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Nanoparticles and Its Implication in Endodontics – A Review

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ABSTRACT

The field of nanotechnology is growing by leaps and bounds. Since its ascend as one of the most favourable technologies, nanomaterials have found applications in different fields. Nanomaterials with their vastly improved properties have also seeped in the field of dentistry and found various applications. The materials manufactured using this technology are either new or are the improved version of the existing materials. Extensive research has been carried out in this field and its application in dentistry in general and endodontics in particular. This article discusses the current concepts of nanotechnology and their applications in endodontics. Nanotechnology is the future of dentistry and will play an important role in improving dental health of the patients..

Keywords:
Nanomaterials, Silver Nanoparticles, Chitosan, Bioactive glass

1. Introduction

Nanomaterials are defined as materials having extremely small size and possessing, at minimum one external diameter measuring 1-100nm. [1]

The improved properties of the nanomaterials are attributed to their enhanced chemical reactivity which in turn is due to the increased surface area and their ultra small size.

Removal of the microorganisms and the irritants from the root canal is the fundamental objective of endodontic treatment. The elimination of the highly organised microbial biofilm from the canal presents a significant challenge. Various methods which include use of antibacterial irrigants, activation of irrigants by ultrasonics, ozone, electrochemically activated water, lasers etc have been used in the eradication of the biofilms with limited success. The use of nanoparticles in elimination of the microbial biofilm is drawing considerable attention. Promising results in endodontics have been achieved due to their various mechanisms of action like targeted cell membrane destruction and production of oxygen free radicals which destroy bacterial DNA .[2]

In the field of endodontics, various inorganic, organic and bioactive nanomaterials are used as endodontic irrigants, as intracanal medicaments using different carriers or as endodontic sealers. Improvement of antimicrobial properties, mechanical properties of the materials and use of these materials in regeneration of previously diseased tissue remains the main focus of nanomaterials in endodontics.

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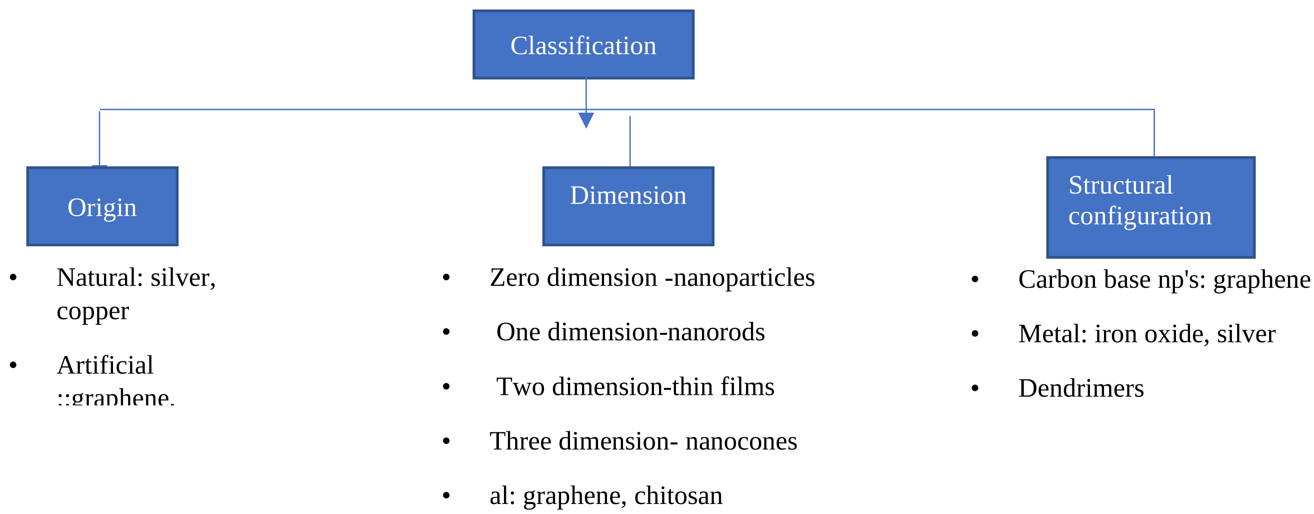
2.History

