

NANOPARTICLES: EXPLORING ITS FRONTIERS IN ENDODONTICS

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ABSTRACT

Nanotechnology is receiving a lot of attention in recent times across the globe. With the help of nanotechnology we can easily analyze and manipulate the atoms, chemical bonds and molecules present between various compounds. Nanotechnology has gradually advanced so much in the last few decades, giving rise to numerous options in various biomedical field. It is also being used in the dental field known as Nanodentistry. Nanomaterials are the cutting edge of rapidly developing area of nanotechnology. In particular, the applications of the nanoparticles in endodontics has made an impact due to its unique properties.

KEYWORDS: Nanoparticles, Endodontics, Nanodentistry, Antimicrobial action.

INTRODUCTION

Nanotechnology is one of the most promising technologies of the 21st century. The National Nanotechnology Initiative (NNI) in the United States defined Nanotechnology as “a science, engineering and technology conducted at nanoscale (1-100nm), where unique phenomena enable novel applications in wide range of fields, from chemistry, physics and biology, to medicine, engineering and electronics.” The term nano is originated from Greek word called “dwarf.” Nanotechnology is a growing field that explores electrical, optical and magnetic activity as well as structural behavior at molecular and submolecular level. The term nanoparticles indicates the physical dimensions that are in the range of one billionth of a meter. This scale is called nanometer scale or nanoscale.^[1]

History

- Dr. Richard Feynman introduced the concept of nanotechnology in 1959. He is also known as the Father of Nanotechnology.
- Dr. Nori Taniguchi coined the term nanotechnology in 1974.
- Prof K Eric Drexler further probed in the dept of idea of nanotechnology. Published a book titled “Engines of Creation-The Coming Era of Nanotechnology” in 1986.^[2]
- The term “nanodentistry” was first popularized in 2000 by research scientist Robert Freitas.^[3]

Definition

The National Nanotechnology Initiative (NNI) in the United States define Nanotechnology as “a science,

engineering, and technology conducted at the nanoscale (1 to 100 nm), where unique phenomena enable novel applications in a wide range of fields, from chemistry, physics and biology, to medicine, engineering and electronics.”^[1]

Applications of Nanotechnology

The different fields that find potential applications of nanotechnology are as follows :

- a) Health and Medicine.
- b) Electronics
- c) Transportation
- d) Energy and Environment.
- e) Space Exploration.^[2]

Applications in Health and Medicine

The application of nanotechnologies to the medical sector is known as nanomedicine. This area of application uses nanometre scale materials and nano-enabled techniques to diagnose, monitor, treat and prevent diseases. These include cardiovascular diseases, cancer, musculoskeletal and inflammatory conditions, neurodegenerative and psychiatric diseases, diabetes and infectious diseases and more. The potential contribution of nanotechnologies in the medical sector includes new diagnostic tools; imaging agents and methods; drug delivery systems and pharmaceuticals; therapies; implants and tissue engineered constructions.^[4]

Classification of Nanoparticles in Dentistry

- NPs can be classified under three main categories as follows:

- 1) On the basis of origin, NPs can be classified as

- a. Natural
 - b. Artificial
- 2) On the basis of dimension
 - a. Zero-dimensional or nanostructures such as NPs
 - b. One-dimensional or nanorods and
 - c. Two-dimensional or thin films.
 - 3) On the basis of structural configuration
 - a. Carbon-based NPs
 - b. Metal NP
 - c. Dendrimers
 - d. Composites.^[5]

Mechanism of action

1) Electrostatic interaction leading to cell membrane disruption : The positively charged nanoparticles react with the negatively charged surface of microorganisms which leads to their accumulation of NPs on the bacterial cell surface. These positively charged NPs bond effectively to the cell membrane leading to disruption of the cell wall framework which leads to an increase in the permeability of the cell allowing the entry of more and more NPs into the bacteria, causing cellular content leakage. These NPs by binding to mesosomes, affect respiration, division, also DNA replication.

