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Nanoparticles Technology and its Implications in Endodontic Management, Literature Review

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ABSTRACT

Graphene/organic nanoparticles are allotropes of carbon used for the formation of anti-bacterial surfaces as well as for the diagnosis and detection of disease. The most abundant natural biopolymer that can be chemically modified is Chitosan, based on the principle of cell membrane disruption by electrostatic interaction. Chitosan has shown excellent antimicrobial, antifungal, and antiviral properties. Non-organic nanoparticles are used to fill the apical third of the root canal because of their naturally high viscosity, among other advantages. Metal nanoparticles are widely used as dental fillers in multiple restorative materials, and also as a polishing agent because of their excellent biocompatibility and large surface area with low toxicity and density. Zirconia-based NPs are the NPs of choice. The Medline, Pubmed, Embase, NCBI, and Cochrane databases were searched for studies on the applied use of nanoparticles in endodontics and general dentistry. The focus was awarded to those studies which reported data on the type of nanoparticle and its application. Nanomaterials (NMs) have superior physical, mechanical, chemical, and biological properties and have been gaining importance in technological advancements. Further clinical studies are more than welcome, as they will allow authentication of the therapeutic value of nanotechnology-based materials.

Key words: *Nanoparticles, Endodontics, Antibacterial, Chitosan, Antimicrobial*

INTRODUCTION

Bacteria is the main actor responsible for the development of primary and persistent endodontic infections, either by persistence in the root canal environment after treatment or by reinfestation of the filled canal system [1-3]. Microorganisms have different pathways at their disposal to access the pulp chamber, such as breaches induced by caries in hard tissues, fractures caused by trauma, or in the wake of dental surgical procedures (for example, a gap in the cemental coating). Infection may also reach the necrotic pulp through a patient's general blood circulation because of transient bacteremia [4]. Root canal treatment is a fairly straightforward way to eradicate the bacteria. Before treatment, primary root canal infections consist typically of obligatory anaerobic bacteria, including but not limited to Gram-positive facultative Streptococcus. However, facultative bacteria (such as non-mutans streptococci, enterococci, and lactobacilli) tend to persist and are more resistant to treatment strategies [5].

Microorganisms capable of colonizing the necrotic root canal system are the likely initiators of periapical inflammatory lesions [6]. Indeed, the success of root canal treatment depends on the complete elimination of these microorganisms. They, along with the inflammation associated with them and the damaged tissues from the root canal act as a medium for re-colonization [3]. Nevertheless, the treatment is very likely to fail if microbes succeed in penetrating the root canal after obturation [7]. But clinical studies have revealed the persistence of bacteria within the root canal system, despite cleaning, shaping, and applying highly efficient antimicrobial agents [4]. The most probable reason for this, apart from the emergence of resistant pathogens, might be the root canal system's intricate anatomy that leaves some areas inaccessible to antimicrobial agents, possibly leaving behind localized bacteria in those areas [8]. Moreover, factors like concentration, time, and amount of bacterial agent within the root canals may affect its potency [9]. This problem is being addressed in part through the development of novel antimicrobial delivery systems [10].

Studies on potential antibacterial means to solve this problem have been performed. They were mostly unsuccessful in achieving desired results because of the pace of degradation of the antibacterial agents, leading to inefficiency and safety concerns [11].

To overcome the drawbacks of conventional antibacterial agents and achieve promising results, antimicrobial nanoparticles were introduced in endodontics. Indeed, they offer numerous advantages such as a large surface-area-to-volume ratio, ultra-small size, and excellent chemical and physical properties [11]. As per the European Commission's Recommendation, the nanomaterial is defined as "*a natural, incidental, or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the range 1–100 nm*" [12].

Prevention and treatment of dental infections have been greatly improved by the introduction of nanoparticles (NPs). Indeed, NP's are positively charged, and in combination with their increased surface area, it allows them to react with the negatively-charged bacterial cells. This causes increased antibacterial activity [8]. NPs can also be combined into polymers or coated onto biomaterial surfaces as a way of enhancing antimicrobial properties [11]. Dr. Richard Feynman was the first to address the concept of nanotechnology in 1959. In 1991, Dr. Sumio Lijima discovered nanotubes.

This review aims to discuss the Nanoparticles technology and in endodontic management and how it helps in the dental industry.

MATERIALS AND METHODS

PubMed database was used for articles selection, and the following keys were used in the mesh (("Nanoparticles technology "[Mesh]) AND ("in endodontic management"[Mesh]) OR ("Nanoparticles technology and in endodontic management Mesh])).

In regards to the inclusion criteria, the articles were selected based on the inclusion of one of the following topics: Nanoparticles technology and endodontic management.

Exclusion criteria were all other articles, which did not have one of these topics as their primary endpoint.

Around 90 publications were chosen as the most clinically relevant out of 1,202 articles indexed in the previous two decades, and their full texts were evaluated. A total of 31 of the 90 were included after a thorough examination. Additional research and publications were found using reference lists from the recognized and linked studies. Expert consensus recommendations and commentary were added where relevant to help practicing physicians assess cirrhosis most simply and practically possible.

Nanoparticles used in endodontics

Graphene/organic nanoparticles are allotropes of carbon (the thinnest material) that form an even crystal lattice without structural dislocations. This NP is used for the formation of anti-bacterial surfaces as well as for diagnosis and detection of disease [13]. The most abundant natural biopolymer that can be chemically modified is Chitosan, a deacetylated derivative of chitin. Chitosan NPs are based on the principle of cell membrane disruption by electrostatic interaction and have shown excellent antimicrobial, antifungal, and antiviral properties. Poly (lactic) co-glycolic acid nanoparticles and photoactive drugs are also administered as a critical adjunct to eliminate microorganisms from endodontic canals. A combination of light and methylene blue-filled NPs is used to combat microbes adhering to the root dentin and canals. Chitosan is one of the most relevant NPs in applied endodontics [14].