The term nanotechnology was first discussed by Dr Richard Feynman in 1959 . The concept of nanotubes was introduced by Dr Sumio Lijima in 1991. In the year 2000 the terminology "nano-dentistry" was introduced by Dr Freitas Jr. Since then nanotechnology has been used for tissue engineering, Molecular imprinting, nanorobotics ect. The ideas thought to be "science fiction", are currently being recognized by clinicians.[3]

3.Methods Of Nanoparticle Production:

Bottom-up approach: Seeks to organize more modest segments into more perplexing gatherings, the covalent obligations of which are amazingly solid.
Top-Down approach: Seeks to deliver more modest gadgets by utilizing bigger ones in accomplishing exactness in construction and gathering.
Functional approach: Develops components without regard to how they might be assembled but of the desired functionality.
Biomimetic Approach: Applies biomolecules for applications in nanotechnology.[4]

4.Classification Of Nanomaterials



5.Mechanism Of Action

Cell membrane disruption due to electrostatic interactions:
The bacterial cell surface is negatively charged. As the nanoparticles with positive charge react with the cell membrane and gather on it, there is an increment in the penetrability of the cell permitting the passage of an ever-increasing number of NPs into the microbes. This causes cell content spillage because of the holding of positively charged NPs to the cell membrane.

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Metal ion homeostasis

Excess of metal NPs leads to disruption in the haemostasis in the microorganisms. As the metabolic capacities are compromised there is irreversible damage which leads to growth disruption or death of the microbe.

Production of reactive oxygen species (ROS)

As the NPs enter the cell membrane of the microorganism, oxidative stress occurs in the cell. This causes the release of reactive oxygen species (ROS) which decreases the respiration and production of ATP in the microbe. The cell membrane is disrupted by active redox cycling and formation of ROS on the metal oxide-NP interface.

Protein and enzyme dysfunction

Inactivation of enzymes, destruction of catalytic activity and degradation of proteins occur by the formation of carbonyls by the nanoparticles...

Genotoxicity and inhibition of signal transduction

A negative effect occurs on the chromosomal and DNA replication of the microorganisms as NPs have a reaction with the cell nucleic acid leading to signal transduction inhibition .[5]

Antibacterial Nanoparticles

An important factor causing primary and recurrent endodontic infection is bacterial biofilms. Conventionally, various chemical irrigants having antimicrobial property were used along with mechanical instrumentation for eliminating these biofilms. [6]—Various in vitro studies have reported on the antimicrobial properties of the nanoparticles in elimination of biofilms and smear layer in endodontic infections.

Chitosan Nanoparticles (CS-NPs)

Chitosan is a natural polymer that is obtained from chitin. The crustaceans exoskeleton i.e. shells of crabs and shrimps remains the major source of chitin. Chitosan being a positively charged compound, exerts its antimicrobial action by its action with anionic bacterial cell membranes. This increases its permeability leading to seeping out of the intra-cellular constituents and subsequently bacterial destruction. Chitosan also has other properties like chelating actions, biodegradability and biocompatibility which makes it an attractive endodontic irrigant.[7]

Chitosan nanoparticle arrangements were found to hinder biofilm development. The bactericidal action of chitosan is time, fixation and contact dependent. There are numerous methods suggested to increase the effect of chitosan nanoparticles within the root canal. Conditioning of the root surface with carboxymethyl chitosan or chitosan -hydroxyapatite nanocomplex before obturation of the canal accounted for improved sterilization. The bacterial attachment to the root dentine was reduced and also sealer penetration into the dentinal tubules was enhanced.. Methods like electrophoresis, lasers, ultrasonics, dynamic activation are used to produce microbubbles enhancing fluid dynamics.

Chitosan also improves the wettability of dentine. Chitosan nanoparticles are shown to settle dentine collagen.. Thus chitosan has shown promising results as a novel irrigant. Certain limitations that require future research include increase in treatment time and contact-dependent nature of chitosan nanoparticle irrigants.