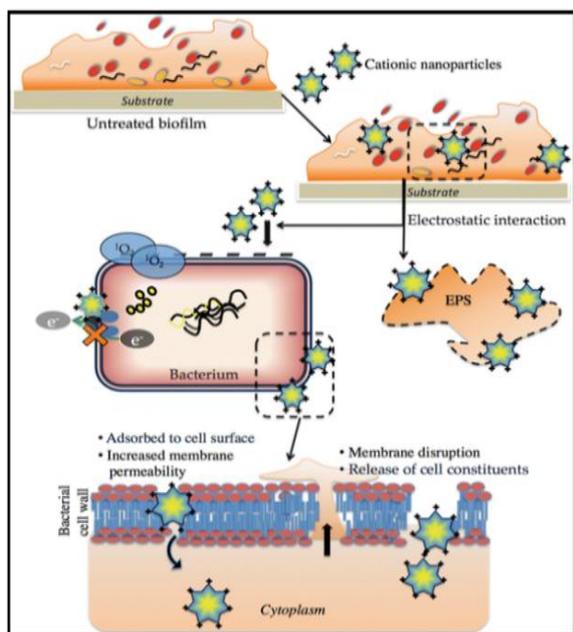


Fig 1: A schematic diagram illustrating the antibacterial mechanism of nanoparticles with positive charge [Eg: Chitosan]^[6]

Applications of nanotechnology in Dentistry

1) Tissue engineering and dentistry

Potential applications of tissue engineering and stem cell research in dentistry include the treatment of orofacial fractures, bone augmentation, cartilage regeneration of the temporomandibular joint, pulp repair, periodontal ligament regeneration, and implant osseointegration.^[7]

2) Bio-nano surface technology and dental implants

Many in-vitro studies have shown that the nanopography of the implant surface considerably affects osteogenic cells and that the nanoscale surface morphology enhances osteoblast adhesion. They provide an increased implant surface area that can react to the biologic environment by augmenting the nanoscale surface morphology to the surface area.^[7]

3) Dental nanorobots

Dental nanorobots are able to move through teeth and surrounding tissues by using specific movement mechanisms. Nanocomputers that have been previously programmed via acoustic signals used for ultrasonography can control nanorobotic functions.

Nanorobots (dentifrobots) left by mouthwash or toothpaste on the occlusal surfaces of teeth can clean organic residues by moving throughout the supragingival and subgingival surfaces, continuously preventing the accumulation of calculus.

Dentifrobots constitute a continuous barrier to halitosis by eliminating bacterial putrefaction products, a major cause of oral malodor. Thus, tooth loss and gingival diseases will be eliminated by providing these daily dental practices from a young age.^[7]

4) Nanocomposites

The latest advance in composite resins is the implementation of nanoparticle technology into restorative materials.

Bacteria cause plaque accumulation and subsequent periodontal disease by adhering to the rough surfaces of restorations. Several reports have indicated that significantly smoother surfaces were achieved using composites with nanofiller compared to other composites; This is because nanocomposites have much smaller sizes and contain much higher amounts of filler.

Nanofiller technology has enabled the production of nanofill composites by bringing together the esthetic features of microfill composites and the mechanical features of hybrid composites. In-vitro studies have shown that these composites had advantageous physical, mechanical, and esthetic features. Considering these features, the nanocomposite may be a concrete example of an ideal composite.^[7]

5) Nanomaterials for periodontal drug delivery

Researchers have attempted to generate an effective and satisfactory drug delivery system for the treatment of periodontal diseases by producing nanoparticles impregnated with triclosan. It was concluded that the application of triclosan particles into the test area alleviated inflammation.^[8]

6) Nanotechnology for preventing dental caries

The use of a toothpaste containing nanosized calcium carbonate enabled remineralization of early enamel lesions. Furthermore, a study that investigated the bacteriostatic effects of silver, zinc oxide, and gold nanoparticles on *Streptococcus mutans*, which causes dental caries, reported that compared to the other nanoparticles, silver nanoparticles had an antimicrobial effect in lower concentrations and with lower toxicity.^[7]

7) Digital dental imaging

Advances in digital dental imaging techniques are also expected with nanotechnology. In digital radiographies obtained by nanophosphor scintillators, the radiation dose is diminished and high-quality images are obtained.

