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NANOTECHNOLOGY IN DENTISTRY

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ABSTRACT

Dentistry is a branch of science and medicine that is sophisticated in the study, diagnosis, prevention, treatment of diseases, disorders or conditions of the oral cavity, and healing arts to maintain oral health. Conventional treatment of dentistry involves various formulations including gels, paste, liquids as well as physical approaches like braces, restorative approaches filling, crowns, bridges, and sealants, root canal treatment, gum treatment. There are many limitations of the conventional dentistry for example sever pain, mouth ulcers, less patient compliance, sensitivity of the area, bleeding in gums and less patient compliance. Nanotechnology is new era in dentistry that is called nanodentistry. Nanodentistry is defined as the branch of science and technology for diagnosis, treatment and prevention of oral and dental diseases using the nanomaterials, biotechnology and nanorobots.

KEYWORDS: Nanotechnology, dentistry, nanodentistry, nanorobots.

INTRODUCTION

Nanotechnology or nanoscience refers to research and development of an applied science at the atomic or molecular level (i.e. molecular engineering, manufacturing).[1] The word “nano” is said to be derived from the Greek word which stands for “dwarf”.[2] Nanoscale though small in size has vast potential.[1] One nanometer is 1 billionth or 10^{-9} of a meter.[3] The American Physicist Richard Feynman through his lecture titled “there is plenty room at the bottom” delivered at Caltech in 1959 was touted as the one who provided the inspiration for the field of nanotechnology, but it was the Japanese scientist Norio Taniguchi of the Tokyo University of Science who first employed the term “nano-technology” in 1974. However, the term “nanotechnology” as against “nano-technology” was coined by Prof. Kevie E. Drexler in his 1986 book titled Engines of Creation: The Coming Era of Nanotechnology.[4]

Nanotechnology can be applied to various medical fields like Pharmacological research, clinical diagnosis, supplementing immune system, cryogenic storage of biological tissues, detection of proteins, probing of DNA structure, tissue engineering, tumor destruction via heating (hyperthermia) separation and purification of biological molecules and cells, magnetic resonance imaging (MRI) contrast enhancement, etc. Nanotechnology influences almost every facet of everyday life from security to medicine. The concept of nanotechnology is that when one goes down to the bottom of things, one can discover unlimited possibilities and potential of the basic particle. In nanotechnology, analysis can be made to the level of manipulating atoms, molecules and chemical bonds between them. The various nanoparticles include nanopores, nanotubes, quantum dots, nanoshells, nanospheres, nanowires, nanocapsules, dendrimers, nanorods, and liposomes.[5],[6] Nanotechnology has various applications in the field of industrial and clinical like Medicine(Diagnostics, Drug delivery) Chemistry and environment (Catalysis, Filtration)Energy (Reduction of energy consumption, Increasing the efficiency of energy production, The use of more environmentally friendly energy systems, Recycling of batteries) Information and communication (Novel semi-conductor devices, Novel optoelectronic devices, Displays, Quantum computers)Heavy industry (Aerospace, Refineries, Vehicle manufactures, Consumer goods, Foods). Nano pharmaceuticals can be used to detect diseases at much earlier stages.Nanotechnology is new era in dentistry that is called nanodentistry. Nanodentistry is defined as the branch of science and technology of diagnosis, treating and preventing oral and dental diseases using the nanomatrials, biotechnology and nanorobots.

Conventional treatment of dentistry

Conventional treatment of dentistry involves two approaches. Medications in dentistry: to control pain (anesthetics, analgesics, NSAID), to control plaque and gingivitis (mouthwashes), to prevent or treat infections (antibiotics), antifungals (candida), to prevent tooth decay (fluoride), to relieve anxiety(muscle relaxant), to treat xerostomia(artificial saliva).

1. **Conventional formulations:** Gels, paste, liquids
2. **Physical approaches:** braces**,** restorative approaches viz filling, crowns, bridges, and sealants, root canal treatment, gum treatment.

Conventional formulations

Gels

A **gel** is a solid, jelly-like material that can have properties ranging from soft and weak to hard and tough. Gel forming formulations current a novel idea of deliver drugs to patients as a liquid dosage form, yet achieve sustained release of drug for the desired period [7] .There are various formulations available in market with their active ingredients and uses.

