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Applications of Nanotechnology in Dentistry - A Review

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Abstract

Maintaining the oral health is as important as maintaining general health. Nanotechnology is a science where the analysis is made at a lower level which includes atoms, molecules, the chemical bond that exists between them and its usage in various existing and emerging fields. Nanotechnology holds as a promise in the various advancing fields particularly in medicine and dentistry where its application can be used from the level of diagnosis to the treatment protocols. Nanotechnology has a great potential to provide various changes in dentistry in near future. As development occurs it may become hazardous and can be misused. Incorporating nanotechnology particularly in the field of dentistry can improve the effectiveness as well as efficiency of the treatment and allows the repair of the dental hard tissues by promoting the rebuilt of the lost structures. This review basically emphasizes on the applications in the fields of Prosthodontics, Orthodontics, Periodontics, Preventive areas, the current trends, limitations, and the future predictions. It provides a glimpse of various applications as well as advancements.

Keywords: Prosthodontics, Orthodontics, Periodontics, Preventive areas.

Introduction

Nanotechnology is the art and science of material engineering at a scale range of less than 100 nanometer. The concept of nanotechnology was introduced in the year 1959 by Laureate Richard Feynman. This was introduced by PROF. K Eric Drexler (a noble prize winner) in a lecture titled "There's plenty of room at the bottom" and through his book Engines of Creation in the year 1980s. Nano means dwarf in Greek. Nanometer is one billionth of a meter. Nanotechnology is a multi-disciplinary field which involves chemistry, physics, biology, engineering, electronics, and social sciences. 1-D nano particles include sheets, 2-D nano particles include nano wires and tubes, 3-D nano particles include quantum dots. It is a field of science creating materials, devices, and systems at a nano scale.

Atoms are the building blocks of human body which are measured in the nano scale. They easily interact with the micro as well as macro sized particles for better efficacy. Various researches were conducted by the United States Human Genome Research Institute so that the limitations of nano technology can be minimalistic and their implications are better understood and changes can be made at earlier stages of development before reaching the market.

Nano technology is engineering of functional systems at molecular scale. The most unique property of nanoparticles is having a high surface to core ratio and can be arranged in several packing configurations. Having higher surface to core ratio, the surface has greater atoms when compared to the core, so the interaction can be faster and stronger bonds can be formed. Since the discipline of nanotechnology has seen advancements in leaps and bounds and in the present day, its footprints are noticed in all spheres of technology.

The main primary challenge of nanotechnology is the production of these particles in a controlled fashion. Production of particles occurs via solid, liquid, gaseous phases. The concept of nanotechnology changes fundamentally the health care in the following ways:

1. New diagnosis and preventive modalities
2. Drug delivery and gene therapy
3. Customized treatment plan

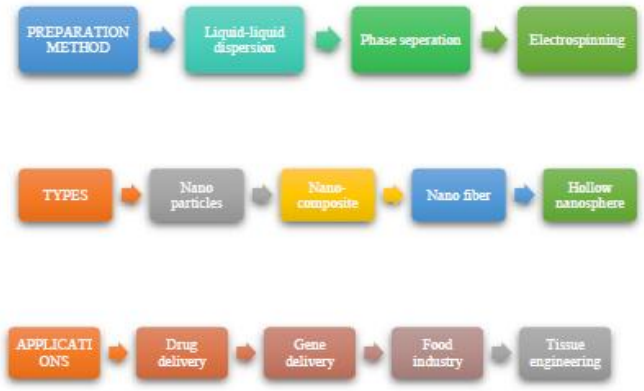


Figure 1:

