REVIEW ARTICLE

Nanodentistry: New buzz in dentistry

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ABSTRACT

There is an unavoidable development in the progress of science; nanotechnology has been part of the mainstream scientific theory with potential medical and dental applications since the early 1990s. Dentistry is undergoing another change with the help of nanotechnology combined with nanomaterials, biotechnology and ultimately dental nanorobotics. Nanodentistry will make possible maintenance of comprehensive oral health by employing nano tissue devices which will allow precise controlled oral analgesia, dentine replacement therapy, permanent hypersensitivity cure and complete orthodontic realignment etc., all in a single office visit, covalently bonded diamondized enamel and continuous oral health maintenance through the use of mechanical dentifrobots. There is an increase in optimism that nanotechnology applied to dentistry will bring significant advances in the diagnosis, treatment and prevention of disease. This article enlightens about potential applications of nanotechnology in dentistry and to illustrate their potentially far reaching impact on clinical dental practice.

Key words
Dentifrobots, nano dentistry, nano technology

INTRODUCTION

Recent years have witnessed an unprecedented growth in research in the area of Nanoscience. There is increasing optimism that nanotechnology applied to medicine and dentistry will bring significant advances in the diagnosis, treatment and prevention of disease.[1]

"Nano" is derived from the Greek word for 'dwarf'. "Nanotechnology" is defined as the research and development of materials, devices and systems exhibiting physical, chemical and biological properties that are different from those found on a larger scale.

Nanotechnology also known as molecular engineering is the production of functional materials and structures in the range of 0.1 to 100 nanometers by various physical or chemical methods.[2]

Nanodentistry will make possible the new potential treatment opportunities in dentistry which include, local anaesthesia, dentition re-naturalization, permanent hypersensitivity cure, complete orthodontic realignments during a single office visit, covalently bonded diamondised enamel, continuous oral health maintenance using mechanical dentifrobots,[1] and creation of artificial bone and teeth.[3]

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HISTORY

The vision of nanotechnology was introduced in 1959 by late Noble Physicist Richard *P* Faynman. The term "Nanodentistry" was first introduced in 2000 by research scientist Robert Freitas.[4]

OVERVIEW OF NANO PARTICLES

The various nanoparticles are Nanopores, Nanotubes, Quantum dots, Nanoshells, Dendrimers, Liposomes, Nanorods, Fullerenes, Nanospheres, Nanowires, Nanobelts, Nanorings, Nanocapsules.[5]

Nanoparticles have special properties like chemical, optical, magnetic and electro-optical properties which differ from those of either individual molecules or bulk spices. The improved relevant properties include enhanced toughness, stiffness, improved transparency, increased scratch, abrasion, solvent and heat resistance and decreased gas permeability.[6]

APPROACHES OF NANOTECHNOLOGY IN DENTISTRY

The fabrication techniques of nanoscale structures can be divided into 2 approaches: Top-Down approach, Bottom-Up approach [Table 1].

The 'Top-Down' approach refers to the building of nanostructures of progressively smaller and smaller dimensions using larger parts. The 'Bottom-Up' approach calls for an assembly of nanostructures from atoms and molecules.[7]

Application of nanotechnology in dentistry

Local anaesthesia

In the era of nanodentistry, a colloidal suspension containing millions of active analgesic micron-size dental nanorobot 'particles' is given on the patients gingivae. After contacting the surface of the crown or mucosa, the ambulating nanorobots reach the pulp *via* the gingival sulcus, lamina propria and dentinal tubules.