8) Nanotechnology in oral and maxillofacial surgery

Selective cell manipulation and surgery performed with tools sized at the molecular level will provide great benefits, particularly in tumor tissue surgery.

9) Nanorobotic Local Anesthetics

Nanorobotic local anesthetics are composed of a colloidal solution of activated nanosized local anesthetic molecules. In nanodentistry, millions of active analgesic nanoparticles in a colloidal suspension are placed into the patient's gingiva, and the anesthesia effectiveness is controlled by the dentist via nanorobots moving into the gingival sulcus. Nanorobotic analgesics are an excellent modality to provide comfort to the patient and alleviate anxiety. Many of the adverse effects and complications associated with the use of typical local analgesic solutions are absent.

10) Dentinal Hypersensitivity

Dentin sensitivity is another pathology that is suitable for nanodental treatment. Many therapeutic agents provide only a temporary effect for this common, painful condition. However, dental nanorobots can seal specific tubules by using natural biomaterials within a few minutes and provide a quick and permanent recovery from this condition.

11) Orthodontic Nanorobots

Orthodontic nanorobots can directly manipulate all of the periodontal tissues, including gingival, periodontal ligament, cement, and alveolar bone. They can correct, rotate, or vertically reposition the teeth within a few hours in a pain-free manner.

12) Photodynamic Therapy

Antimicrobial photodynamic therapy (aPDT) is a relatively newly introduced treatment modality for removal of infectious pathogens. It uses a photosensitizer and light of a specific wavelength, eg, toluidine blue at 600-nm wavelength. Effective oral biofilm destruction with methylene blue dye (photosensitizer) encapsulated within poly(D, L-lactide-co-glycolide) (PLGA) nanoparticles (\approx 150 nm to 200 nm in diameter). A newly developed photosensitizer, indocyanine green

(ICG), with loaded nanospheres when activated with 805-nm wavelength using a diode laser, has an a PDT-like effect and may serve as a potential photodynamic periodontal therapy.

13) Nanocomposite Artificial teeth

Artificial composite teeth containing homogeneously diffused nanofillers have been reported to be superior to conventional acrylic teeth in terms of surface smoothness, abrasion resistance, and color stability.^[26,27] Enhanced antifungal activity along with increased fracture toughness is seen in silver nanoparticle modified denture teeth.

14) Nanodiagnostics

The advances in Nanodiagnostics are Nanoscale cantilevers, Nanopores, Nanotubes, Quantum dots, Nano Electromechanical Systems (NEMS), Oral fluid nanosensor test (OFNASET), Optical Nanobiosensor, Lab-on-a-chip methods.^[8]

Applications of Nanoparticles in Endodontics

Nanoparticles can be used as endodontic irrigants, photodynamic therapy, intracanal medicament, endodontic regeneration, root canal sealers and obturating material.

NANOPARTICLES USED AS IRRIGANTS

1) Chitosan Nanoparticles

Chitosan due to its chelating property sets apart the trace metals or essential nutrients and inhibits enzyme activities which is required for the survival of the bacterial cell. Chitosan exhibits its broad spectrum of antimicrobial action. The cationic compound interacts with the negatively charged bacterial cell membranes, which increases its permeability and leads to leakage of the intra-cellular constituents which ultimately leads to the cell death. Apart from its antimicrobial properties, chitosan is also biodegradable, biocompatible and has chelating abilities, making it an attractive alternative to modern root canal irrigants. Chitosan also exhibits excellent antibacterial, antiviral, and antifungal properties.^[9]

