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Silver nanoparticles in dentistry

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ABSTRACT

Objective. Silver nanoparticles (AgNPs) have been extensively studied for their antimicrobial properties, which provide an extensive applicability in dentistry. Because of this increasing interest in AgNPs, the objective of this paper was to review their use in nanocomposites; implant coatings; pre-formulation with antimicrobial activity against cariogenic pathogens, periodontal biofilm, fungal pathogens and endodontic bacteria; and other applications such as treatment of oral cancer and local anesthesia. Recent achievements in the study of the mechanism of action and the most important toxicological aspects are also presented.

Methods. Systematic searches were carried out in Web of Science (ISI), Google, PubMed, SciFinder and EspaceNet databases with the keywords "silver nano* or AgNP*" and "dentist* or dental* or odontol*".

Results. A total of 155 peer-reviewed articles were reviewed. Most of them were published in the period of 2012–2017, demonstrating that this topic currently represents an important trend in dentistry research. *In vitro* studies reveal the excellent antimicrobial activity of AgNPs when associated with dental materials such as nanocomposites, acrylic resins, resin co-monomers, adhesives, intracanal medication, and implant coatings. Moreover, AgNPs were demonstrated to be interesting tools in the treatment of oral cancers due to their antitumor properties.

Significance. The literature indicates that AgNPs are a promising system with important features such as antimicrobial, anti-inflammatory and antitumor activity, and a potential carrier in sustained drug delivery. However, there are some aspects of the mechanisms of action of AgNPs, and some important toxicological aspects arising from the use of this system that must be completely elucidated.

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1. Introduction

The use of silver in oral care has been known for centuries and gained worldwide spread in the 19th century as one the main components in dental amalgams used for tooth restoration. Its use in amalgams has been reduced since 1930 as they were progressively substituted by esthetic polymer-based resins [1]. Since nanoscience has evolved and the outstanding antimicrobial properties of nanostructured silver-based formulations have been demonstrated against microorganisms such as bacteria, viruses, and fungi [2–8], the interest in silver has been renewed, and several promising new technologies are currently under development, especially in dental materials. In this context, AgNPs have been demonstrated to be effective antimicrobial components in prosthetic materials [9], adhesives [10,11], and implants [12,13], to promote caries arrestment [14], to prevent biofilm formation [15], and for osteogenic induction [16]. Fig. 1 shows the increasing interest in AgNPs in the 21st century in dentistry. As a result, it is reasonable to foresee that, in the near future, AgNPs will play an important role in oral healthcare.

Silver has a $[Kr]4d^{10}5s^1$ electron configuration. Since the 4d shell does not effectively shield the $5s^1$ electrons, they are strongly attracted to the nucleus, and a relatively high standard reduction potential is observed ($E^0(Ag^+/Ag) = +0.799$ V). Hence, metallic silver is rather unreactive. On the other hand, silver has the lowest first ionization potential in Group 11 and thus, Ag^+ is the most stable species in aqueous solutions, including physiological fluids, and in solids. Due to the filled 4d orbital, Ag^+ compounds present a significant covalent character and they do not tend to form organometallic compounds. In addition, they do form complexes with coordination numbers as low as 2 [17]. Silver ions form bonds preferably with sulfur but also with nitrogen and oxygen. So Ag^+ can bind to enzymes with S-pending groups as well as N atoms from nucleic acids [18]. Besides formulations containing Ag^+, other silver-based compounds have also been successfully applied in dentistry. For instance, the linear complex $[Ag(NH3)2^+]F$, which was recently cleared for caries arrestment in the US, is used in Japan for more than 80 years [19,20]. However, with the development of nanotechnologies, AgNPs have gained most of the focus.

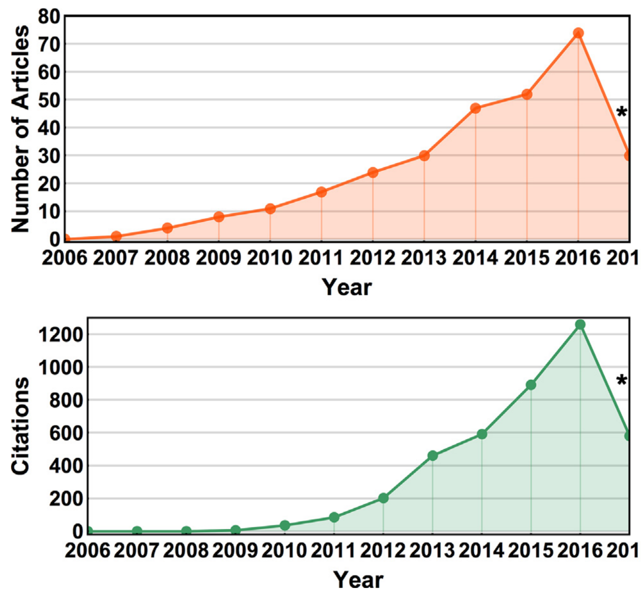

Fig. 1 – Flow chart of (top) the absolute number of publications enrolling the evaluation of AgNPs in Dentistry and (bottom) the citations associated with these publications. The literature search was based on Web-of-Science^{TM}, with the keywords "silver nano* or AgNP*" and "dentist* or dental*". For 2017 it was considered publications up to May (*).

It is now possible to produce AgNPs with controlled size and morphology, high homogeneity (i.e. low polydispersity index) [21], and specific target functions, (i.e. functionalized with molecular capping agents, from small hydrophilic and hydrophobic chemical groups to large biomacromolecules, such as proteins) [22]. The nucleation and growth process of AgNPs can be mediated both by synthetic reagents and by biologically available products from plants and microbes [23–25]. As the nanoparticle composition, particle size distribution, morphology and surface chemistry can be finely tuned [26–28], AgNPs can access different sites in the oral cavity; in such a way they can currently be conceived as multifunctional building blocks [29] for dental materials and dentistry protocols.