Heal Talk

Nano-Technology Inspired Next Generation Dentistry

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Abstract

Continuous zest for improvement in dental materials and procedures is pushing dentistry into the realm of nanotechnology. Nanotechnology duly supported by technological advancement is predicted to provide solutions to many roadblocks in dentistry.

Nanostructures such as nanoparticles, nanotubes, nanorods, quantum dots, nanospheres, nanofibers, etc. are being studied as promising candidates for material development in dentistry. Nanotechnology promises to provide holistic oral health care by virtue of its understanding of the pathophysiologic basis of disease and with the aid of the supporting properties of nanomaterials and dental nanorobotics.

Introduction

Nano is derived from the Greek word meaning "dwarf". Nanomaterials are the substances with dimension less than100 nm in at least one dimension. Nanoparticles include clusters of atoms, grains smaller than 100 nm, fibres and films thinner than 100 nm, nanopores and structures integrating various nanoparticles. Nano-technology is a promising area that deals with nanometer (10^{-9} m) sized items. It is predicted that nanotechnology will build up at some level for materials, devices, and systems. Nanoparticles were studied because of their size-dependent physical and chemical properties[1] and the study is evolved to their commercial application stage. The field of dentistry has been indirectly gaining from nano-related progress in the electronics industry in terms of the computerization of modern practices. The rapid progress made by science has connected nanotechnology to dentistry from its hypothetical basics to practical realisation. Continuous development of medical applications using nanotechnology in dentistry has been instrumental in the emergence of a novel field called nano-medicine. The science and technology of diagnostic and treatment procedures have also benefited from the use of nanoscale-structured materials. Nanodentistry is an attractive method for the maintenance of oral health. Uses of nanomaterials, ranging from tissue engineering to dental nanorobots indicate the newer principles and methods of expertise dental materials, tools, and practices. In this paper, the importance and applications of nanotechnology in the field of dentistry are discussed with an introduction to nano-structures and nanomaterials that are used in dental applications.

Historical prospects of nano-technology in dentistry

The term "nanotechnology" was proposed by Professor Kerie E. Drexler, a researcher of nanotechnology. The last decade has witnessed various hypothetical predictions that are based on the prospective relevance of nano-technology in dentistry. [2] Nano-technology has affected dentistry and healthcare more intensely than many other progress of the previous times. It provides considerable benefits, including enhanced health, optimal use of natural resources with nominal environmental pollution. Nobel Prize-winning physicist Richard P. Feynman in 1959, lectured that "nanotechnology is a development which I think cannot be avoided". [3]In 2000, Freitas repeated the Richard Feynman prediction that accompanied the origin of nanotechnology's definition and a vision that the atomic-level accuracy given by molecular devices operating at the nanoscale was a predictable technologic prospect. [4] The impact of nanotechnology on dental health has attracted the interest of dental professionals. Application of nanotechnology in medicines and dental materials will help to improve the diagnostic opportunities and provide more effective therapies supported by preventive properties.

Nano-structures used in dentistry

Nanodentistry has the potential to provide complete oral health by exploiting properties of nanomaterials for use in treatment and restructuring of teeth. Nanomaterials are zero-dimensional, one-dimensional, two-dimensional and three-dimensional nano-structures. The spectrum of nanostructures encompasses nanoparticles, nanorods, nanospheres, nanotubes, nanofibers, quantum dots (QDs), nanoscale cantilevers, and liposomes to target exact tissue or organ. These nanostructures may provide useful tools for diagnosis and treatment of dental disease.

