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Review Article

Role of nanotechnology in endodontics

Preethi Kasha[1], Vamsee Krishna N[1,*], S. Datta Prasad[1], M Chandra Shekar[1], C. SunilKumar[1], S. SunilKumar[1]

[1]*Dept. of Conservative Dentistry and Endodontics, CKS Teja Institute of Dental Sciences and Research, Tirupathi, Andhra Pradesh, India*

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ABSTRACT

Nanotechnology is the advance science exploiting phenomena and direct manipulation of materials on the nanoscale. It can bring tremendous changes in the fields of medicine and dentistry. In dentistry, there is widespread recognition of microbial as the contributory factor for dental infection. Treatment of infected root canals presents with a significant challenge of bacterial persistence after treatment. Antibacterial Nanoparticles based treatment can improve the antibiofilm efficacy. A day may soon come when Nano dentistry will succeed in maintaining near-perfect oral health through the aid of nanorobotics and nanomaterials.

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1. Introduction

Nanotechnology includes aspects of health, including the dentistry.[1] Nanotechnology is an advanced science in various field that is undergoing rapid development and has become a powerful tool for multiple applications in biomedical such as tissue regeneration, drug delivery, biosensors, gene transfection, and imaging.[2] It is the new science producing functional materials and structures in a range of 0.1 nm to 100 nm. The word "nano," which derived from the Greek word (nano) meaning "dwarf," is a prefix that refers to 1 billionth of physical size or 1 billionth of a meter. The concept of nanotechnology discovered in 1959 by Father of nanotechnology, i.e., late Nobel Physicist Richard P Feynman, once he said, "There is plenty of room at the bottom," at the annual American Physical Society meeting on December 1959. He proposed employing machine tools to make still smaller machine tools.[1–3]

* *Corresponding author*.
E-mail address: dr.vamseekrishna@gmail.com (V. Krishna N).

2. Materials and Methods

For data, collection search was carried out online on various sites: Pubmed, Medline, Research Gate, and EBSCO. For search-words and phrases:- 'Nanotechnology,''Nanotechnology'in dentistry,' and 'classification of nanoparticles' were used in various combinations. Forty articles were found, out of which 16 were selected. The selected items comprised of research and review articles.

2.1. Inclusion criteria

Review and research articles on Nanotechnology comprising of studies on their applications in different fields of dentistry and their usage in endodontics.

2.2. Exclusion criteria

Studies other than dentistry excluded.

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3. Applications in Dentistry

The structures fabricated by two approaches, either "top-down" and "bottom-up."

1. Bottom-up approach: Seeks to arrange them from smaller components into more complex assemblies, the covalent bonds of which are reliable.
2. Top-Down approach: Seeks to produce smaller devices by using larger ones in achieving precision in structure and assembly.
3. Functional approach: Seeks to develop components of the desired functionality without regard to how they might assemble.
4. Biomimetic Approach: Seeks to use biomolecules for applications in nanotechnology.[1]

This Top-Down approach and Bottom-Up approach considered from conservative and endodontics.[4]

Top-down approach	Bottom-up approach
Nanocomposites and Nanoclusters	Local anaesthesia
Nano-light curable glass ionomer cement	Hypersensitivity cure
	Tooth regeneration
Nano-impression materials	Orthodontic treatment nano Robotics
Nanoparticles coating in dental implants	Nano diagnosis
Nano-based bone replacement cements	Oral tissues biomimetics
Nanoencapsulation	Endodontic regeneration
Nanoneedles	Impression materials

4. Used in Endodontics

MainlyNanotechnology widely used in dentistry also, the growing interest in this field is giving emergence to a new track called Nano dentistry, it is a science and technology which helps inpreventing, diagnosing and treating diseases, and preserving & improving human health, using nanoscale structured materials.Introducing these nanotechnology according to their uses in endodontics such as Nanorobotics, Denbur Nano brush, Nano application in endodontic instruments, Nano scaffolds for endodontic regeneration, Nanoparticles added to irrigants, Endodontic sealer incorporated Nanoparticles and obturation.

