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Review Article

Nanoparticles in Periodontology

Dr Simran Shakya[1], Dr. Pooja Kadam[2], Dr. Sangamithra S[3]

[1]BDS intern D.Y Patil Dental College and Hospital,pimpri Pune
[2]MDS Assistant Professor, Department of Periodontology, Dr. DY Patil Dental College & Hospital, Pimpri, Pune.
[3]MDS Associate Professor, Department of Periodontology, Dr. DY Patil Dental College & Hospital, Pimpri.

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Corresponding Author: Dr. Simran Shakya, BDS intern D.Y Patil Dental College and Hospital, pimpri Pune.

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INTRODUCTION

Nanotechnology was first introduced in 1959 by Nobel Physicist Faynman while the term was first used by Norio Taniguchi. Furthermore, Drexler published a book named "Engines of Creation" to promote the prospective of molecular nanotechnology.

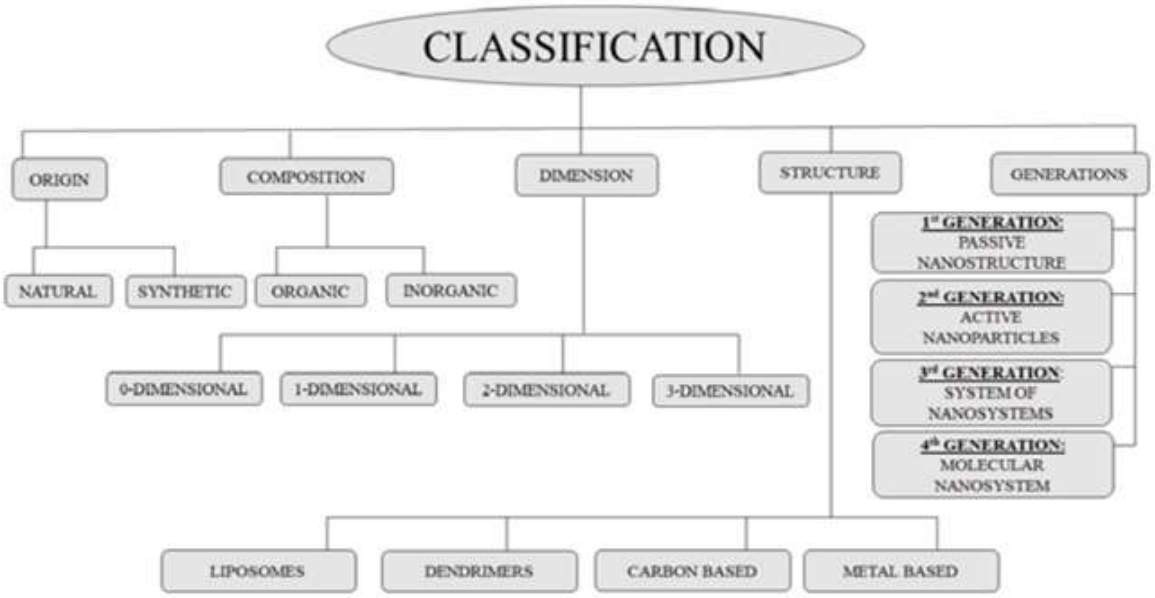
A widely used definition for nanotechnology is "The creation and utilization of materials, devices, and systems through the control of matter on the nanometer scale (1-100 nm), i.e. at the level of atoms, molecules, and supramolecular structures." Nanotechnology is the art and science of material engineering on a scale of less than 100nm.

Generations of nanotechnology

Nanotechnology is currently housed under four generations, which is categorized as follows:
1) First generation (From 2000): Passive (steady function nanostructures): E.g.,
Nanostructured coatings invasive; noninvasive diagnostics for rapid patient monitoring.
2) Second generation (From 2005): Active (evolving function nanostructures): E.g. Reactive nanostructured materials and sensors; targeted cancer
therapies.
3) Third generation (From 2010): Integrated nanosystems:
E.g. Artificial organs built from nanoscales; evolutionary
biosystems.
4) Fourth generation (From 2015/2020): Heterogenous
nanosystems: E.g. Nanoscale genetic therapies; molecules intended to self-assemble themselves.