Table1. Marketed formuations of gels used in dentistry

Name	Active ingredients	Uses
Corsodyl dental gel	chlorhexidine	Antiseptic and disinfectant agent.
Healing Super Relief Gel contains Oxygene®	Oxygene (Sodium Chlorite)	Disrupts bacterial colonization, eliminates oral odors.
Numbing gel	benzocaine	An anesthetic agent that is applied externally to tissues like gums
Gel-Kam Dental	Fluoride	Applied to teeth to prevent cavities

Paste

A thick, soft, moist substance typically produced by mixing dry ingredients with a liquid. Toothpaste is a paste or gel dentifrice used with a toothbrush as an accessory to clean and maintain the aesthetics and health ofteeth. Toothpaste is used to promote oral hygiene: it serves as an abrasive that aids in removing the dental plaque and food from the teeth, assists in suppressing halitosis, and delivers active ingredients such as fluoride or xylitol to help prevent tooth and gum disease (gingivitis). Triamcinolone acetonide 0.1% dental paste is a prescription medicine used to treat painful lesions in the mouth. Triamcinolone is commonly used in various conditions and is available in oral, nasal, injectable, topical, ophthalmic injection, and spray preparations. Triamcinolone was first approved by the FDA in 1957.

Liquids

Liquid used for rinsing the mouth is also called mouthwash. Mouthwash can help keep gums and teeth healthy. The main function of most mouthwashes is to freshen breath, although if you suffer from severe chronic bad breath (halitosis). some types of mouthwash**,** such as fluoride rinses**,** can help protect teeth against acids produced by plaque bacteria.

Physical approaches

Braces

Dental braces also known as orthodontic braces are devices used in orthodontics that align and straighten teeth and help to position them with regard to a person's bite, while also

working to improve dental health. They are often used to correct under bites, as well as malocclusions, overbites, cross bites, open bites, deep bites, crooked teeth, and various other flaws of the teeth and jaw. There are different types of braces are used like color braces, Invisalign braces, traditional braces, ceramic braces, damon braces.

Crowns

A dental crown is a tooth-shaped "cap" that is placed over a tooth -- to cover the tooth to restore its shape and size, strength, and improve its appearance. Need of crowns in dentistry

- To protect a weak tooth (for instance, from decay) from breaking or to hold together parts of a cracked tooth
- To restore an already broken tooth or a tooth that has been severely worn down.
- To cover and support a tooth with a large filling when there isn't a lot of tooth left.
- To hold a dental bridge in place.
- To cover misshapened or severely discolored teeth.
- To cover a dental implant.
- To make a cosmetic modification.

Nanodentistry

Nanodentistry is defined as the branch of science and technology of diagnosis, treating and preventing oral and dental diseases using the nanomaterials, biotechnology and nanorobots.In the past few years, considerable advances in the field of nanotechnology have led to a large number of nanomaterials being developed. These novel materials are known to enhance the performance of diagnosis, treatments and disease prevention. Today, Nanotechnology is understood by the following two pproaches

Approaches to nanodentistry

Bottom-up approaches

Top-down approaches

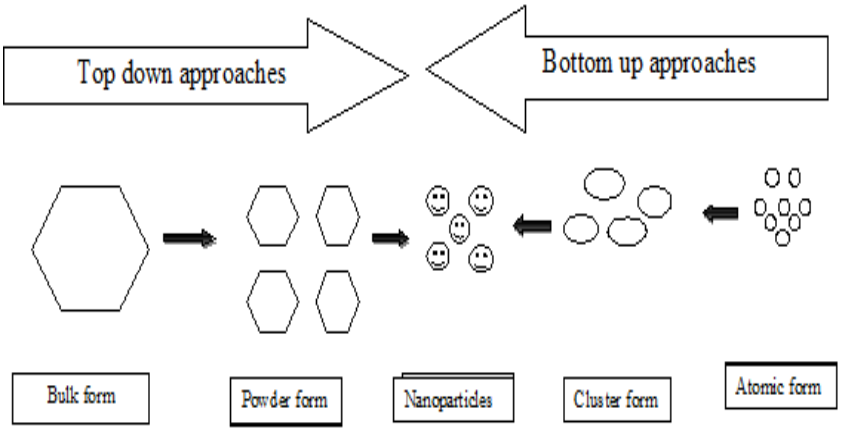

Figure 1: Nanoparticles as Seen in This Figure Are The Minute Components Used in Both Top Down and Bottom Up Approaches to Achieve nano dentistry

I. The Bottom Up Approach

Seeks to arrange smaller components into more complex assemblies, the covalent bonds of which are extremely strong.[8]

II. The Top Down Approach

Seeks to produce smaller devices by using larger ones in achieving precision in structure and assembly [8] .solid state materials can also be used to create devices known as N E M S (Nanoelectromechanical systems) which are used in cancer diagnosis.

