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Nanodentistry - A Critical Dental Update

Abstract

Introduction: Dentistry is undergoing another change with the help of nanotechnology combined with nanomaterials, biotechnology and ultimately dental nanorobotics. Nanotechnology is the engineering of functional systems at the molecular scale. Application of nanotechnology in the field of dentistry includes dental restorative materials, tooth reposition, tooth repair, local anesthesia, diagnosis, and surgical procedures. Various nanostructures such as nanoparticles, nanopores, nanotubes, nanorods, nanospheres, nanofibers, nanoshells, quantum dots, dendrimers, and dendritic copolymers are used for various functions. Application of nanotechnology has been extended to local drug delivery, cancer therapy, and tissue engineering for repair or regeneration of tissues.

Key Words

Nanodentistry; nanotechnology; nanorobots; tissue engineering; dentifrobots

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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] 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,[2] and creation of artificial bone and teeth.[3]

History

The word "nano" is derived from nan (n) os, the Greek word for "dwarf, little old man." Nanotechnology is about manipulating matter, atom by atom. Nanotechnology includes nanorobots that are nanoscale materials.[4] One nanometer (nm) is 1 billionth or 10–9 of a meter. Various nanostructures for different functions includes nanoparticles, nanopores, nanotubes, nanorods, nanospheres, nanofibers, nanoshells, quantum dots, dendrimers, and dendritic copolymers. The concept of nanotechnologies was first stated by the Nobel Prize winning physicist Richard Feynman (1959) in his lecture, "there's plenty of room at the bottom."[5] In 1980, Eric Drexler introduced the term “nanotechnology”.[6] Since then, nanotechnology has come a long way to find its application in supramolecular chemistry self-assembling drug carriers and gene delivery systems, nanoparticles and nanocapsules, antibody technologies, polymer–drug conjugates, polymer–protein and antibody conjugates, nanoprecipitation, nanocrystals, emulsification technologies, liposome technology, in situ polymerization, tissue engineering and repair, dendrimer technologies, molecular imprinting including recent innovations in dental diagnostics, material, and therapeutics.[2] Nanotechnology mainly consists of the processing, separation, integration, and deformation of materials by one atom or one molecule.[6] The purpose of this article is to review current status of nanotechnology in dentistry.

Mechanism

Nanorobotic functions may be controlled by an onboard nanocomputer that executes preprogrammed instructions in response to total local robots via acoustic signals (as are used in ultrasonography) of other means similar to an admiral commanding a fleet. Command to shutdown will be sent through computer signal once it finishes desired function, and then it will be removed from the body in an inactive state by back of body.[1,3]

Nanodentistry

Nanodentistry includes: Nanorobotics, nanodiagnostics, and nanomaterials. Nanodentistry application can be classified into two broad categories as bottom-up and bottom-down approaches.

Application of Nanotechnology in Dentistry

I. Bottom-up approach

1. Inducing anesthesia

Nanotechnology uses millions of active analgesic micrometer-sized dental nanorobots in a colloidal suspension for local anesthesia. On reaching the dentin, the nanorobots, within 100 s, are said to enter dentinal tubular holes that are 1-4 μm in diameter and proceed toward the pulp, guided by a combination of chemical gradients, temperature differentials, and even position of navigation, all under the control of the onboard nanocomputer as directed by the dentist.[7]

2. Major tooth repair

Complete dentition replacement refers to replacement of the whole tooth, including cellular and mineral components. A combination of genetic engineering, tissue engineering, and nanotechnology is required for the same.[8]

3. Hypersensitivity cure

Reconstructive dental nanorobots selectively and precisely occlude selected tubules in minutes, using native biological materials, offering patients a quick and permanent cure for hypersensitivity caused by the changes in pressure transmitted hydrodynamically to the pulp.[9]

4. Dental durability and cosmetics

Covalently bonded artificial materials such as sapphire or diamond in a fracture-resistant nanostructured composite material that possibly include carbon nanotubes are used for replacing upper enamel layers for aesthetic purposes.[10]

5. Nanorobotic dentifrice (dentifrobots)

Nanorobotic dentifrice (dentifrobots) delivered by mouthwash or toothpaste control all supragingival and subgingival surfaces at least once a day metabolizing trapped organic matter into harmless and odorless vapors, performing continuous calculus debridement and identifying and destroying pathogenic bacteria residing in the plaque and elsewhere, while allowing the 500 species of harmless oral microflora to flourish in a healthy ecosystem.[11]

6. Tooth repositioning

Orthodontic nanorobots could directly manipulate the periodontal tissues including: Gingiva, periodontal ligament, cementum and alveolar bone, allowing rapid painless tooth straightening, rotating, and vertical repositioning in minutes to hours, in contrast to current molar uprighting techniques which require weeks or months for completion.[6]

7. Diagnosis of diseases

Nanotechnology may permit less invasive, less markers of disease, thus aiding in cancer diagnosis. In quantum dots, nanoscale crystals may be used as a potential reporting agent. In treatment of oral cancer, quantum dots bind to the antibody present on the surface of target cell land, and when stimulated by ultraviolet light, they give rise to reactive oxygen species, thus lethal to target cells. Nanometer-scale tubes and wires are said to help monitor local chemical, electrical, or physical property changes in cells or tissues. Biosensors used to investigate important biological processes at the cellular level invivo. Iodinated nanoparticles that have been localized successfully to lymph nodes after bronchoscopic instillation. Bio barcode assay, identify the target, and amplify the signal.[7] The oral fluid nanosensor test technology is used for multiplex detection of salivary biomarkers for oral cancer.[1]