Nanoparticles

A nanoparticle (Fig1) is a particle with one dimension of 100 nm or lesser in size. The properties of many conventional materials exhibit a remarkable change in their properties when converted from bulk to nanoparticles. Nanoparticles of different compositions match up with the most commonly used nanoscale units in dentistry. So application of nanoparticles for dental composites and reformulations of interfacial silanes is of great interest. Nanoparticles have been in use for several years to coat and bond inorganic fillers into RBC matrices for dental restoration; and also for tailoring of newer types of silane bonding agents. Nanoparticles and related alterations of existing RBC systems have shown noteworthy clinical usefulness. [5] Nanohybrid RBCs are presently the most promising example of nanotechnology. Xia et al reported that surface modification by the organosilane of TiO2 nanoparticles within a resin matrix was found to improve the microhardness and flexural strength of dental

RBCs. [6]

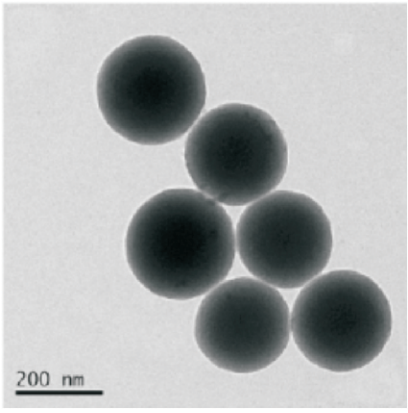

Fig 1 Nanoparticles

Nanorods

Nanorods (Fig 2) are nanoscale objects having dimensions ranging from 1 nm to 100 nm. These are of particular significance in a curative perspective. Hydroxyapatite (HA)-based composites exhibit swaying bioactivity. However, information on the influence of nanosized HA on the properties of dental materials is yet insufficient. Nanorods having a nanosized HA adhesive system may have practical applications in dental clinics. Chen et al have created enamel-prism-like HA nanorods that have self-assembly properties. [7] They are very similar to the enamel rods that are used to construct the vital crystalline of dental enamel. This implies that nanorods may provide a convenient artificial model of this naturally occurring structure. HA nanorods may be regarded as an alternative to other fillers such as silicates for use in dental adhesives. [8]

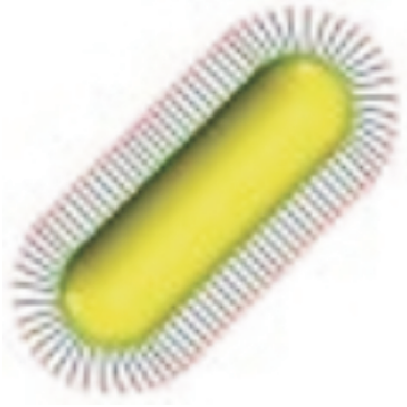

Fig 2 Nanorod

Nanospheres

Nanospheres (Fig 3)are also being explored for their potential use in curative systems to mimic nanoscale processes for inherent development in natural tooth. During the secretion of enamel, the amelogenin-rich organic matrix self-assembles in effect forming nanosphere structures that are allied along the budding enamel crystallites. [9] Nanosphere assembly in combination with calcium phosphate deposition and amelogenin nanochain assembly can be considered in a restorative perspective. [10]

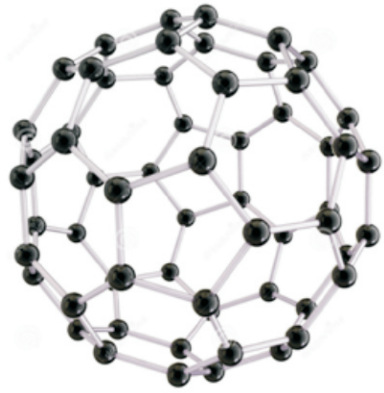

Fig 3 Nanosphere

Nanotubes

Nanotubes (Fig 4) are nanometer-scale tube-like structures that are being studied for various dental applications. Titanium oxide nanotubes have been observed in vitro to accelerate the kinetics of HA formation; this could used for bone growth applications for dental implants. [11]Single-walled carbon nanotubes (SWCNTs) silicon dioxide applied to them in combination with specialized organosilane bonding agents also display their ability to improve the flexural strength of RBCs. [12] Also novel nanostructured titania tubes have been successfully introduced in the poly (methyl methacrylate) (PMMA) bone cement matrix to improve its mechanical properties with extended and strong interfacial adhesion. [13]