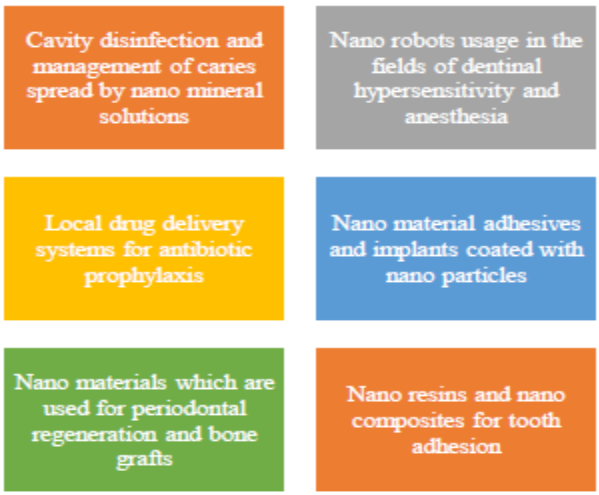
Aims of nanotechnology

The main aims of nanotechnology include

1. Analysis of structures at nanoscale
2. Manufacturing of nanoscale particles
3. Understanding the physical properties of nanoparticles
4. Develop devices with the nano precision and to establish link between micro and macroscopic universities (Oz Bay, 2006)

Classification of Nanoparticles

Figure 2:

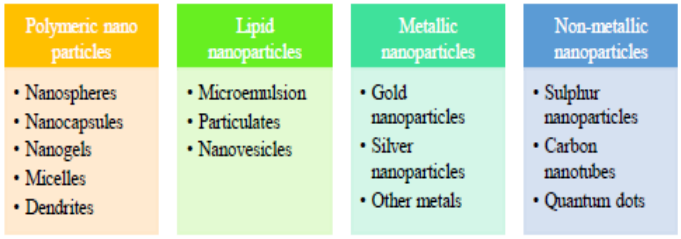


Nano Tools Used in Dentistry

Nano particles are divided into

1. Nanorods
2. Nanowires
3. Nanotubes

Figure 3:



Nanotubes

They are available as single or multi walled tubes. The main material constitutes of carbon. Their applications include scaffolds or templates for the building.

Nanowires

The dimensions of nanowires include 10nm. Materials include ceramic, metal, metal oxide. The main applications constitute of magnetic devices, nano wire battery, nano generator, semiconductor.

Nanorods

The nanorods resemble structurally as enamel rods measuring about 10-120nm. Materials include metal, carbon, and metal oxides. The applications include drug

delivery, bio-imaging, photo thermal therapy nano capacitors.

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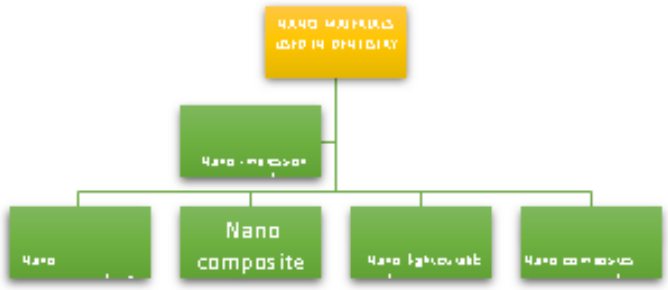
Figure 4:



Applications ofnano technology

The application of nanotechnology includes

Medicine

a) In the field of medicine, the nanotechnology is used in manufacturing of nanoscale materials and devices and applied in the advanced drug deliveries and targeted drug delivery.

b) Understanding the Genomics,Proteomics, Robots.

c) Molecular machines and nanorobots aid in the diagnosis and treatment.

1. Chemistry and environment
2. Heavy industry
3. Energy
4. Information and technologyDentistry

Properties of nano materials

The major properties of nano materialsinclude

1. Small size
2. Quantum size
3. Quantum tunnelling
4. Surface effect

Figure 5:

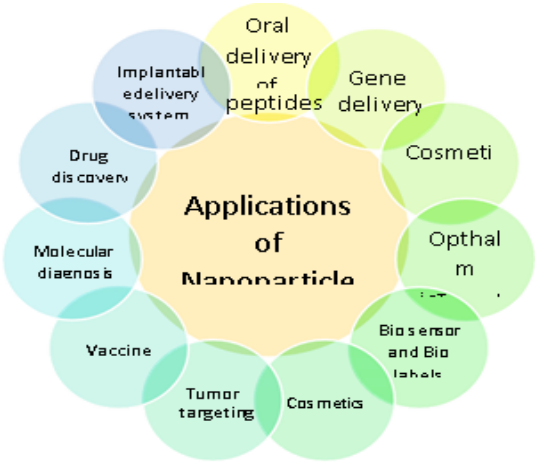
Methods of production of these nanoparticles