II. Nanodentistry materials/bottom-down approach

1. Nanolight-curing glass ionomer restorative

Nano-ionomer is glass ionomer cement whose formulation is based on bonded nanofiller technology. Mechanical properties of nano-ionomer are improved by the combination of fluoroaluminosilicate glass, nanofillers, and nanofiller clusters.[1,3]

2. Nanoimpression materials

Nanofillers are integrated in vinyl polysiloxanes, producing a unique edition of siloxane impression material. The material has a better flow, improved hydrophilic properties, tear strength, and enhanced detail precision.[1,3]

3. Nanocomposites

Nonagglomerated discrete nanoparticles are homogeneously distributed in resins or coatings to produce nanocomposites. The nanofiller used include an aluminosilicate powder having a mean particle size of 80 mm and a 1:4 M ratio of alumina to silica and a refractive index of 1.508. These composites having nonagglomerated discrete nanoparticles are homogeneously distributed in resins or coatings to produce nanocomposites. The nanofiller used includes an aluminosilicate powder having a mean particle size of 80 mm and a 1:4 M ratio of alumina to silica and a refractive index of 1.508.[1]

4. Nanosolutions

Nanosolutions produce unique and dispersible nanoparticles, which can be added to various solvents, paints, and polymers in which they are dispersed homogenously.[3]

5. Nanoencapsulation

Targeted release systems that encompass nanocapsules including novel vaccines, antibiotics, and drug delivery with reduced side effects. Understanding of medicine at molecular level, development of nanotechnology has given a way to the development of the target-specific local drug delivery system. Using nanotechnology (nanopores), the drug can be targeted to a precise location that would make the drug much more effective and reduce the chances of possible side effects of chemotherapy.[11,12] Local targeted delivery has been enhanced by the use of nanosensors, nanoswitches, and other nanodelivery systems. The main aim of nanodrug delivery system is the entry of the drug into the cell by endocytosis using nanoparticles as carriers and a targeted delivery of the drug to the desired tissue or cell so as to minimize the side effects. Fibers or thread-like devices placed circumferentially into the pockets with an applicator and secured with cyanoacrylate adhesive for the sustained release of the trapped drug into the periodontal pockets.[13]

6. Prosthetic implants

Nanotitanium is a new form of titanium metal that has been introduced. It is highly compatible with bone and is thought to provide stronger, up to 20 times faster bonding with improved strength, biocompatibility, long life, and improved wear and tear.[1,3]

7. Na1eedles

Suture needles with nanosized stainless steel crystals have been developed. Nanotweezers are also under development that will make cell surgery possible in the near future.[1]

8. Nanovectors

Calcium phosphate nanoparticles were found to potentially serve as a good vehicle (nanovectors) to deliver target genes to fibroblasts for periodontal regenerative purposes in vitro.[3]

9. Orthodontic wires

Allows orthodontic wires with good formability and corrosion resistance.[6]

10. Mouthwashes

Mouthwashes containing nano-calcium fluoride show higher solubility and reactivity. It reduces dentine permeability.[6]

11. Biodegradable nanofibers

Bionanotechnology, especially with the powerful electrospinning method to fabricate the nanofibrous scaffold, is believed to be a promising technology. The synthetic aligned matrix along with the advantages of synthetic biodegradable polymers.[1,3]

12. Bone replacement materials

The hydroxyapatite nanoparticles have nanocrystallites that show a loose microstructure in which nanopores are situated between the crystallites. An application of nanotechnology has been extended in the medical field to tissue engineering. Nanotechnology help to produce or repair damaged tissue using engineering principles and biological sciences.[14] This tissue engineering makes use of artificially stimulated cell proliferation using suitable nanomaterial-based scaffold and growth factors. In future, tissue engineering might replace conventional organ transplant.[11] Native tissues or organs are composed of proteins within nanoscale and cells directly interact with nanostructured extracellular matrices, nanobiomaterials such as nanofibers, nanotubes, nanoparticles, and other nanofabricated devices capable for cell growth and tissue regeneration.[14] Electrospinning is a technique to produce ultrafine fibers by electrically charging a suspended droplet of polymer melt or solution. Various kinds of materials that can be electrospun into nanofibrous structures for various functions such as wound healing, cell adhesion, and stem-cell differentiation.[14] The combination of gene therapy and tissue engineering within a single system is thought to be a new treatment for regeneration medicine.[15]

Clinical Applications[4]

1. Periodontal treatments
2. Melanin removal
3. Incision of soft tissue without anesthesia
4. Caries prevention
5. Cutting of enamel and dentin.

Issues Related to Nanotechnology[4,6]

1. Precise positioning and assembly of molecular scale part

2. Economical nanorobot mass production technique
3. Simultaneous coordination of activities of large numbers of independent micron-scale robots
4. Biocompatibility issue
5. Funding and strategic issues
6. Insufficient integration of clinical research
7. Inefficient translation of concept to product because of inadequate venture capital, excessive bureaucracy, and lack of medical input
8. Social issues of public acceptance, ethics, regulation, and human safety.

CONCLUSION

The scope of "nanotechnology" may be broadly defined as the comprehensive monitoring, control, construction, repair, defense, and improvement of all human biological systems. Application of nanotechnology in dentistry has improved the quality of material and treatment delivery. 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.

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