Nanoparticles have greater surface area per unit mass than larger particles.
The concept of nano medicine was given by Freitas in 1993 defined as observing, controlling, and treating the biological systems of human body at molecular level using nano structures and nano devices.
It is a revolution in medical history as it has improved mechanical and physical properties of materials and help introduce nano-delivery systems.

Nanoperiodontics involves the analysis of matter at subatomic and microscopic level, which has progressed in the field of Periodontics. Nanoperiodontics will perpetuate periodontal health by relating nanomaterials and biotechnology, including tissue engineering and dental nanorobotics.



Nano materials

Properties of nano materials

Nanomaterials are those materials whose components are less than 100 nm in minimum of at least one dimension, including clusters of atoms, grains as small as less than 100 nm in size, fibers which are as minute as less than 100 nm diameter and atlast films which are less than 100 nm in thickness, nanoholes, and composites that are also a constituent of these nanoparticles.

Nanoparticles because of their surface area, dimensions and quantum effects exhibit enhanced rigidity, increased abrasion, stability, fire resistance and gas penetrability. Another striking feature about nano materials is its self assembling ability.

PROPERTIES OF NANOMATERIALS

1. Nanomaterials contain constituents <100 nm in minimum one dimension.
2. They have significant surface effects, size effects, quantum effects and show better performance properties than traditional materials.
3. They have special chemical, optical, magnetic, and electro-optical properties.
4. Important property of self-assembly by which they autonomously organize themselves into patterns or structures without any other intervention.

Nanomedicine

Nanomedicine is defined as the science and technology of diagnosing, treating and preventing disease, relieving pain and stabilizing, and improving human health,

using nanoscale structured materials , biotechnology, and genetic engineering, and finally complex machine structures, and nanorobots.Nanomedicine helps in prevention, diagnosis, and treatment of various diseases.

Application of nanotechnology in clinical dentistry.

Nanoneedles and nanoanaesthesia

Nanosutures are assimilated with nano sized stainlesssteel crystals. Colloidal suspension with micro sized dental robots are instilled into the gingiva of the patient which responds according to the dentist. Nanorobots then can reach the pulp via the gingival sulcus, lamina propria or dentinal tubules. Nanorobots can complete its journey in 100s to the pulp chamber. As the nanorobots reach the pulp chamber the anaesthetic nanorobots can block the sensitivity in the pulp chamber through the control of the dentist. As soon as the treatment gets completed the dentist commands for the stoppage of anaesthesia provided by the nanorobots through the acoustic data links. The advantage of using this method Is elimination of patient's anxiety and fear of needle. Most importantly it is quick and completely reversible procedure. Furthermore, this anesthesia has least side effects or complications in the oral cavity.

Oral Diagnosis and Treatment

Oral cancer can also be diagnosed by nanoelectromechanical systems, oral fluid nanosensor tests and an optical nanosensor. Nanoshells (miniscule beads) are specific tools used in cancer therapeutics. It has an outer metallic layer that selectively destroys cancer cells leaving normal cells undamaged. Saliva contains various proteomic and genomic markers for molecular disease identification.

As Nanosolutions

Nano solutions can be used as a bonding agent. Homogeneity of the solution is certified, because the adhesive is mixed perfectly reach time whenever used. Nanoparticles are also used as a sterilizing solutions in the form of nano-sized emulsified oil droplets that bombard various pathogens.

In Orthodontics

Painless tooth uprighting tooth uprighting, rotating, and vertical repositioning, along with rapid tissue repair can be possible with nanorobots.

As nanocomposite

As nanoparticles there is significant development in the performance of the composites.

The improved relevant properties include enhanced toughness, stiffness, improved transparency, increased resistance to scratch, abrasion, solvent, and heat and decreased gas permeability. Filler particles of submicron size, like zirconium dioxide, are also essential to improve composites polishing ability as well as esthetics.However, when particles of this size are used, the material may be more prone to brittleness, cracking and fracturing after curing. To overcome it, hybrid composites and composites containing a wider distribution of filler particles are used. Although these composites exhibit a better strength and esthetics, they are weak due to nanoparticle clumping or agglomeration.