2) Silver Nanoparticles

- The antibacterial properties of Silver nanoparticles is because of its interaction with the sulfhydryl groups of proteins and DNA, which in turn alters the hydrogen bonding/respiratory chain followed by unwinding of DNA and its interference with cell wall synthesis/cell division.^[10]
- In regard to endodontic infections, AgNPs were shown to possess antimicrobial and antibiofilm efficacy against *E. faecalis*.
- A study showed that the antibiofilm efficacy of AgNPs for root canal disinfection depended on the mode of application and it was proved that gel was more effective than solution.
- In another study it was reported that AgNPs antimicrobial activity was on par with conventional

endodontic irrigants such as 2% chlorhexidine, 1% NaOCl and 5% NaOCl. On the other hand, some studies have questioned the efficacy of AgNPs-based irrigants in comparison to conventional endodontic irrigants. AgNPs solutions were less effective at reducing viable *E. faecalis* in biofilm than 2% chlorhexidine after 5 minutes of irrigation and only equally effective after 15 minutes.

- A 0.02 % AgNP gel as medicament significantly disrupted the structural integrity of the biofilm and resulted in the least number of post-treatment residual viable *E. faecalis* cells compared with 0.01 % AgNP gel, calcium hydroxide groups, and syringe irrigation with 0.1 % AgNP solution.
- They suggested that the prolonged duration of interaction between positively charged AgNPs and negatively charged resident biofilm bacteria when used as medicament for 7 days resulted in marked destruction of biofilm structure and killing of biofilm bacteria.
- Resin-based composites containing silver ion-implanted fillers that release silver ions have been found to have antibacterial effects on oral cariogenic bacteria (e.g. streptococcus mutans) . It could also be demonstrated that metallic implant coatings (silver and bismuth) released particles after 168h in culture medium in amounts of AgNPs (550g/L) or bismuth (80g/L).^[11]
- The cytotoxicity of AgNPs and their tendency to aggregate are the disadvantages of Silver nanoparticles.. The cytotoxic effects could be due to the production of reactive oxygen species that initiate pro-inflammatory host responses, the extent of which depends on the concentration, dimensions and aggregation of AgNPs. Furthermore, aggregation of AgNPs may also affect the release of Ag ions and hence decrease the antimicrobial efficacy. Stabilizing agents such as imidazole can prevent the aggregation of AgNPs and dampen the cytotoxic effects. Abbaszadegan et al reported that that imidazolium-based ionic liquid-protected AgNPs exhibited minimal cytotoxicity.^[12]

3) Metal Oxide Nanoparticles

- Metal oxide nanoparticles have also been investigated as potential endodontic irrigant. The mechanism of action Zinc oxide nanoparticles (ZnONPs) is similar to that of AgNPs.
- Zinc oxide nanoparticles (ZnONPs) have excellent bactericidal properties. When AgNPs and ZnONPs were combined in a polymeric solution there was greater activity against *E. faecalis* compared to when each of them were used independently. Nevertheless 2.5% NaOCl was still the best when it came in the reduction of colony forming units (CFU).
- When ZnONPs was used as a final irrigant, the mean fracture resistance of root canal treated teeth was greater when compared to NaOCl.^[13]

Magnesium oxide, titanium dioxide and iron oxide likewise exhibit antimicrobial properties, albeit the body of research on these compounds as potential endodontic irrigants is comparably less.

- Iron-oxide nanoparticles are widely utilized to eradicate biofilms on dental implants.
- TiO₂ nanoparticles are mostly used in medical and in the field of dentistry.
- These Particles are mainly used in the implant dentistry.^[14]

4) Gold Nanoparticles

- Gold is generally used in the nitrate form to induce antimicrobial effect, but when gold nanoparticles are used, there is a huge increase in the surface area that is available for the microbial expose on gold ions which is used in the formulation of dental resin composites, in coatings of medical devices, tooth pastes etc.
- Due to the nanostructure and high surface volume, biocompatibility of gold nanoparticles have been experimented with the treatment of gum disease, dental caries and they also possess antifungal and antibacterial activity.
- Gold nanoparticles have been reported to be a promising nanomaterial with substantial biomedical applications. However, they have not been as commonly investigated for their use in endodontics, possibly due to reservations regarding their antimicrobial efficacy.^[15]