Nano particles are present in various forms they include nano pores, nano tubes, Quantum dots, nano shells, dendrimers, liposomes, nanorods, fullerenes, nano spheres, nano wires, nanobelts, nano rings, nano capsules. The nano particles being smaller in size is difficult to produce them. They are mostly produced by the following methods that is top-down method

Bottoms up method,

Self-assessment method,functional.

Figure 6:



Top-down method

This method mainly involves the production of smaller components by using bigger ones in guiding their assembly. Reduction of large pieces of materials all the way down to nanoscale. This requires larger number of materials, which are patterned and carved down to nanoscalestructures. Nanomaterials that can be produced by top-down method include

1. Nanocomposites
2. Nano solution
3. Impression material
4. Nano encapsulation
5. Nano needles
6. Bone graft

Bottom-up method

Assembly of small components into compound structures. Building of structures from atomic and molecular levels. Nanomaterials produced using bottoms up method include

1. Local anesthesia
2. Hypersensitivity cure
3. Treatment of oral cancer
4. Orthodontic treatment
5. Cosmetic procedure
6. Nano robotic dentrifice

Self-assessment method

Organization of the nano particles into patterns without human intervention.

Table 1:

Nano particles					
Vaccinedelivery	Increase residence time	Higher absortion	Target tissue released	Drug released control	Bio availability for low absortion drugs
1.Mesoporo us silica	1. Solid lipid 2. Carbon nano tube	1. Alginate Nano fibres	1. Liposomes	1. Chitosan-alginate	1.DNA nano capsule 2. PLGA

Applications of nano technology in the field of dentistry

There are wide range of applications of nano technology particularly in the field of dentistry.

Prosthodontics

a. Totu et al in 2017 used 0.4% TiO2(Titanium oxide) in 3-D poly

b. methyl methacrylate to improve the anti-bacterial and mechanical properties. These were measured using Fourier Transform Infrared Spectros copy {FTIR}.

c. Zirconium oxide increases the hardness levels, flexural strength

d. and fracture toughness of PMMA denture base when compared tothe conventional one.

e. Nanofillers were used in various materials due to their superior dispersion properties, less aggregation potential and bio compatibility.

f. Gad et al in 2016 reported that Nano zirconia increases the physical properties of denture base and increase the transversestrength of a repaired denturewhen compared to the regular denture base.

g. Repairs using auto polymerised resin modified with 2% or 5% zirconia oxide had increased the transverse strength levels using 3-point bending test.

h. Nano metals include the deposition of nano structure Ti onthe surface of pure titanium.

i. This property decreased the adhesion of oral streptococci on the altered nano structural surfaces than onthe counterpart.

Nano ceramics

- Zirconia silica sol-gel nano addition increased the hardness.
- Hot pressed Alumina improved the biological and mechanical properties.
- TiO2 reinforced PMMA increases the saturation per unit.

Nano resins

- Nanoparticles TiO2 (Titanium oxide) and ferric oxide increases the anti-fungal properties of candida species.
- Nanoparticle Ag added to PMMA (Poly methyl methacrylate) improves the microbial properties.

Endodontics

- Introduction of nanoparticles such as Bio glass, zirconia and glass ceramics in endo sealer.
- Utneja et al 2015 introduction of nanoparticles had better adhesion properties even in the nano irregularities which increased the dimensional stability, insolubility, chemical bond to tooth, Osseoconductivity.
- This was collaborated with Wang et al study in 2017 who tested the anti-bacterial property and effects against endo biofilms, bond strength to dentin and ionic release of calcium and phosphorous when an endo sealer was used. The endodontic sealer is mixed with Dimethyl amino hexadyl metha cry late (DMA HDM), amor phous calcium phos phate and 2-metha cry Loy loxy ethyl phosphoryl choline (MPC) which inhibit the endo dontic strains,increases remineralization andincreases the bonding to dentin.