Once installed in the pulp, the analgesic dental robots may be commanded by the dentist to shut down all sensitivity in any particular tooth that requires treatment. After oral procedures are completed, the dentist orders the nanorobots to restore all sensation to relinquish control of nerve traffic and to egress from the tooth by similar pathways used for ingress.[7]

Nanorobotic analgesics offer greater patient comfort and reduce anxiety. They have greater selectivity, controllability of the analgesic effect with rapid complete reversible switchable action and avoid associated side effects, complications caused by local anaesthetics.[1]

Tooth repair

Chen *et al.,* took advantage of the latest developments in the area of nanotechnology to simulate the natural bio mineralisation process to create the hardest tissue in the human body, dental enamel by using highly organised micro architectural units of nanorod-like calcium hydroxyapatite crystals arranged roughly parallel to each other.[8]

Orthodontic treatment

Orthodontic nanorobots could directly manipulate the periodontal tissues, allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours. This would eliminate the need for the cumbersome and dreaded braces.[3]

Table 1: Approaches of nanotechnology in dentistry

Top-down approach	Bottom-up approach
Nanocomposites	Dentine hypersensitivity
Nanosolutions	Local anaesthesia
Impression materials	Tooth repair
Nanoencapsulation	Tooth repositioning
Nanoneedles	Nanodentrifices
Bone replacement	Diagnosis of oral cancer

Tooth renaturalization

Durability and appearance of tooth may be improved by replacing upper enamel layers with covalently bonded artificial materials such as sapphire or diamond, which have 20-100 times the hardness and strength of natural enamel or contemporary ceramic veneers and has good biocompatibility. Pure sapphire and diamond are brittle and prone to fracture but can be made more fracture resistant as part of a nano structured composite material that possibly includes embedded carbon nanotubes.[1]

Nanorobotic dentifrice (Dentifrobots)

Subocclusal dwelling nanorobotic dentifrice delivered by mouthwash or toothpaste could patrol all supra gingival and sub-gingival surfaces at least once a day, metabolising trapped organic matter into harmless and odourless vapours and performing continuous calculus debridement. Properly configured dentifrobots could identify and destroy pathogenic bacteria residing in the plaque and elsewhere, while allowing the 500 or more species of harmless oral micro flora to flourish in a healthy ecosystem. With this kind of daily dental care available from an early age, conventional tooth decay and gingival diseases will disappear into the annals of medical history.[2]

Halitosis

Properly configured dentifrobots provide continuous barriers to halitosis since bacterial purification is the central metabolic process involved in oral malodour.[2]

Photosensitizers and carriers

Quantum dots can be used as photosensitizers and carriers. They can bind to the antibody present on the surface of the target cell and when stimulated by UV light they can give rise to reactive oxygen species which will be lethal to the target cell.[9]

Diagnosis of oral cancer

Oral cancer can be diagnosed with Nano electromechanical Systems (Nems), Cantilever Array Sensors and Multipexing Modality.[7]

Treatment of oral cancer

- Nanomaterial for brachytherapy – BrachySil (Sivida, Australia) delivers 32P, a drug under clinical trial
- Drug delivery across the blood brain barrier-More effective treatment of brain tumours, Alzheimer's and Parkinson's disease in developing
- Nanovectors for gene therapy - Non-viral gene delivery systems.

Dendrimer nanoparticles are made of spherical, highly branched polymers, have shown promise as drug delivery vehicles capable of targeting tumours with large doses of anticancer drugs.[7]

Nanoneedles

Suture needles have been used to perform a delicate surgical operation on a single living cell using a needle that is just a few billionths of a meter wide. Nanotweezers are also under development which will make cell-surgery possible in the near future.[10]

Bone replacement materials

Nanotechnology is used to create "smart" material that will assist in the repair and regeneration of cellular tissue in the bone.[2]

Hydroxyapatite nanoparticles used to treat bone defects are Ostim (Osartis GmdH, Germany), Vitoss (Orthovita, Inc. USA) and NanOSSTM (Angstrom Medica, USA).