Bottom-up approaches

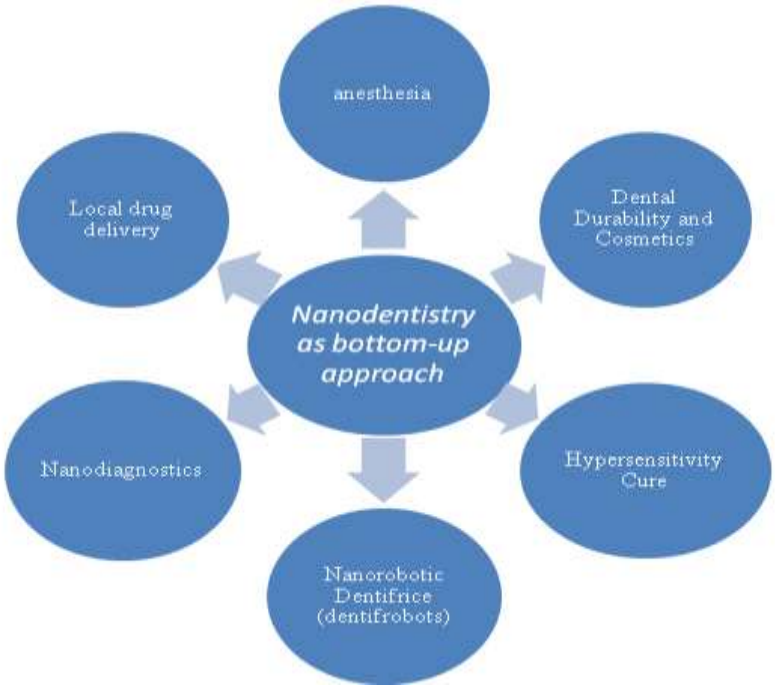

Figure 2: Nanodentistry as bottom- up approach

Nanoanesthesia

Nanorobots will play a powerful role in the induction of local anesthesia in the era of nanodentistry. A colloidal suspension containing millions of active analgesic micron-size dental robots will be instilled on the patient's gingival that will result in anesthesia. Anesthesia is fast acting, and reversible, with no side effects or complications with its use.[9,10]

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.[9]

Hypersensitivity cure

Hypersensitivity may be caused by changes in the pressure transmitted hydrodynamically to the pulp. The dentinal tubules of a hypersensitive tooth have twice the diameter and eight times the surface density of those in nonsensitive teeth. Dental nanorobots could selectively and precisely occlude selected tubules in minutes using native logical materials, offering patients a quick and permanent cure. [10]

Dental nanorobots

Although medical robots are not anticipated to have an effect on dentistry in the near future, it is not too early to consider their potential effects.[11] Dental nanorobots are able to move through teeth and surrounding tissues by using specific movement mechanisms. Nanocomputers that have been previously programmed via acoustic signals used for ultrasonography can control nanorobotic functions.[9]

Nanorobots (dentifrobots) left by mouthwash or toothpaste on the occlusal surfaces of teeth can clean organic residues by moving throughout the supragingival and subgingival surfaces, continuously preventing the accumulation of calculus. These nanorobots, which can move as fast as 1 to 10 micron/second, are safely deactivated when they are swallowed.[10]

Nanodiagnostics

Nanotechnology may permit less invasive, less uncomfortable means of identifying and quantifying the markers of disease, thus aiding in cancer diagnosis, monitoring recurrence or

metastasis, and defining the locations, biologic types, and behaviors of malignancies. The diverse techniques include.

• Physicochemical nanoscale modification i.e "nanotexturing" of surfaces on a mass spectrometry planar or micro or nanoparticle substrate is present. It has been proposed to provide size exclusion, elective capture, and resultant enrichment of selected regions of the low molecular weight proteins from body fluids and other biologic samples.

• 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 UV light, they give rise to reactive oxygen species, thus lethal to target cells.

• Bio Barcode Assay, identify the target and amplifying the signal. A magnetic probe captures a target molecule using either monoclonal antibody or complementary oligonucleotide. Target-specific gold nanoparticles sandwich the target, thus distinguishing the target and amplifying the signal. The barcode oligonucleotides are released and detected using the scanometric method.