5) Graphene Nanoparticles

- Graphene nanoparticles are used for the diagnosis and detection of disease and formation of anti-bacterial surfaces. But one of the main disadvantage of Sodium hypochlorite as an irrigant is it causes rapid hemolysis and soft tissue ulceration if extruded apically. By incorporating graphene into silver nanoparticles, the antibacterial property remained the same however, cytotoxic effects to bone and soft tissues showed reduction.
- He et al. in a study investigated the antimicrobial efficacy of Graphene oxide NPs against common pathogens like *S. mutans* and concluded that these nanoparticles were extremely effective in killing the growth of *S. mutans*.
- Graphene nanoplatelet, a derivative of Graphene has also shown antimicrobial properties against various microorganisms especially *S. mutans* in a study performed by Rago et al. The SEM images have shown that, a strong mechanical bond exists between the graphene nanoplatelet and cells which involves shrinking and trapping of cells ultimately leading to the death of these microorganisms.^[5]

Nanoparticle-Incorporated Root Canal Sealers and Obturation materials

1) Quaternary ammonium polyethylenimine (QAPEI) nanoparticles

QAPEI nanoparticles into AH Plus sealer shows superior antibacterial efficacy.

The bactericidal action of QPEI nanoparticles is improved by not only disrupting membrane integrity directly but also indirectly acting on distant regions of biofilms, although the exact mechanism is yet to be elucidated.^[16]

The addition of QPEI nanoparticles into AH Plus, an epoxy resin-based sealer, and Pulp Canal Sealer, a zinc oxide eugenol-based sealer, was also found to modulate osteoblast and osteoclast growth and differentiation by regulating intracellular signalling pathways, with the degree of impact depending on the concentration, bone cell type and sealer used. Furthermore, studies have shown the possibility of combining commercially available sealers and QPEI nanoparticles without having detrimental effects on sealer cytotoxicity and the physicochemical properties, such as solubility, flow, compressive strength and dimensional stability.^[17]

2) Silver Nanoparticle GuttaFlow sealer

- Gutta-Flow Sealer is a silicon based 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, limited toxicity to tissues, 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. No heating is required, hence no shrinkage and improved sealing capability (cold obturation).^[18]
- Silver Nanoparticle exhibit excellent antimicrobial properties, however concerns have been raised regarding their tendency to aggregate. Therefore to increase their potential application as endodontic sealers, nanostructured silver vanadate has been suggested as a means to stabilize Silver Nanoparticle. The extent of benefit from the addition of silver vanadate nanowires decorated with AgNPs may depend on the type of commercial sealer and the concentration used. It has been recommended that only higher concentrations of these compounds enhance the antimicrobial activity of sealers, thus more clinically relevant experiments should be carried out to ascertain the extent of the benefits against the costs, such as cytotoxicity and tooth discolouration.^[19]

3) Bioactive glass Nanoparticles

- Bioactive glass nanoparticles belong to non-organic nanoparticles. SiO₂, Na₂O, and P₂O₅ at altered

concentrations form the main components of Bioactive glass based NPs. Their size ranges from 20 to 60 nm in size.

- Bioactive glass nanoparticles have been suggested to cause closure of the interfacial gap between the root canal walls and core filling materials.
- In a study they have also used a combination of polyisoprene (PI) or polycaprolactone (PCL) and nanometric BAG 45S5 that could create a hydroxyapatite interface and thus ultimately make them as a use of an endodontic sealer.^[20]

4) Zinc Oxide Nanoparticles and Chitosan Nanoparticles

- ZnONPs can be used as an endodontic sealers or they can also modify existing zinc oxide eugenol sealers in order to improve physicochemical and antibacterial properties. The apical microleakage was less when obturated with gutta-percha and nano-zinc oxide eugenol sealer in comparison to AH 26TM and micro-zinc oxide eugenol sealer.^[21]
- The cytotoxic effects of nano-zinc oxide eugenol sealer were reported to be not more than that of other commercially available sealers, such as AH 26TM and PulpdentTM. Zinc oxide eugenol sealer was modified with different amounts of ZnONPs by Versiani et al and found that by replacing 25% of zinc oxide powder with ZnONPs there was improvement in physicochemical properties, such as dimensional stability, flowability, radiopacity and solubility.^[22]
- Several studies have explored the possibility of modifying existing zinc oxide eugenol sealers by using chitosan nanoparticles which improved their antibiofilm and antibacterial efficacy.^[23] The antibiofilm efficacy of a calcium hydroxide-based sealer and Apexit PlusTM was improved by using the combination of chitosan nanoparticles and ZnONPs, however only the sealer modified with ZnONPs was effective against the endodontic isolate strain of *E. faecalis*.^[24]