4.1. Anaesthetic Dental Nanorobotics

The diameter of nanorobotics is $0.5 - 3\mu$ and the dimensions in the range of 1 to 100 nm.[5] A suspension of Nanorobots sent into the areas where anaesthesia is mandatory. Which is controlled by the dentist; these robots will block the sensory nerves from transmitting pain sensation. After the dental procedures completed, the devices can be direct the robots to unblock the nerves and de-activate them.[6,7]

4.2. Denbur nano brush

It is an innovative applicator which is made of pliable material, that follows the anatomy to access the root canal which is used to remove the pulp and debris in the canal. For deep penetration of sealers into the dentinal tubules and lateral canals, nano brush is used to apply restorative materials.[3]

4.3. According to the Anil Kishen et al Classification of nanoparticles based on composition[8]

Inorganic	Metallic	Polymeric	Quantum dots	Fuctionalized
Zinc oxide	Gold	Alginate	Cadmium sulfide	Drugs
Iron oxide	Silver	chitosan	Cadmium selenide	Photosensitizers
Titanium dioxide	Iron			Antibodies
Cerium oxide	Copper			

4.3.1. Cobalt coatings of the NiTi file were coated with fullerene-like WS2 nanoparticles

Itisa newer advance used in endodontics even though there have been various rotary files used nickel-titanium is one of the most commonly used instruments. These types of alloys have numerous characteristics, including superelasticity and high corrosion resistance. This rotary file makes explore the complex anatomy of a root canal to ensure appropriate endodontic treatment, but these also have disadvantages like clogging of the instruments, friction and heat build-up to overcome these drawbacks. cause a significant improvement in the breakage time and fatigue resistance.[9]

4.3.2. Antimicrobialphotodynamic therapy NP-based photosensitizers

Modification of nanoparticles which can increase the antimicrobial efficacy of PDT. NPS envelop the bacterial cells with a higher concentration on the bacterial cell walls. Combination of NPs with photosensitizers can be achieved by:Photosensitizers bound or loaded to NPs, NPs themselves serving as photosensitizers. Within the root canals, cationic methylene blue-loaded poly(lactic-co-glycolic) acid NPs have the potential to be used as carriers of photosensitizer PDT. Anionic Rose Bengal conjugated CS NPs (CSRBnp) havedeveloped that showed significantly better properties as compared to either agent alone, which exhibits considerably higher bacterial phototoxicity in both planktonic and biofilm phases. Improved antimicrobial efficacy attributed towith high concentration of photosensitizers, per mass which resultantproduction of ROS; from the target cell, there reduced efflux of photosensitizers. Thereby decreasing the possibility of drug resistance; due to more significant interaction associated with the surface charge there is a possibility of targeting the bacteria; afterconjugation, photosensitizers have more excellent stability; Reduction of physical quenching effect; there can be a controlled release of ROS following photoactivation.[9]

4.3.3. Silver nanoparticles used as intercanal medicament and sealer

These nanoparticles which can interact with multiple targets in the microbial cell, such as cell membrane, plasmids, and enzymes, simultaneously providing the bacteria least capacity to gain resistance.[10,11] Silver nanoparticles showed the antibacterial properties of some intra-canal medicaments such as calcium hydroxide; it as has been demonstrated by Afkham et al. in their study which tested the effect of the combination on E. faecalis.[12] The antimicrobial properties of silver nanoparticles first demonstrated by Jose Ruben et al. Silver nanoparticles can bind to the negatively charged which is a partof the bacterial cell membrane, causes disturbances in its functions such as respiration and permeability, causing leaking of the cytoplasmic content and rupture of the bacterial cell. As a result, the nanoparticles will penetrate inside the cytoplasmic content and interact with sulfur- and phosphorus-containing proteins such as DNA and RNA, causing further damage to the bacterial cell. Additionally, the silver nanoparticles which release silver ions when in contact with an aqueous media, further disturbing the bacterial functions. Use of these silver nanoparticles as an antimicrobial agent against pathogens shows further investigation evaluate any effect on the color stability of the tooth structure, the dentine surface, and possible cytotoxic actions on human cells.[12]