Figure 7:

(Increases the Remineralization and bonding to dentin)

- Afkhami et al 2015 utilizes intra canal medicaments (Calcium hydroxide) and added nano silver particles to it which was effective against Enterococcus faecalis for about one week.
- Mozayeni et al 2014 stated that this is not effective after one week.
- Nano silver particles were introduced as a gel matrix, where its effectiveness lacked when compared with chlorhexidine or triple antibiotic paste. Research attributed that the effect of nano particles when used in the gelform probably inhibited their release and activity.
- Leet al in 2015 tried using the nano diamond particles with GP (gutta percha) which increases the chemical pro per ties, bio com patibility, superior mechanical properties, quality adaptation to canal walls and deceasesthe void formation.
- Pulp regeneration is the procedure where the tissues are developed, or damaged dental pulp can provide an alternative to pulp removal. Alpha- MSH is known to process anti- inflammatory properties, could help to revitalize the damaged teeth.

Conservative dentistry

- Xie et al in 2016 stated that rechargeable amorphous calcium phosphate (ACP) filled composite resin was recently reported. Nano particles not only increases the re mineralization property butalso increases the calcium and phosphorous release (SMART material). This was collaborated with
- Wu et al 2015 reported on the re mineralization ability of ACP by decreasing the secondary caries.
- ACP was incorporated into the luting cements and bonding agents to increase the bonding of these cements with dentin when compared to the conventional cement. This was collaborated with

- Zhang et al in 2015 tested the re mineralization ability of the bonding agents and ACP releases calcium and phosphorous ions up to 3 weeks,without altering the bonding strength of dentin.
- Ionescu et al in 2015 used lactose modified chitosan (chitlac) with nano silver particles prevents the initiation and progression of secondary caries. This decreases the biofilm formation by 80% after 48 hours.
- Shvero et al in 2015 tried using cross linked quaternised poly ethyleneimine (QPEI) with resin composites which decreased the anti-bacterial effects against Enter ococcus, Strep to coccus, Actino mycosis, Lactobacillus and chances of secondary caries by disruption of ionic exchange through bacterial mem branes.
- Velkobor sky et al in 2010 used tooth whitening agents with calcium peroxide nano particles which penetrates through the cracks leading to longer surface contact and increase in whitening effect. Also used nano lipobelle (H-EQ10), which is acompound of 10% vitamin E and 5% coenzyme which increases the chemical and mechanical condition of whitened enamel.
- Moshaverinia et al in 2008 and Lucas et al in 2003 combined glass inomer cement with hydroxy apatite or fluorapatite for increasing the compressive, biaxial and tensile strength when compared to theconventional glass inomer cement.
- Zebarjad et al in 2011 combined zinc poly carboxylate cement with nanoparticles such as Zno (zinc oxide) and MgO (magnesium oxide) where the tensile as well as compressive strength of modified cement increased when compared to the conventional cement.
- Chen et al in 2014 applied this concept of nano technology to the CAD or CAM blocks which showed superior esthetics, durability and fracture resistance.
- Sadat-Shojai et al in 2010 used this nano technology concept for the introduction of nano particles into the luting cements. The luting cements have shown a better bonding ability when combined with these nano particles since having a smaller particlesize they penetrate deeper into the dentinal tubules to have a better bond.

Periodontics

- Sharma et al in 2016 tested the drug delivery systems for the treatment of periodontal diseases by intro duction ofTriclosan where drug delivery would occur in the incremental forms by increasing the contact duration with the diseased site.
- Pradeep kumar et al in 2012 used niosomes for the targeted drug delivery. Also used light cured methacrylate resinmatrix with amorphous calcium phosphate (ACP) as a bone graft which adheres to thetissues.
- Fullerenes (C60) which is a hollowcarbon molecule used for the drug delivery, used for the radicalscavenging and as an antioxidant.
- Tomsia et al in 2011 added few nano particles (which include hydroxy appatite, gold, silver, Titanium oxide) to the implant surface. They enhanced the results of Osseo integration by mimicking with the topography of theextracellular matrix.
- Anti-fungal properties of chlorhexidine are tested by Garner et al in 2015 where chlorhexidine was coated with nano particles that is sodium triphosphate trimeta phosphate or hexa meta phosphate which inhibits the fungal infections in dental silicones (dentalobturators).