A surface coating can be added, eliminating weak spots and providing consistent strength throughout the entire "fill" of the core build-up. In addition, the even dispersal of the nanoparticles results in a smoother, creamier consistency, and improves its flow characteristics. Once the material is cured to its hardened state, the properties contribute to the dentin- like polishability.

Nanoparticles used in dentistry

Table 1

Name of the nanoparticle	Purpose of use	Advantages	Toxicity
Silica	Dental filling material, tooth polishing, anticariogenic, treat dentinal hypersensitivity.	Biocompatible, cost effective,	Can induce silicosis, lung cancer. Induce oxidative stress leading to apoptosis.
Silver	Antimicrobial agent, Dental filling material and dental prosthesis.	Long therm antibacterial activity, decreases bacterial colonisation.	Chronic exposure causes argyria. May lead to cytotoxicity.
Titanium	Mainly dental implants	Less bacterial adhesion and Improved hardness	Proved to cause cancer.

Table 1

Name of the nanoparticle	Purpose of use	Advantages	Toxicity
Hydroxyapatite	Reduce dentinal hypersensitivity, remineralisation of enamel.	Similar composition to bone thus biocompatible and integrates easily into dentinal tubules.	They bind with proteins to produce protein-particle complexes which is eventually killed by macrophages, which gets dispersed to spleen, lungs, liver and blood acting as an inflammatory stimulus thus leading to oxidative stress and lastly apoptosis

Caption

Application of nanotechnology in Periodontology.

The application of nanotechnology in the periodontal management was put forward by Kong et al. the concept given by their researches formulated many concepts regarding tissue engineering in periodontal regeneration. The applications of nanoscale particles in Periodontics can be broadly discussed under the topics namely prevention, detection and treatment.

Prevention

Antibacterial Agents: Nanoparticle derived antimicrobial agents are seen to have superior effect due to their large surface area. Various agents that can exhibit antimicrobial effects includes silica, silver, copper and zirconia. Nanotechnology based disinfectants are available commercially in the market.Eco-True containing silver salts are employed for disinfecting instruments and surgical areas.

Oral Hygiene Maintenace: The mouthwash and dentifrices containing nanoparticles are shown to aid in oral hygiene maintenance. The mouthwash incorporated with nanorobots and selenium nanoparticles controls halitosis through the destruction of volatile sulphur compound producing bacteria. Dentifrices incorporated with nanorobots are employed to destroy the pathogenic flora while preserving around 500 oral commensals; but these are under study.

Personal Protective Equipment (PPE): PPE and masks incorporated with nanoparticles having antibacterial effect are shown to exhibit enhanced protection.

Surface Coatings: Nanomaterial coatings used in paints, medical instruments and other highly contagious surface can be employed to control the spread of COVID-19.

Detection

Nanotechnology based diagnostic kits exhibit increased efficacy compared to their original counterpart, besides they are easily portable and highly sensitive and specific.

Nanotubes: These are employed for detecting and locating altered disease-causing genes. Under this category comes the quantum dots that radiate bright light on stimuli and are used for cancer diagnosis.

Nanobelts: Are similar to nanotubes in their application except that they are cost effective and technique insensitive compared to nanotubes.

Nanoplasmic Sensors: With the emergence of COVID-19 pandemic the need for rapid detection kits are increasing. This sensor rapidly detects live viruses using their corresponding antibodies.

Treatment

Treatment of dentinal hypersensitivity.

The dentinal tubules of a hypertensive tooth have twice the diameter and eight times the surface density of those in non-sensitive teeth. Changes in pressure transmitted to the pulp hydrodynamically are the main cause of dentinal hypersensitivity. Nanorobots selectively and accurately block these dentinal tubules using native materials, thus offering quick and permanent relief to the patient.

Periodontal drug delivery

The properties of nano material change with the change in the size of the material. The development of the nanopharmaceuticals, nanosensors, nanoswitches and nanodelivery systems have bought considerable significance in the field of local drug delivery system.