• Nanometer scale tubes and wires are said to help monitor local chemical, electrical, or physical property changes in cells or tissues.

• Iodinated nanoparticles that have been localized successfully to lymph nodes after bronchoscopic instillation and may be visualized precisely through the use of computerized tomography (CT).

• Nanoelectromechanical systems (NEMS) are supposed to enable the ability to monitor health status, disease, progression, and treatment outcome through non - invasive means.

• Biosensors used to investigate important biological processes at the cellular level in vivo, include - cant i lever ar ray sensor, nanotube sensor and nanobiosensors. Cantilever arrays with their extraordinary multiplexing capabilities could aid cancer diagnosis and could be engineered to bind to molecules associated with cancer, such as DNA sequences, single nucleotide polymorphisms, and proteins.[9]

Local drug delivery

Nanotechnologic packaging of therapeutics will provide the ability to co-localize delivery of multiple and complimentary therapeutic agents.[12]

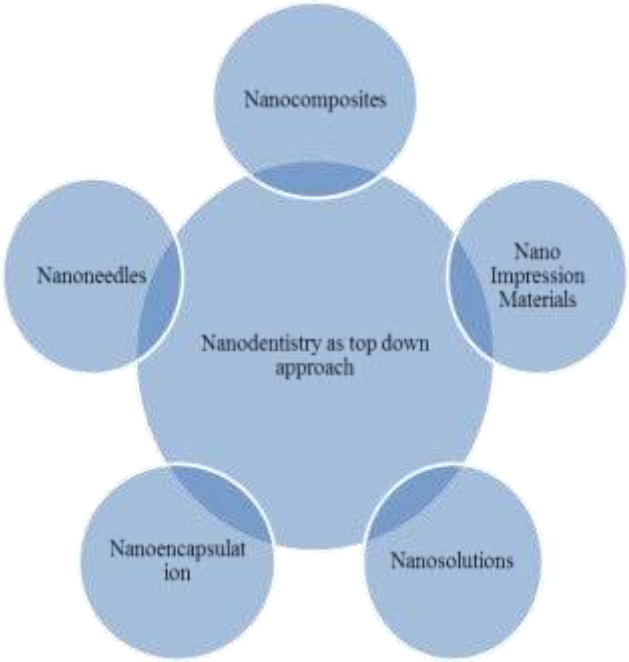

Figure 3: Nanodentistry as top down approach

Nanocomposites

Efforts to improve the clinical performance of composite filling material are focused on the following main topics:

• Reduction of the polymerization shrinkage. Nanocomposites, have a filler loading upto 95% that help reduce polymerization shrinkage,

• Improvement of the mechanical properties, especially wear resistance,

• Improvement of biocompatibility by reducing the elution of components.[12]

Nanofiller particles maybe of two types

• Nanometric, particles (NM) - are monodisperse non aggregate and nonagglomerated silica particles which are treated with 3 methacryloxypropyltrimethoxysilane, (MPTS - coupling agent) to prevent any agglomeration or aggregation and allow chemical bonding of theNMfiller of the res in, mat r ix dur ing curing.[13]

• Nanocluster (NC's) Particles have a primary particle size of 2 to 20 nm, while the spheroid agglomerated particles have a broad size distribution, with an average size o f 0. 6 micro meters.[13] Nanoparticles with an adapted refractive index and radiopacity were obtained by synthesizing mixed oxides such as silica Zirconia nanoparticles. Moreover, well designed nano and microstructures sol gel can be utilized for producing protective and wear resistant coatings of teeth, metal alloys, and glass fillers of special compositions. According to Tussi et al, regardless of the finishing and polishing technique, the nanofilled composites exhibited the lowest pretesting surface roughness and wear.[14]

Nano Impression Materials

Nanofillers are integrated in vinylpolysiloxanes, producing a unique edition of siloxane impression material. The material has a better flow, improved hydrophilic properties, tear strength and enhanced detail precision. The presence of the nanostructure increases the fluidity of the material, especially when pressure is applied.[15]

Nanoneedles

Suture needles with nano sized stainless steel crystals have been developed. Nano tweezers are also under development which will make cell surgery possible in the near future. The characteristics in general can be said to be a combination of properties of ordinary austenitic stainless and low alloyed ferritic steels. This means that properties such as elastic modulus, mechanical properties and thermal expansion are comparable to ferritic steels (such as low alloyed carbon steels or chromium steels) while properties such as corrosion resistance is more comparable to austenitic stainless steels.[16]

Nanosolution

Nanosolutions produce unique and dispersible nanoparticles, which can be used in bonding agents. Ensures homogenecity and ensures that the adhesive is perfectly mixed everytime.