4.3.4. Magnesium halogen-containing nanoparticles used as intercanalmedicament

Its main mechanism is it penetrates inside the bacterial cell, causes a disturbance in the membrane potential. The lipid peroxidation and DNA binding effects of the nanoparticles facilitated by penetration, causing more destruction of the bacterial cell. Magnesium-oxide nanoparticles were bactericidal when there are inan aqueous form, on the bacterial cell surface the action of superoxide anions formed. Mg-NPs used as an irrigants solution which showed an extended antibacterial effect over time.[12]

4.3.5. Zinc oxide nanoparticles incorporated in intercanal medicament and sealer

Aszinc ions produced by Zinc oxide nanoparticles inside the bacterial cell causes disturbances in its enzymatic system, the mechanism of amino acid metabolism resulting in further damage. The antibacterial effect of zinc oxide nanoparticles has been shown to depend on concentration, higher levels resulting in the maximum antibacterial effect.[12] ZnO-NPs used as an irrigants solution and when added to zinc oxide-based sealer, which decreased the number of colonies forming units of the tested bacteria. ZnO-NPs enhanced the antibacterial property of zinc oxide-based sealer. Dentine treated with zinc oxide nanoparticles reduced bacterial adhesion to dentine wall by 95%.[13] ZnO-NPs used as intra-canal medicament when incorporated with polyethylene glycol with and without calcium hydroxide. ZnO-NPs with calcium hydroxide had a higher inhibitory effect against P. aeruginosa and lower effect against E. faecalis and varying degrees of effectiveness against the other tested microorganisms.[14] Zinc oxide nanoparticles (ZnO-NPS) showed high antibacterial effectiveness, destroying microbial cells in a higher pH environment. The antibacterial activity of zinc oxide nanoparticles is similar to that of other types of nanoparticles, causes increased permeability of the cell wall membrane, a release of cytoplasmic content and cell death. This bactericidal effect of zinc oxide nanoparticles shown to related the smaller the size, the higher will be the antibacterial effect and the production of reactive oxygen species such as hydrogen peroxide when in contact with an aqueous medium. Shown that zinc oxide nanoparticles could reduce the colony-forming units of E. faecalis in a biofilm state. The same antibacterial effect was noticeable when zinc oxide nanoparticles incorporated into a resin-based root canal sealer. It also has shown a 95% reduction in the ability of E. faecalis to adhere and form biofilm in a dentinal wall.[12]

4.3.6. Chitosan Nanoparticles

Chitosan[poly (1, 4), β-d glucopyranosamine] is a derivative of chitin. It can also be available such as powder (micro- and NPs), capsules, films, scaffolds, hydrogels, beads, and bandages. They have excellent antibacterial, antiviral, and antifungal properties. Chitsan nanoparticles mainly used in sealer.Gram-positive bacteria are more susceptible than Gram-negative ones. The electrostatic attraction of positively charged CS with the negatively charged bacterial cell membranes leads to altered cell wall permeability. Results in rupture of cells and leakage of the proteinaceous and other intracellular components leading to cell death. They are also used to reinforce collagen matrices.

4.3.7. Advantages of chitosan include

1. It is non-toxic towards mammalian cells.
2. Colour compatible with tooth structure.
3. Cost-effective.
4. Availability.
5. Ease of chemical modification.

Chitosan nanoparticles were incorporated into a zinc oxide eugenol-based sealer and assess for their antibacterial effect against E. faecalis biofilm done on bovine root dentine treated by phosphorylated chitosan, chitosan conjugated with rose Bengal and a combination of phosphorylated chitosan and chitosan conjugated with rose Bengal. Inhibition of E. faecalis biofilm formation seen, the degree of inhibitory effects with the different treatment solutions used.[9,12]

4.3.8. Bio ceramic-based nanomaterial (Endo Sequence BC sealer) used as sealer

Which is composed of calcium phosphate, calcium hydroxide, calcium silicates, zirconia, and a thickening agent, has been developed recently. Nanoparticles have improvedphysical properties. A nanocomposites structure of hydroxyapatite and calcium silicate formed during the hydration reaction in the root canal. This 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 the delivery of material from 0.012 fine needles and adapt to dentin surfaces irregular. Providing excellent seal and dimensional stability.[3]