Non-organic nanoparticles (such as Mesoporous calcium silicate) are NPs with sizes ranging from 80 to 100 nm which have a high pore volume ratio and specific surface area. Typically, these NPs are used to fill the apical third of the root canal because of their naturally high viscosity [15]. They also offer other advantages in Endodontics, such as their drug delivery, their antibacterial efficiency, injectability, and apatite mineralization.

Metal nanoparticles (such as Silica Nanoparticles) are more used in conservative dentistry than in Endodontics. They remain, however, extremely useful: they display excellent biocompatibility and large surface area with low toxicity and density. This makes them widely used as dental fillers in multiple restorative materials, and also as a polishing agent (metal nanoparticles have the ability to produce less roughness of the polished substrate) [16]. Zirconia (ZrO2) has optical and metallic properties similar to the tooth and is a chemical oxide that has been considerably used in dentistry. ZrO2 is a high-performance ceramic material: it is tough, strong, shows high corrosion resistance, and has excellent chemical properties. It is also insoluble in water, which has been shown to eradicate bacterial colonization with few cytotoxic effects [17, 18]. Zirconia-based NPs are highly effective against specific microorganisms like E. Faecalis, which makes them a popular anti-microbial agent in endodontics [14].

Treatment

Irrigation is described as "washing by a stream of fluid". Intracanal irrigation "*facilitates physical removal of materials from the canal and introduction of chemicals for antimicrobial activity, demineralization, tissue dissolution, bleaching, deodorizing and hemorrhage control*" [19]. The most popular irrigant is Sodium Hypochlorite, as it has most of the ideal properties of an irrigant: it causes oxidation and hydrolysis of cellular proteins and dissolves organic and inorganic tissue. However, a major concern is its cytotoxicity, which creates impediments in usage due to the possibility of accidental extrusion beyond the apical foramen of the tooth [20]. Since conventional irrigants have known limitations, novel irrigation materials with nanoparticles have been introduced. It has been recognized that Chitosan nanoparticles enhance antibiofilm efficacy, and are capable of disabling bacterial endotoxins. Results have shown enhanced bacterial breakdown caused by an organized release of singlet oxygen species. They should be used as a finishing rinse in root canal irrigation, as they have been proven to be non-toxic to eukaryotic cells [21].

Antibacterial and anti-inflammatory agents can also be used between appointments with the practitioner. These intracanal medicaments have good biocompatibility and are placed into root canals to inhibit the invasion of bacteria from the oral cavity. They are available as gels, pastes, or points that are introduced into the canal, the most common being Calcium hydroxide paste. This paste causes the release of hydroxyl ions, which creates an increase in pH within the root canal. This distresses the DNA, cytoplasmic membranes, and enzymes of microorganisms. This product is available commercially and is known as NanocarePlus Silver and Gold (NanoCare Dental, Nanotechnology, Katowice, Poland). It has shown encouraging results as an intracanal medicament with antimicrobial properties.

Obturation is the process of filling a canal after it has been chemo-mechanically prepared and disinfected. For this purpose, a bulk filler (solid or semisolid) is used, alongside a sealer. Gutta-percha (GP), silver points, and Resilon are the most common fillers for the obturation procedure. The obturating material known as Gutta Percha is biocompatible, inert, and structurally stable. The latest preparations with GP have assimilated nanoparticles and bioglass to obtain proactive properties. However, Lee *et al*. reported that a nano-diamond GP (NDGP) composite combined with amoxicillin resulted in better mechanical properties (such as elastic modulus and strength) than just GP [22].

As for sealers, combining Endodontic sealers and obturating materials is an essential step to achieve a superior three-dimensional seal in the root canal system. Indeed, GP cannot be held to the root dentin despite the fact its flowability is increased when heated. Because of this drawback and to achieve a snug seal, a sealer is therefore required to fill the gaps between the obturating material and root dentine. A study by Kishen incorporated chitosan and zinc oxide nanoparticles in obturating sealers and showed inhibited bacterial penetration in the canal. The conclusion was that including these NPs in the sealers resulted in a successful outcome [23]. Zinc Oxide is commercially available as NanoSeal-S (Prevest DenPro) and has been synthesized for applications as a sealer. It was also demonstrated in a study by Del Carpio-Perochena that chitosan-loaded endodontic sealers maintained their anti-bacterial efficacy for a longer time [24].

RESULTS AND DISCUSSION

Nanotechnology is the manipulation of matter at the nanometre or molecular level. It currently has several different areas of application, including electronics and medicine. Its application in dentistry has led to the emergence of a new field, called nano dentistry, in the hopes of providing practically ideal oral health in practically all aspects of dentistry with the use of nanomaterials and nano-techniques [25, 26].

CONCLUSION

The influence of nanoparticles and nanotechnology in the field of dentistry is rapidly progressing every year, specifically in endodontics relating to the treatment of various oral diseases. Nanomaterials (NMs) have superior physical, mechanical, chemical, and biological properties and have been gaining importance in technological advancements. Their performance is much improved by these enhanced properties as compared to their conventional counterparts. Nanomaterials have also shown a much better capacity in reducing the formation of biofilm, encouraging tooth structure remineralization by stopping/slowing its demineralization process, and counteracting the endodontic and caries-related microorganisms. Further clinical studies are more than welcome, as they will allow authentication of the therapeutic value of nanotechnology-based materials.

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