Nanoencapsulation

Targeted release systems that encompass nanocapsules including novel vaccines, antibiotics and drug delivery with reduced side effects. Future specialized nanoparticles could be engineered to target oral tissues, including cells derived from the periodontium.

PATENT RELATED TO DENTISTRY

A few patents granted for dentistry are mentioned below in table 2.

Patent no.	Title	Year	Patentee/ assignee	References
US 7,699,612	Method for fixing an implant, fixing member for the implant and implant composite	April 20, 2010	Akagawa; Yasumasa, N/A (Hiroshima, JP), Kubo; Takayasu (Hiroshima, JP), Doi; Kazuya (Hiroshima, JP) Covalent Materials Corporation (Tokyo, JP)	Akagawa et al.[17]
US 7,723,421	Molding compositions with solid thermoplastic	May 25, 2010	Guzauskas; Robert (West Palm Beach, FL)	Guzauskas et al.[18]

	elastomer thickeners and products obtained therefrom			
US 7,875,342	Porous ceramic composite bone grafts	January 25, 2011	Smith; Timothy J. N. (Kingston, CA), Jason; Hendry (Kingston, CA), Sydney; M. Pugh (Glenburnie, CA), Reginald; Smith (Kingston, CA) Assignee: Warsaw Orthopedic, Inc. (N/A)	Smith et al.[19]
US 8,071,131	Mineralizing composite materials for restoring teeth	December 6, 2011	Rutherford; Bruce (Seattle, WA) Assignee: Ivoclar Vivadent, Inc. (Amherst, NY)	Rutherford et al.[20]
US 8,414,294	Dental probe with bristles	April 9, 2013	McWhorter; Robert D. (Pocatello, ID)	McWhorter et al.[21]
US 8,594,782	Apparatus and methods for determining the location of the apex of a dental root canal	November 26, 2013	Laxhuber; Ludwig (Herrsching, DE), Endosafe GmbH (Bregenz, AT)	Laxhuber et al.[22]
US 8,974,805	Dental cleanser composition for improving adhesion to teeth	March 10, 2015	Chung; Chong-Pyoung (Seoul, KR), Park; Yoon-Jeong (Seoul, KR), Lee; Jue-Yeon (Gyeonggi-do, KR)	Chung et al.[23]
US 8,979,991	Substances and method for replacing natural tooth material	March 17, 2015	Torabinejad; Mahmoud (Loma Linda, CA), Moaddel; Homayoun (Pomona, CA)	Torabinejad et al.[24]
US 9,028,254	Dental prosthetics comprising curable acrylate polymer compositions and methods of their use	May 12, 2015	Orlowski; Jan A (Altadena, CA), Butler; David V (West Covina, CA), Chin; Alice (Monterey Park, CA)	Orlowski et al.[25]
US 9,237,939	Hand tool for dentistry and dental prosthetics	January 19, 2016	Maurer; Philipp (Lucerne, CH), Taormina; Matteo (Zurich, CH), Linder;	Maurer et al.[26]

			Andreas (Basel, CH), Straumann Holding AG (Basel, CH)	

FUTURE FOR NANOTECHNOLOGY

Nanotechnology faces many challenges that need to be overcome such as - precise positioning and assembly of molecular scale part, economical nanorobot mass production technique, biocompatibility, simultaneous co- ordination of activities of large numbers of independent micron scale robot and social issues of public acceptance, ethics and regulation and human safety.[15] The risk to health and environment from nanoparticles and nanomaterials and the risks posed by molecular manufacturing and social risks need further inverstigation.[9]

CONCLUSION

Multifunctionality is the key advantage of nanoparticles over traditional approaches. The emergence of consensus concerning the direction, safety, desirability and funding of nanotechnology will depend upon how it is defined. Nanotechnology offers great potential in the field of dentistry ranging from dental restorative materials to implants to surgical procedures to bone replacement material etc. However, with every great good, comes great evil. While it is appropriate to examine carefully the risks and potential toxicity of nanoparticles and other products of nanoscale technology, the greatest risks are posed by malicious and unwise use of molecular manufacturing. The future utilization of the advantages of nanotechnology will facilitate improvements in oral health. Advanced restorative materials, new diagnostic and therapeutic techniques, and pharmacologic approaches will improve dental care.

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