Drug delivery using nanotechnology has been formulated as they have increased biocompatibility, targeted release, decreased antimicrobial resistance, long duration of action and less toxicity. Various drug delivery agents include liposomes, micelles, dentrimers, polymers, nanorattels, nanowires and niosomes. Besides nanocomposite hydrogel-based delivery system through the use of triclosan, chitosan and biodegradable nanoparticles are also productive delivery vehicle.

Local anaesthesia

Computer controlled micron sized nanorobots with colloidal suspension of analgesic molecules are employed. They are placed on gingiva and reach the dental pulp through gingival sulcus and dentin and they stay behind until the procedure is complete. Again, on command they reach the gingiva through the same way after restoring all sensations. They are painless and are said to have rapid onset of action in comparison to traditional LA.

Bone Grafts

Nanotechnology based grafts have proved to deliver superior outcome as they mimic the minute bone particles.They can be successfully used for the treatment of intrabony defects, socket preservation and sinus augmentation procedures.

Tissue engineering

Non biologic self assembling system by nanotechnology has made tissue engineering possible. Polymer based scaffold for cell seeding, growth factor delivery and tissue engineering via the nanoparticles embedded in site of tissue damage can also be constructed.

Nanoparticles and lasers

Irradiation with laser on nano titanium particles have shown to increase collagen production. Gingival depigmentation can be carried out.

Chronic periodontitis

Kadam et al hypothesized that adjunctive use of silver nanoparticle gel with scaling and root planing has superior effect in comparison to tetracycline gel in management of chronic periodontitis. This is believed to be possible because of nanoparticle's increased level of penetration into affected tissue.

Biofilm management

Biofilms incorporate wide array of microorganisms that results in increased antimicrobial resistance and pathogenicity. Till today, effective technique for biofilm management has not been devised. Nanoscale materials including zinc oxide, titanium dioxide, copper oxide, carbon nanotubes, chitosan, gold and quaternary ammonium

compounds are shown to exhibit antibiofilm activity through the disruption of bacterial cell membrane by generating reactive oxygen species.

Nanoantibiotics
Nanoparticles are coated with antibiotics and are delivered via nanocarriers. They manifest broad spectrum of activity and decrease the probability of secondary infections.

Wound healing
Improved wound healing with the use of nanomaterials has been reported in many studies. Polymer and lipid-based materials revealed excellent antimicrobial and antiinflammatory property with enhanced wound healing capacity. Carbon based particles showed good wound healing and angiogenesis, besides the metal-based nanoparticles showed scarless healing.

Toxicity of Nanoparticles
Even though the increased surface area of the nanoparticles may seem like a boon in the medical field, it has its own disadvantages. They can cause increased toxicity by enhancing the duration of action, aquaphobic drug solubility and also their ability to cross blood brain barrier. Because of their small size, the host immune system reaction to the nanoparticle cannot be detected. Biocompatibility of traditional nanoparticles is unsure, since the nanoparticles in gas exhausts from vehicles and industries are shown to elevate respiratory and cardiovascular morbidity & mortality.

Challenges in nanotechnology
Although variety of opportunities open up in usage of nanomaterials, there are certain obstacles faced such as engineering challenges, biological challenges and social challenges. It is really challenging to position and place the nanoparticles precisely. Biological compatible molecules which are environmentally friendly, economically and ethically acceptable still are a distant site in the field of nanodentistry.

Conclusion
There is a gradual increase in the use of nanotechnology in dentistry. Nanotechnology is a promising technology that is playing an increasingly important role in the diagnostics, prognostics, prediction, and management of various diseases. Nano-materials and nanotechnology have provided a promising hand into the commercial applications of nano dentistry. It is believed that the exploration and the use of nanotechnology will further increase in the upcoming times because of its better physical and mechanical properties in the field of dentistry.

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Nanotechnology in Periodontics: A Review Vaishali S, Nashra Kareem*
Department of Periodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India.
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1Parvathi Thenappan, 2R.Vijayalakshmi,3JaideepMahendra, 4T. Ramakrishnan, 5C.BurniceNalinaKumari
Nanotechnology in Periodontal Management
Shiva Manjunath R.G., Anju Rana
Department of Periodontology, Institute of Dental Sciences, Bareilly, Uttar Pradesh, India.