Results obtained include they did not affect the hydrophilicity and water uptake of the dentures when immersed in saliva for a period of 16 weeks. This also increased the anti-fungal activity property by inhibiting the metabolic activity of candida. This increases the

longevity of prosthesis and maintenance of oral health at low cost.

- Periodontal drug delivery uses the administration of triclosan with the nano particles. One of the best examples is the local drug delivery system with Arestin (local drug administration with Microspheres containing Tetracycline).

Orthodontics

Nano indentation and atomic force micro scopy studies on brackets and arch wires concluded that the roughness and surface free energy play an important role in reduction of friction and plaque formation.

Arch wires

Nano coatings are added over the arch wireswhich reduced the frictional forces acting between wire and bracket. IF-WS2 (Inorganic fullerence like nanoparticles of tunsten sulfide) was used as lubricant for the orthodontic stainless steel.

Redlich et al coated the stainless-steel wire with Ni / P electrode film which was impregnated in IF-WS 2, reduced the frictional forces by 54%.

Orthodontic appliance

Due to the decreased particle size and increased filler load, this led to the achievement of decrease in the polymerization shrinkage, increase in the tensile strength and compressive properties.

Gerald Eli and Perdigao concluded that nano composites better bond to enamel and dentin when compared to the conventional composites.

Nano fillers decrease the surface roughnessof orthodontic adhesives and is mostsignificant for bacterial adhesion.

Nano ionomer which is resin modified glass ionomer cement increased the mechanical property and increased the fluoride release. Uysal et al tested the nano composite and nano ionomer where this was suitable for achieving clinical acceptability by suggesting good shear bond strength.

Bishara and Ajlouni compared shear bond strength of a nano hybrid restorative material.

Elastomeric ligature

Ligature wire was combined with nano particles which were anti cariogenic and anti in flammmatory. Anti - cario genic property is due to the release of fluoride ions from the nanoparticles where it is rapidduring the first few days and gradually decreases later.

Shape memory polymers (SMP)

They have an ability to memorize a macroscopic or equilibrium shape and latermanipulate the dormant shape under specific conditions of temperature andstress, where they can revert to the originalform. These SMP once kept in the mouth, depending on the body temperature gets activated and then thuds bringing about desired movement.

Bio MEMS for maxillary expansion

Bio medical micro electro me chemical system is made up of silica. The electrical stimulation enhanced the cellular enzyme phosphorylation activities leading to synthetic and secretory processes by increasing the bone remodelling process.

Enzymatic batteries generate electricity which help in the tooth movement when they are placed on the gingival tissues near the alveolar bone which will further lead to the teeth movement.

Anchorage devices

In cases of incomplete Osseo integration they are difficult to remove. In cases of no signs of Osseo integration establishment of primary stability is very difficult. To overcome all these situations temporary anchorage devices (TADs) were coated

with titanium nanotubes, where the initial layers of coating increased the chances of Osseo integration.

Smart brackets

Smart brackets were introduced by Lapaki et al. These are helpful for multidimensional force and movement control.

Nano mechanical sensors are fabricated at the base of brackets to provide real time feedback about the ortho dontic forcesapplied.

Control of oral bio films during ortho dontic treatment

S J Ahn et al compared the properties of silica and silver nano particles with RMGIC(resin modified glass ionomer cement) to evaluate the physical and antibacterialactivity. Bacterial adhesion decreased in composite where the surface is smooth and also helps in prevention of enamel de mineralization around the brackets.

Local anesthesia

Nano robots are used to induce local anesthesia which would be guided by a nano computer as well as by a dentist.

The local anesthesia would be deposited on the gingival surfaces further reaches the dentinal surface and moves towards the pulp. Administration of local anesthesia by using these nano robots would reduce the apprehension and it is also fast. Nano robots also are used in reduction of dentinal hypersensitivity.