Intracanal Medicaments

1) Calcium Hydroxide nanoparticles

- Compared to the conventional counterparts, several studies have proved that calcium hydroxide showed deeper penetration into dentinal tubules and had better antibacterial activity against *E. faecalis*.^[25]
- Compared to conventional calcium hydroxide dressing, nano-calcium hydroxide resulted in lesser reduction of dentine microhardness. Conventional calcium hydroxide also exhibited lesser fracture resistance compared to the application of their nanosized counterparts. However cytotoxicity was found to be greater for nano-calcium hydroxide compared to conventional calcium hydroxide, although this finding was not statistically significant.^[26]

2) Silver Nanoparticles and Chitosan

- AgNPs exhibited better antibiofilm properties as medicaments rather than irrigants as a 4-week placement resulted in approximately 25% greater proportion of dead cells in *E. faecalis* biofilm compared to placement for 2 weeks. Hence longer periods of dressing lead to better effects.^[27]
- Application of a chitosan nanoparticle-based medicament resulted in appreciable antimicrobial properties and was less detrimental to dentine strength compared to calcium hydroxide, likely due to the promotion of collagen cross-linking and the neutralizing effect on matrix metalloproteinases. However, the same study found that the depth of sealer penetration into dentinal tubules may be compromised due to chitosan's tendency to agglomerate.^[28]

3) Bioactive Glass Nanoparticles

- Bioactive glasses have the ability to transform the alkalinity of the environment. Due to this they also possess antibacterial properties. Waltimo et al found that nanoparticulate bioactive glasses had greater antibacterial activity when compared to their micron-sized equivalents as they released more alkaline species. Nanosized bioactive glasses were modified with bismuth oxide to improve radiopacity whilst maintaining bioactive capacity as radiopacity is an important characteristic of endodontic sealers. Due to its antibacterial properties bioactive glass (BAG) received considerable interest in root canal disinfection.^[20]

4) Poly (lactic) co-glycolic acid Nanoparticles

- Poly (lactic) co-glycolic acid Nanoparticles incorporated with photoactive drugs are used as an essential adjunct in the eradication of microorganisms from endodontic canals. The combination of these methylene blue filled NPs and light are used to reduce microbial counts adhered to the root dentin and canals. It is one of the most important NPs used in the application of endodontics.
- According to a study conducted by Firas Elmsmari et.al in the article titled Calcium hydroxide-loaded PLGA biodegradable nanoparticles as an intracanal medicament, they concluded that $\text{Ca}(\text{OH})_2$ biodegradable PLGA NPs demonstrated prolonged drug release and increase penetration depth inside the dentinal tubules of extracted teeth which may constitute a suitable alternative as an intracanal antibacterial medicament. Further studies are needed to assess the antibacterial capacity of the $\text{Ca}(\text{OH})_2$ NPs.^[28]

Adverse effects of Nanoparticles

1) Effects on oral tissues

Than conventional endodontic irrigants, such as 3% NaOCl and 17% EDTA, AgNPs-based irrigation solutions were reported to be less cytotoxic to human

gingival fibroblasts. The extent of cytotoxicity indeed depends on the material, as more favourable interactions have been associated with chitosan nanoparticles. Photoactivated rose bengal-conjugated chitosan likewise showed low levels of cytotoxicity. To ensure the biocompatibility of novel nanoparticle-based endodontic obturation materials and intracanal medicaments special efforts should be made, given the possibility of extrusion beyond the apex and direct contact with the periapical tissues. Calcium hydroxide, the widely used intracanal medicament is known for being cytotoxic to periapical tissues, however its nanoparticle equivalents were found to be significantly less cytotoxic. A novel endodontic sealer incorporating QPEI nanoparticles was reported to have favourable biocompatibility, with no observed lysis of L929 fibroblasts. Similarly, a mesoporous calcium silicate nanoparticle-based root filling material had no cytotoxic effects to periodontal ligament cells and even encouraged osteogenic properties by modulating gene expression.