Calcium phosphate based biomaterial is an easily flowable, mouldable paste that conforms to and interdigitates with host bone. It supports the growth of cartilage and bone cells.[7]

Implants

Implants using nanotechnology can effectively expedite bone growth and increase predictability and reduce the time for osseointegration. These implants use nanometer-scale calcium phosphate to create a more complex topography on the implant surface, which has been proven to expedite osseointegration by 150% thereby decreasing the length of treatment by one to three months. The addition of nano-scale deposits of hydroxyapatite and calcium phosphate creates a more complex implant surface for the osteoblastst to form on.[11]

Nano-fibre coatings

Investigations of the biological effect of nano-fibre coatings on the transmucosal element of the endosseous dental implants have demonstrated that human gingival fibroblast cells have the ability to align, proliferate and secrete collagen in the direction of nanofibres in preference to other topographies forming a tight fibrous collar. This fibrous soft tissue attachment will protect the underlying osseous attachment from bacterial attack and breakdown.[2]

Nanomaterials for periodontal drug delivery

Pinon Segundo *et al.,* produced triclosan-loaded nanoparticles by the emulsification–diffusion process in an attempt to obtain a novel delivery system adequate for the treatment of periodontal disease. The nanoparticles were prepared using poly (D, L-lactide-coglycolide) poly (D, L-lactide) and cellulose acetate phthalate. Poly (vinyl alcohol) was used as a stabilizer.

Nanomaterials including hollow spheres, core-shell structure, nanotubes and nanocomposite have been widely explored for controlled drug release. Drugs can be incorporated into nanospheres composed of a biodegradable polymer and this allows for timed release of the drug as the nanospheres degrade. This also allows for site-specific drug delivery. E.g., Arestin, in which tetracycline is incorporated into microspheres for drug delivery by local means to a periodontal pocket.[6]

Salivary diagnostics powered by nanotechnology

Miniaturized saliva based diagnostic technologies will enable the use of minute amounts of bodily fluids to yield critical patient information that reflects health and disease status and allow clinicians to achieve real-time and simultaneous assessment of multiple diseases.

Nano-electromechanical system biosensors exhibit high levels of sensitivity and specificity for analyte detection, down to the single molecule level.[12]

Oral fluid nano sensor test

The OFNASET is a handheld, automated, easy-to-use integrated system that will enable simultaneous and rapid detection of multiple salivary protein and nucleic acid targets.[6]

Application of nanotechnology in operative dentistry

Nanocomposites

The nanofiller used include an aluminosilicate powder having a mean particle size of 80 nm and a 1:4 M ratio of alumina to silica and a refractive index of 1.508.

Advantages of Nanocomposites are superior hardness, flexural strength, modulus of elasticity, translucency and aesthetic appeal, excellent colour density and shade matching with surrounding, high polish retention, 50% reduction in filling shrinkage, excellent handling that allows for easier placement and contouring and universal applicability for both posterior and anterior teeth.[3]

Nano glass ionomer

Glass-ionomer cements have significantly poorer surface-finish and aesthetic properties than the newer composites. "Nano ionomers," have surface finish more closely approximate that of a hybrid Composite. It Contains Acid Reactive Fluoro Alumina Silcate Glass And Nano Fillers.[13]

Bonding agents

The new bonding agents manufactured from nano solutions contain stable nano particles homogeneously dispersed throughout the solution. The silica nano filler technology contributes to higher bond strength performance. Since the nano particles are stable, they do not cluster nor do they settle out of dispersion. Nano Interaction Zone" (NIZ - <300 nm) with minimal decalcification and almost no exposure to collagen fibres producing an insoluble calcium compound for a better bond less likely to deteriorate from enzymes contained in the mouth.[2]

Coating agents

These light cured agents contain nanosized fillers and are used as a final coating over composite restorations, glass ionomer restorations, jacket crowns, veneers and provisional's. These coating agents have higher wear resistance, preventing abrasion and discolouration.