Dentifrorobots

They survey all the gingival surfaces and break down all the harmful materials and are efficient for calculus removal.

Gene theraphy

The concept of nano technology is useful for the treatment of genetic diseases by the correction of faulty genes.

Oral cancer

Nano technology and their principles and concepts are used for the treatment of oral cancer (Nano scale cantilevers, Nano pores, Tubes, Quantum dots).The treatment of oral cancer which includes chemo therapy, radiation, surgical procedures also utilize the property of nano technology.

Implants

The implants are coated with nano structural particles such as diamond, hydroxy apatite coatings, metallo ceramic coatings.

Wound healing

Bio degradable nano fibres are used for the control of hemostasis. Wound dressings are given with silver nano fibres. Nano crystalline silver particles have anti- micro bial property.

Dentinal hypersensitivity

Nanorobots can selectively and precisely occlude the selected tubules in minutes and decrease the hyper sensitivity. Nano robots are of diameter ranging from 0.5 to 3 microns and length of about 1 to 100 nm.

Nano sensors are used for identifyingthe air bone harmful material and weaponsof chemical warfare and to identify drugs and other substances in the expired air.

Diagnosis

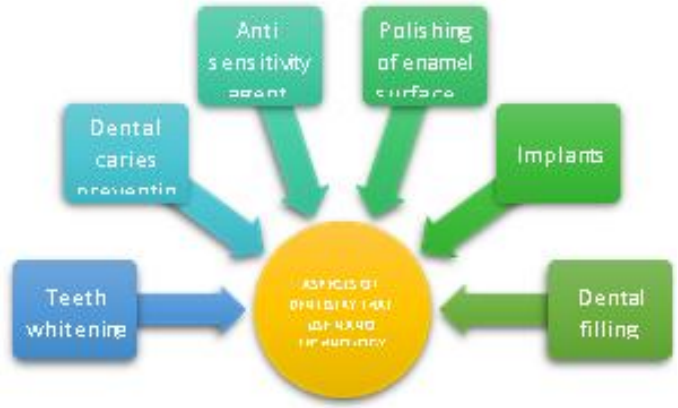
Cantilevers are flexible rods with endings that attach to cancer molecules and helps inthe detection and diagnosis.

Nanopores enable the passage of one strand of DNA. These strands may be assessed and genetic defects are corrected which are at arisk of carcinogenesis.

Nanotubes have a diameter half that of DNA. Exact location of the defect can be detected, detection of dentin collagen network, tooth hyper sensitivity, surface of dental implants.

Dendrimers are useful for the elimination ofcancer cells in the oral cavity.

Nano wires detect the antigens in the proteins, viruses, genes in the saliva samples.



Challenges anddisadvantages

Despite having these many applications invarious fields, the main challenges that are faced by nanotechnology include:

1. Precise positioning
2. Cost effectiveness
3. Social issues
4. Bio compatibility concern
5. Environmental and health issues

Nano particles when they enter the human body through inhalation, saliva, absorbed through skin, injected during medical procedures, they cross the blood brain barrier (BBB) and cause an overload over the phago cytes and thereby trigger the stress reactions and lead to in flammation and weaken the body's defense against other pathogens.

FDA and EFA are two organization regulating the major health risk factors associated with nano materials.

Conclusion

In the fast-growing world, the clinical application of nanotechnology is yet to come into practice sooner or later, which will benefit the diagnostic approach in a better way. With the rapidly progressing technology, a successful future is ahead which incorporates nano technology into application. The current usage of nano technology is very limited. It is both a hope as well as a hype. Once this nanotechnology comes into practice it brings about enormous changes in the diagnostic and treatment plan level. The main aim of nano technology is to prevent the oral health diseases at a primary level.

Nano technology is an enormous milestone and a great step in the field of dentistry. Since it is a study at a nanoscale or level, cannot be seen with a naked eye yet processes significant benefits. At present, it is a friction but to the future it is a scope which will change the life profoundly. It also changes the way we look at the oral health care and has a few environmental hazards.

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