4.3.9. Quaternary ammonium polyethyleneimine (QPEI nanoparticles

Recently, these antibacterial quaternary ammonium polyethyleneimine (QPEI) nanoparticles have added intopresent sealers such as AH plus, Guttaflow, and epiphany, etc., Resin composites containing QPEI nanoparticles resulted in prolonged antibacterial activity without compromising the mechanical properties. To obtain same antibacterial effect in endodontic sealers, 0-2 wt.% QPEI nanoparticles added into the commercially available sealers. The addition of QPEI nanoparticles is very stable, leaching no by-products in the surrounding, and there shown no effect on the biocompatibility; however, the antibacterial properties remained excellent.[3]

4.3.10. Nano-diamond gutta-percha

GP offers numerous advantages, including biocompatible, cost efficiency, ease of removal, and a long history of use, its inability to provide an adequate seal to prevent bacterial percolation is a challenge in endodontic therapy. For instance, inadequate root canal seal around voids within the obturated root canal space may allow leakage due to absence of bonding between GP and the dentinal surface. Such voids with leakage may allow regrowth of bacterial within the root canals, including those in dentinal tubules, and establish reinfection of the root canal space, causing treatment failures. We developed Nano-diamond gutta-percha composite (NDGP) embedded with Nano-diamond amoxicillin (ND-AMC) conjugates which can reduce the likelihood of root canal reinfection and enhance the treatment outcomes. NDs are carbon nanoparticles that are approximately 4-6 nm in diameter; they are waste by-products that readily processed for biomedical applications. With the advantage of the ND surface chemistry, abroad-spectrum antibiotic, such as amoxicillin, can be adsorbed to the ND surface. Embedding amoxicillin-linked NDs into GP may facilitate the eradication of residual bacteria within the root canal system after completion of obturation. NDGP may also kill bacteria entering through the lateral canals following contact with NDantibiotic agents. The homogeneous dispersion of NDs throughout the GP matrix also leads to an increase in toughness, as evidenced by mechanical tests comparing the tensile strength of unmodified GP and NDGP. Importantly, root canals were effectively obturated using traditional obturation techniques for both NDGP and unmodified Gp.[15,16] Another example is a silicon-based sealer (Gutta-Flow Sealer) addition with gutta-percha powder and silver nanoparticles. The alkaline pH (12.8) gives antimicrobial properties. This material is available in the various form of a uni-dose capsule which can mix and inject directly. This nano-sealer has excellent biocompatibility and dimensionally stable, which sets within half an hour. This material iscapable of improving the sealingand resistance for bacterial penetration. The antibacterial activity of these endodontic sealers can be beneficial in the infection point of view.[3]

4.4. Nano scaffolds

The newmanagement of diseases has entered drug usage, namely “Nano scaffolds” for tissue regeneration and “nanorobotics” for both diagnosis and therapy. Out of many studies one study assessed the differentiation of human odontogenic DPSCs on NF(PLLA) poly L-lactic acid scaffolds.There is another study using highly porous structures of NF-PLLA which mimicked collagen type-I fibers with and without the usage of growth factors “(BMP-7) Bone Morphogenic Protein-7” and (DXM) dexamethasone medium. The mixing of both growth factors BMP-7 and DXM stimulates the differentiation of odontogenic DPSCs much more effectively than DXM alone. Finally, the environment which was provided by the Nano scaffolds shows excellent support for DPSCs in regenerating dental pulp, enamel, and dentin.[8]

4.5. Disadvantages

1. High cost
2. Technique sensitive
3. Risk of silver toxicity.
4. More as a medicament, than an irritant.
5. Use of silver NPs can lead to browning/blackening of dentin and toxicity toward mammalian cells.
6. Photosensitizers thatconjugated with different readily available synthetic polymers and liposomes possess

limited biocompatibility when applied in vivo.[9]

5. Conclusion

Since nanotechnology is an evolving science, the scientific community should show great responsibility while embracing this new field. In terms of endodontics, nanotechnology will not only improve the mechanical properties but also make a profound improvement in the biological properties of a material. It is not too far away that nano dentistry will succeed in maintaining near-perfect dental health with the help of nanomaterials, nanorobotics, and biotechnology.