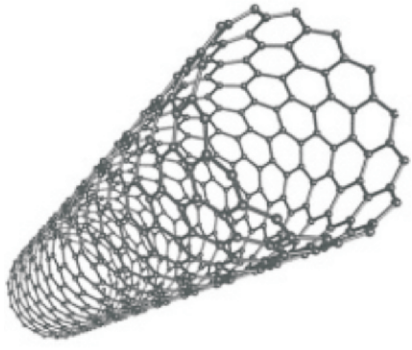

Fig 4 Nanotube

Nanofibers

Nanofibers (Fig 5) are defined as fibers with diameters less than 1000 nm. These are being studied for several biomedical applications. [14] Nanofibers are also being used to produce ceramics containing HA and fluor-HA. [15] Moreover, nanofibrillar silicate crystals have been explored for their capability for strengthening dental composites. [16] Nanofibers were established to improve the physical properties of composites by adding in the right ratios with uniform distribution of the fibers/crystals. [17] Nanofibers have a high aspect ratio with a large surface area to volume ratio;which might be instrumental in enhancing the physical and mechanical properties. [18]

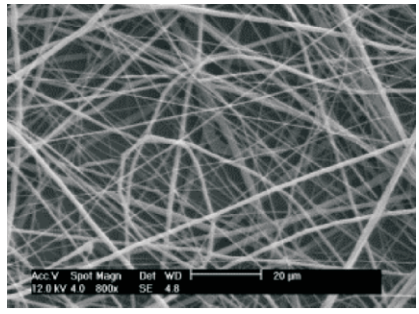

Fig 5 Nanofibers

Quantum dots

Quantum dots (Fig 6) typically are semiconductor nanocrystals that are of great interest virtue of their unique electronic, magnetic, chemical, and optical properties. They are predicted to be highly useful in many applications in the field of physical, engineering, chemical, biological, and medical sciences; especially in dentistry. [19] QD conjugates display standard epifluorescence microscopy that indicates brilliant single cell resolution of both in-vitro and in-vivo biofilm. The photostability of QD conjugates helps in micromanipulation of feasible spatially determined communities from the enamel chip surface. Alves et al studied dental resins doped with different concentrations of CdSe/ZnS coreeshell QD and found that incorporation of QD core into dental resins helps in the fabrication of restorative materials with fluorescence properties that closely mimic those of natural human teeth. [20]

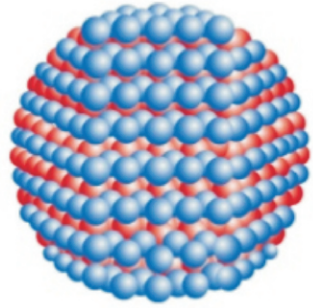

Fig 6 Quantum Dot

Nanoscale cantilevers

Nanoscale cantilevers (Fig 7) are flexible beams similar to a row of diving

boards. They are built by semiconductor lithographic techniques that can be engineered to attach to molecules associated with cancer. They may attach to altered DNA sequences or proteins that exist in certain types of cancer. These can be used for sensitive detection of cancer-related molecules. [21] As a cancer cell secretes its molecular products in form of DNA or proteins, the antibodies coated on the nanoscaled cantilever fingers selectively attach to these secreted proteins, in effect altering the physical properties of the cantilever and indicating the presence of cancer cells.

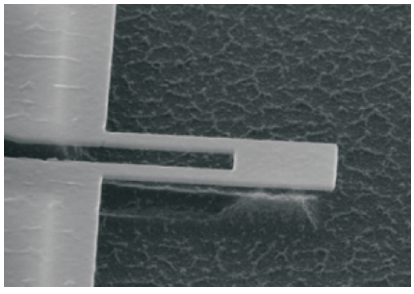

Fig 7 Nanoscale Cantilever

Liposomes

The limitation of conventional drug delivery systems is short retention time in the oral cavity virtue salivation, food intake and abrasion due to movements of soft tissue. The use of liposomes as a dental drug delivery system is a novel approach that might provide solution to this problem. Liposome (Fig 8) is a vesicular structure with an aqueous core embedded in a lipid bilayer. In vitro experiments have proved that liposomes adsorb to HA, which is the major component of dental enamel. [21] Nguyen et al have analysed the potential of liposomes as a dental drug delivery system, in particular for teeth targeting via in vitro adsorption of charged liposomal formulations to HA. [22]