Recently, a nanotechnology liquid polish system was designed to overcome the limitations of liquid polishers. The addition of nanofillers provides excellent results such as a glossy surface for direct or indirect resin composite restorations.[14]

Impression materials

Nanofillers are integrated in vinylpolysiloxanes, producing a unique edition of siloxane impression materials. The material has got advantages of better flow, improved hydrophilic properties, hence fewer voids at the margin and better model pouring and enhanced detail precision.[9]

Preventive dentistry

Cavity prevention and aesthetics by ultrafine polishing

Ultra fine polishing of surface of human teeth leads to nanoscale roughness. Roughness left on the tooth after the polishing is just a few nanometers. It may protect the tooth surface against the damage caused by cariogenic bacteria as the bacteria can be removed easily from such polished surfaces. This also leads to less staining of the teeth and better aesthetics.[2]

Dentine hypersensitivity

Reconstructive dental nanorobots using native biological materials, could selectively and precisely occlude specific tubules within minutes, offering patients a quick and permanent cure. This analgesic technique is patient friendly as it reduces anxiety, needle phobia and most importantly quick and has completely reversible action.[15,16]

Nanotechnology microscope

Nanotechnology is emerging to underpin a new generation of deep-probe detectors; a new area of the electromagnetic spectrum is becoming available for probing the human body as well as revealing hidden matter. This is known as Terahertz radiation, the area is in between light and radio waves in the spectrum. It can be used to see tumours within the skin and more importantly to spot cavities in teeth.[17]

Application of nanotechnology in endodontics

Nanoparticles as antimicrobial agents

Nano particulates exhibit higher antibacterial activity as a result of their poly cationic or poly anionic in nature with higher surface area and charge density, resulting in a greater degree of interaction with the bacterial cell.

Chistosan nano particles have been applied in various fields in the treatment of bacterial bio films as well as wound healing primarily because of their antimicrobial properties and biocompatibility. It has been used as a carrier for the delivery of drugs and gene *in vivo* to treat various systemic diseases and have low levels of cytotoxicity. These have been shown to provide a significant improvement in the root canal disinfection by effectively eliminating the residual adherent and non adherent bacteria as well as increasing the diffusion of antibacterial components from the root canal sealers.[18]

Nanotechnology based root-end sealant

Nano material enhanced retrofill polymers (NERPs) provide better bond strength and adaptability to the tooth structure. In the extracted-tooth-model study, NERP materials were also found to significantly reduce the micro-leakage, demonstrating their ability to seal effectively.

Bio aggregate (BA), white nano particle ceramic cement is a novel root-end filling material composed primarily of calcium silicate, calcium hydroxide and hydroxyapatite. De-Deus *et al.,* found that BA displayed similar biocompatibility to that seen for MTA when cultured with primary human mesenchymal cells. However, there have been no reports so far on potential cytotoxicity of BA on osteoblast cells or BA effects on mineralization associated gene expression osteoblast cells.[19]

Nanotechnology: Role in dental biofilms

Nanotechnology helps in understanding of the role of interspecies interaction in the development of bio-film and used to study the dynamics of demineralization/ remineralization process in dental caries by using tools such as atomic force microscopy which detect bacteria induced demineralisation at an Ultrasensitive level.

Another nanotechnology application used so far is $^{16}O/^{18}O$ reverse proteolytic labeling to determine the effect of biofilm culture on the cell envelope proteome of oral pathogen, Porphyromonas gingivalis which is linked to chronic periodontitis.[20]

Nanotechnology can further enable us to detect both cultivable bacteria and non cultivable with the help of nano chip and can be used to selectively remove cariogenic bacteria while preserving the normal oral flora in a more targeted and proactive approach to dentinal caries than the conventional operative dentistry.

New silver nanotechnology chemistry has proven to be effective against biofilms. Silver has high affinity for negatively charged side groups on biological molecules such as sulphydryl, carboxyl, phosphate and other charged groups distributed throughout microbial cells. Silver attacks multiple sites within the cell to inactivate critical physiological functions such as cell wall synthesis, membrane transport, nucleic acid synthesis, translation, protein function and electron transport. It is effective against pathogens associated with biofilms including *E. coli, S. pneumoniae, S. aureus* and *A. niger*.[21]

CONCLUSION

Recent developments of nanoparticles and nanotubes in operative dentistry, Endodontics, periodontal management, nanoporous materials and nanomembranes will play a growing role in materials development for the dental industry. Continual refinement of traditional methods, development of advanced restorative materials, new medications and pharmacological approaches will continue to improve dental care.[22]

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