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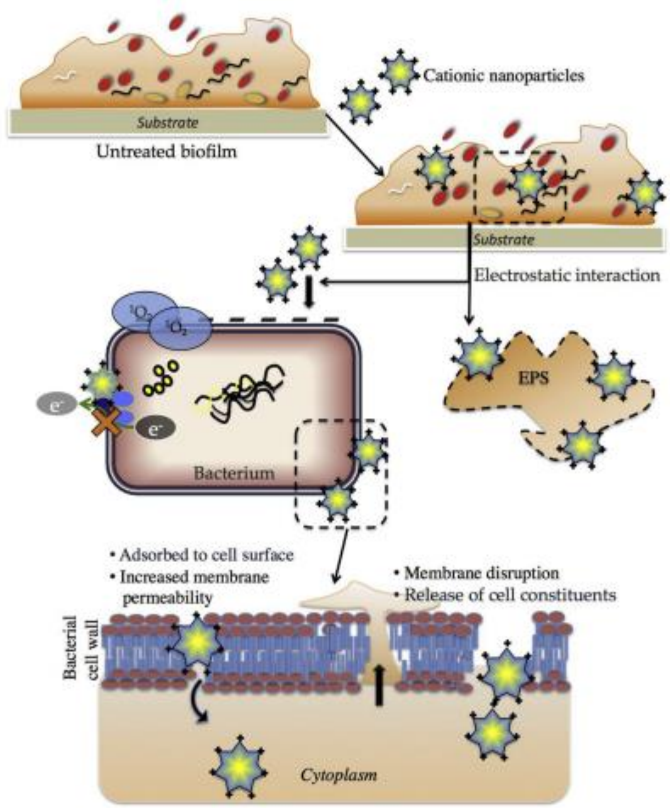

Figure 1 showing the antibacterial mechanism of nanoparticles with positive charge (e.g., chitosan).

Bioactive Glass (BAG)

Bioactive glass has been used extensively in dentistry due to its antibacterial and osteoinductive property. It is proposed that the antibacterial action of BAG is exerted by 3 different ways..[8] (figure: 2). The chemical composition of BAG consisting of CaO2, SiO2, Na2O, and P2O5 at different weights closely resembles that of the dentin[9]. Bioactive glass in micro-and nano forms has been used in root canal disinfection. The size of these particles range from 20 to 60 nm . The antibacterial action of BAG is dependent on the following factors.[10]

1. High pH: An increase in the ionic content leads to an increase in the pH.
2. Osmotic effects: As the osmotic pressure increases above 1%, it leads to death of many bacteria.
3. Ca/P precipitation: Induces mineralization on the bacterial surface.

Studies have found that nanoparticulate bioactive glasses are more alkaline and hence had greater antibacterial activity. Bioactive nanoparticles are amorphous in nature, exhibit a large surface area and have higher alkaline capacity thus eliminating biofilms significantly better.[11] When used with root canal sealers, bismuth oxide is added to nanosized BAG to improve the radiopacity of the sealer.

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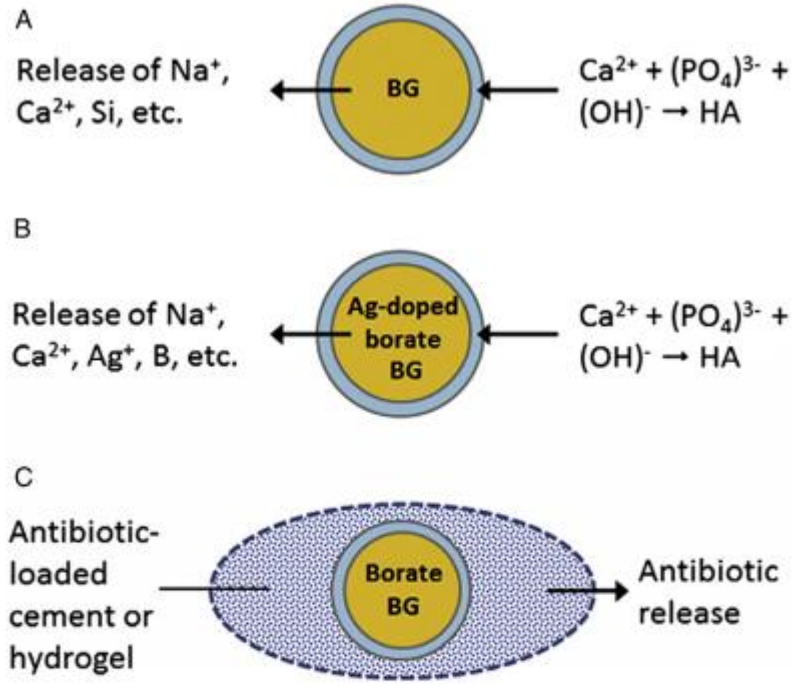

