl passes beyond the apex, it is extremely toxic to the periapical tissues. [34] Lotfi et al. [35] compared the antibacterial effect of NaOCl and AgNP solution against Enterococcus faecalis, which is a bacterium often isolated from failed endodontic treatment cases. They have observed that there were no significant differences among 5.25% NaOCl and 0.005% AgNPs, suggesting that this solution, in a remarkably lower concentration, possesses the same bactericidal effect as 5.25% NaOCl; hence, it could be used as a new intracanal irrigant**.**

Another important endodontic material is the mineral trioxide aggregate (MTA), used in many indications such as perforations sealing, external/internal root resorption repair, and apexification. In spite of being a material of wide application, the antimicrobial properties of MTA are controversial, and they seem to be limited. [36,37] Aiming to improve its antimicrobial potential, Samiei et al.[38] modified MTA by adding AgNPs, at 1% weight. Its effect against oral bacteria and fungi species was assessed. Results have showed that AgNPs-containing MTA possesses higher antimicrobial effect against Enterococcus faecalis, Candida albicans, and Pseudomonas aeruginosa, compared to unmodified MTA. To be used for antisepsis in root canal therapy longer than one session, silver nanoparticles must be able to penetrate dental tubules and the lateral channel systems and accessories. In this way, an adequate fluidity is necessary to facilitate penetration and draining of the radicular canal. [39]

CONCLUSION

The impact of nanotechnology on the field of dentistry is creating major changes with respect to improvement of health. Use of silver nanoparticles has had its greatest effect on restorative dentistry by contributing to the enhancement of antimicrobial properties of dental materials. Silver has been most extensively studied and used since ancient times. The uses of silver nanoparticles are varied and many. They are already entrenched for many commercial applications, certain medical applications and in dentistry. In dentistry it has been advocated as an antifungal agent used against all type of microbes. AgNPs possess great prospective due to their antibacterial, antifungal, antiviral, and anti-inflammatory properties. However, the pitfall of silver nanoparticles is that they can induce toxicity at various degrees. It is demonstrated that higher concentrations of silver nanoparticles are toxic and can cause various health problems. [40] AgNPs containing dental materials specially root canal irrigants and root canal filling materials present good antimicrobial properties. Many researchers have done in vitro studies. Since laboratory conditions do not entirely reproduce oral conditions in vivo studies are of great significance. Use of animal models and clinical studies to get a better understanding of the antimicrobial properties is necessary. [16] Studies should be carried out to determine the optimal concentration of this silver compound, in order to assure the antimicrobial effect without increasing its cytotoxicity and also to interrogate the Ag ion release and long-term properties of the AgNP-containing dental materials. Although AgNP is a promising antimicrobial, there are only a few studies employing it in endodontic materials. Considering that endodontic treatment success is highly connected to the elimination of bacteria, research involving AgNPs incorporation to root canal filling materials and intracanal irrigating solutions should be encouraged. Researchers must study the most suitable method of silver nano particles incorporation into endodontic materials.

CONFLICT OF INTEREST

There is no conflict of interest amongst the authors.

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We authors report no financial interests or potential conflicts of interest.

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