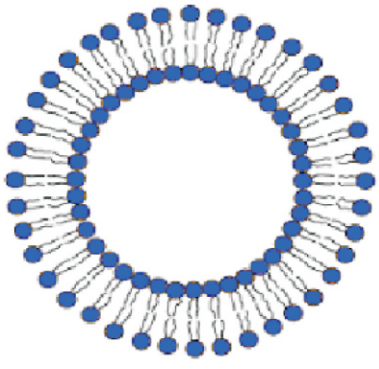

Fig 8 Liposome

Nanomaterials used for dental applications

Nanotechnology offers a wide range of applications in dentistry. It is predicted that nanotechnology will solve various issues in areas of disease diagnosis, drug delivery, targeted drug delivery and imaging. Newer and improved treatment in dentistry including local anesthesia, permanent hypersensitivity cure, dentition renaturalization, complete orthodontic realignments in a single visit to the clinic, etc are a few names to list . [23] Materials play an important role in all these procedures and improvisation of procedures is forecasted by virtue of the properties of nanomaterials.

a) Nanocomposite and nanosolutions: Nanocomposites are homogeneous mixtures of distinct nanoparticles in resins or coatings. Nanocomposites show better hardness, superior flexural strength, modulus of elasticity, and translucency, superior handling properties, and display a 50% decrease in filling shrinkage. A nanosolution is diffusion of nanoparticles that is mostly used as a bonding agent. Nanosolutions ensure homogeneity along with certainty that the adhesive is entirely mixed forever during bonding.

b) Impression materials: Accuracy and dimensional stability supported by pleasing smell and taste, with minimum setting time and effortless removal of set impression are the qualities that are wanted in impression material. Nanofillers are included in vinylpolysiloxanes to create an exclusive addition of siloxane impression materials. The material has improved flow, improved hydrophilic properties, and better feature accuracy. [24]

c) Nanorobotic dentifrice: The use of traditional topical anesthetics does not ensure pain-free dental local anesthesia. The effectiveness of conventional systems is dependent upon the gauge of the needle used and the duration of application. Administration of colloidal suspension having millions of dynamic analgesic micron-sized dental robots have been observed to be effective for performing intra-oral procedures, including periodontal manipulations, operative dentistry, and oral surgery. Nanorobots are small scaled machines that can be manipulated to allow accurate interactions with nanoscale objects. Orthodontic nanorobots are predicted to be effective in the periodontal tissues, including gingivae, periodontal ligament, cementum, and alveolar bone. Nanorobots can be used to to probe the nerve passages and restore all the sensations and deformities. [25]Nanorobots may be prescribed by an on board nanocomputer that follows pre-programmed directives in response to local sensor stimuli. Nanorobotic dentifrice (dentifrobots) integrated into mouthwash or toothpaste can be administered to guard supragingival and subgingival surfaces, metabolizing intended organic matter into safe and unscented vapors and performing uninterrupted calculus debridement. [26]

The durability and appearance of teeth can be improvised by substituting upper enamel layers with covalently bonded artificial materials such as sapphire or diamond, which are much harder than natural enamel. Sapphire is an excellent standard whitening sealant that provides a cosmetic alternative, but it is vulnerable to acid corrosion. As sapphire and diamond are brittle they are prone to fracture but this limitation can be overcome by the addition of carbon nanotubes. [27]

Conclusion

There has been continuous evolution of various dental materials and procedures. Nanotechnology has a deep impact on the field of dentistry. It has been observed that it has a remarkable effect on restorative dentistry by virtue of the enhancement of existent infrastructure with the help of nanostructures such as nanoparticles, nanotubes, nanorods, quantum dots, dendrimers, nanospheres, nanofibers, etc. Also nanocomposites or nanomaterials are more effective and are promising candidates for material development in dentistry. Nanotechnology has the potential to provide complete oral health care by virtue of the supporting properties of nanomaterials and dental nanorobotics. Nanotechnology improves the understanding of the pathophysiologic basis of disease and helps in refining diagnosis, treatment and prevention.

References

References are available on request at editor@healtalkht.com