Figure 2. (A) Depicts change in the physiological condition by bioactive glass (B) Adding trace antibacterial elements like(Ag) which leach out as the glass degrades. (C) BAG used with antibiotics.

Silver Nanoparticles (Ag-NPs)

Silver nanoparticles have found large applications in endodontics due to their antibacterial properties and biocompatibility. The various mechanisms by which silver acts is

a.It interacts with the sulfhydryl groups of proteins and DNA thereby altering the hydrogen bonding/respiratory chain.

b.It interferes with cell wall synthesis/cell division.

c. They destabilize the bacterial membrane and increase bacterial permeability.

AgNPs can be obtained from various as bacteria, fungi, yeasts, leaf extracts, roots, and bark.

It was found that the antibacterial effect of AgNPs solution was comparable to 5.25% sodium hypochlorite against E faecalis. When used as an endodontic irrigant AgNPs in concentration of 50 µg/ml (0.005%) is bactericidal and concentrations above 80 µg/ml are considered cytotoxic levels.

MTA has varied applications in endodontics such as in pulp regeneration, treatment of perforations and , endodontic sealers. Samiei et al.,2013 tested the antibacterial effect of modified MTA by adding AgNPs, at 1% weight. Its effect on bacteria and C. albicans was studied. Results have shown that AgNPs-containing MTA shows a higher antimicrobial effect against pathogenic microorganisms compared to unmodified MTA.[12]

Magnesium-containing nanoparticles (Mg-NPs)

Magnesium-containing nanoparticles exhibit antimicrobial action against endodontic pathogens. Halogens are incorporated in Mg nanoparticles which help in infiltration of the cell wall and disruption in the membrane potential. As the cell membrane is destroyed more penetration of nanoparticles occur which cause the DNA to bind ultimately leading to cell destruction.[13]

Zinc oxide nanoparticles (ZnO-NPs)

The mechanism of action of Zinc oxide nanoparticles (ZnONPs) is identical to that of AgNPs. Their antibacterial effect depends on its concentration. Higher concentration results in more bactericidal action. Biofilm matrix disruption and elimination of planktonic *E. faecalis* are done by ZnONPs-based irrigants while retaining its bactericidal activity even after 90 days.

When the antibiofilm efficacy of zinc oxide nanoparticles was assessed against E. faecalis it was found that there was decrease in the cfus. When endodontically treated teeth were compared to hypochlorite group ZnONP resulted in almost 400N greater fracture resistance when used as a final irrigant.

Studies have shown improved properties of zinc oxide eugenol sealers after using ZnONPs. There was greater antimicrobial action, lesser microleakage, better dimensional stability and radioopacity.[14]

Endodontic Sealer

Gutta-percha powder and Ag- nanoparticles are added to Silicon-based sealers (Gutta-Flow). It is marketed as a uni-dose capsule .It is mixed and then injected in the canal This sealer has a setting time of half an hour and has good biocompatibility, and is dimensionally stable. The sealing capacity and resistance to bacteria are improved by the nano materials.[15]

6.Conclusion

The impact of Nanoparticles in the field of endodontics is quickly advancing . Their applications in the diagnosis and treatment of infections, in regenerative procedures is increasing. Their unique properties like larger surface areas, better reactivity have resulted in better antibacterial actions in contrast to their bulk counterparts. Additional clinical investigations are required to further enhance their properties and applications.

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