2) Effects on Systemic Health

Smaller particle sizes and higher concentrations can lead to greater cytotoxicity. Nanoparticles are readily absorbed by various organs and tissues as they have similar dimensions to biological molecules. They have also been found to accumulate in the lungs, liver and reticuloendothelial system. Toxic concentrations can cause damage by both reactive oxygen species-dependent and independent mechanisms. By instigating DNA mutations, cytokine release, protein denaturation, lipid peroxidation and cell apoptosis, oxidative stress might have a significant role in causing tissue damage. For example, AgNPs have been reported to induce inflammation in the lungs and cause damage to the alveoli. When exposed to peripheral blood mononuclear cells, AgNPs at high concentrations were found to be potentially cytotoxic and could modulate cytokine expression. The organic biopolymer chitosan, on the other hand, is generally considered to be non-toxic and biocompatible. However, it has been suggested that greater cytotoxicity is associated with smaller particle sizes and higher concentrations. QPEI nanoparticles, were incorporated into restorative materials and reported to exert no adverse effects on macrophage viability. These examples highlight the importance of a full understanding of the potential hazardous health effects of nanoparticle applications in endodontics before clinical research is undertaken.

3) Effects on Environment

Environmental concerns are associated with the use of nanoparticles. Nanoparticles may act as pollutants and accumulate in the environment and given that the toxic effects are often concentration-dependent, bioaccumulation could result in subsequent systemic toxicity to exposed living organisms. There is a level of uncertainty that exists regarding the ideal policies for proper recycling and safe disposal of nanoparticles, as the extent of the harmful effects from their

biopersistence is yet to be fully elucidated. Overall, the potential adverse effects of the application of nanoparticles in endodontics must not be overlooked as they could hamper the success of the treatment, health of the patient and the environment. It is important to thoroughly investigate the extent of potential harm and ascertain safe methods of application to minimize the biological and environmental risk whilst maximizing the therapeutic benefit.^[11]

Futuristic applications of Nanoparticles are being proposed on utilizing

Nanotechnology has presented its impression on almost every field of science and development. They have the potential to bring about significant benefits, such as improved health, better use of natural resources, and reduced environmental pollution. Naturally, medicine and dentistry too have been inspired by this technology having an enormous potential. This being said, there is no doubt that the future of endodontics is heading down the nano-direction as most of the challenges faced (microorganisms, dentin) are all nano- sized. The era of nano-endodontics is paving its way to be the bright future in dentistry.^[6]

- Nanobots: To treat Dentinal Hypersensitivity, carious lesion, induced dental anesthesia, tooth repositioning.
- Dentifrobots: Dentifrobots can selectively identify and destroy pathogenic bacterial species in plaque biofilms and prevent halitosis.
- Lab- on-a- chip: Lab-on-a-chip combines various laboratory functions on a single chip. The analysis is done on chemically activated beads that are embedded onto silicon wafers. The advantage of this method includes a small sample requirement, short analysis time, and reduced cost. In dentistry, these have been used to assess the levels of interleukin-1 beta (IL-1 β), C-reactive protein (CRP), and matrix metalloproteinase-8 (MMP-8) in the whole saliva, which acts as biomarkers for diagnosing and categorizing the severity and extent of periodontitis.^[8]

CONCLUSION

Nanotechnology will be the future of dentistry as well as restorative and conservative dentistry. With the implementation of new technologies the use of nanotechnology in materials will be increased along with enhancement of their properties. But we must explore possibility of cost effectiveness of nanotechnology to make it approachable to everyone. Besides that the safety and cytotoxic effects of these materials must be evaluated.

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