6. Conflict of Interest

The authors declare that there is no conflict of interest.

7. Source of Funding

None.

References

1. Markan S, Lehl G, Kapoor S. Recent Advances of Nanotechnology in Endodontics, Conservative, and Preventive Dentistry-A Review. *J Dent Oral*. 2017;2(10).
2. Xavier JR, Desai P, Varanasiv G, Al-Hashimii, Gaharwar AK. Advanced Nanomaterials: Promises for Improved Dental Tissue Regeneration. *Nanotechnology in Endodontics*. 2015;p. 5–22.
3. Chole D, Khan I, Kundoor S, Bakle S, Gandhi N, Deshpande R, et al. Nanotechnology: Conservative Dentistry and Endodontics. *IOSR J Dent Med Sci (IOSR-JDMS)* . 2017;16(4):102–7. doi:10.9790/0853-160401102107.
4. Khurshid Z, Zafar M, Qasims S, Shahab S, Naseem M, AbuReqaiba A, et al. Advances in Nanotechnology for Restorative Dentistry. *Materials (Basel)*. 2015;8(2):717–31. doi:10.3390/ma8020717.
5. Sujatha V, Suresh M. Nanorobotics- A futuristic approach. *SRM University J Dent*. 2010;1(1):86–90.
6. Mithra S, Karthik A, Anuradhab. Nanorobotics - A small wonder. *Biosci Biotech Res Asia*. 2016;13(4). doi:10.13005/bbra/2374.
7. Dr, Mehra P, Nabhi D. A Nanorobotics - The Changing Face of Dentistry. *Int J Sci Res*. 2016;5(3):192–7.
8. Kishen A, Shrestha A. Nanoparticles for Endodontic Disinfection. *Nanotechnol Endod*. 2015;p. 97–119.
9. Alenazy MS, Mosadomi HA, Al-Nazhan S, Rayyan MR. Clinical considerations of nanobiomaterials in endodontics: A systematic review. *Saudi Endod J*. 2018;8(3):163–9. doi:10.4103/sej.sej_67_16.
10. Raim K, Deshmukhs D, Ingle A, Gadek. Silver nanoparticles: the powerful nanoweapon against multidrug-resistant bacteria. *J Appl Microbiol*. 2012;112(5):841–52. doi:10.1111/j.1365-2672.2012.05253.x.
11. Makkar S, Aggarwal A, Pasricha S, Kapoor I. To Evaluate the antibacterial properties of silver nanoparticles based irrigant as endodontic root canal irrigant. *Int J Dent Health Sci*. 2014;1(4):485–92.
12. Ibrahim IO, Moodley DS, Petrik I, Patel N. Use of antibacterial nanoparticles in Endodontics. *SADJ: J South Afr Dent Assoc*. 2017;72(3):105–12.
13. Kishen A, Shi Z, Shrestha A, Neoh KG. An investigation on the antibacterial and antibiofilm efficacy of cationic nanoparticulates for root canal disinfection. *J Endod*. 2008;34(12):1515–20. doi:10.1016/j.joen.2008.08.035.
14. Guerreiro-Tanomaru JM, Pereira KF, Nascimento CA, Bernardi MIB, Tanomaru-Filho M. Use of nanoparticulate zinc oxide as intracanal medication in endodontics: ph and antimicrobial activity. *Acta Odontológica Latino*. 2013;26(3):167–72.
15. Lee DK, Kim SV, Limansubroto†AN, Yen A, Soundia A, Wang CY, et al. Nanodiamond-Gutta Percha Composite Biomaterials for Root Canal Therapy. *ACS Nano*. 2015;9(11):11490–501. doi:0.1021/acsnano.5b05718.
16. Alexander B. Prospects of nanotechnology in dentistry. *Int J Currt Res*. 2018;10(7):71865–8.

Author biography

Preethi Kasha, Post Graduate

Vamsee Krishna N, Associate professor

S. Datta Prasad, Professor and HOD

M Chandra Shekar, Professor

C. SunilKumar, Professor

S. SunilKumar, Reader

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