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NANODENTISTRY

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ABSTRACT

Nanotechnology is a phenomenon present since the late 1950's and is currently finding a strong ground in the field of dentistry. Nanotechnology when integrated into dentistry gives rise to a new stream nanodentistry. The purpose of this paper is to review nanodentistry in its current form categorizing broadly into bottom up approach and top dowm approach hence covering various applications of nanotechnology ranging from the nanorobots in nano anesthesia to its varied use in dental materials and implants. Nanotechnology is an empire in the rising and though it faces many challenges such potential toxicity of nanoparticles, risks due to malicious and unwise use of molecular manufacturing, it still offers great potential for innovations in dentistry.

KEYWORDS : Nanodentistry, Nanotechnology, Dentistry

Nanotechnology is a term that is gaining importance and expertise in every area of medicine. Although the term 'nanotechnology' was unknown in the 1950s, late Nobel Physicist Richard P Feynman in a dinner talk, inadvertently introduced the concept with his celebrated words, "There is plenty of room at the bottom" indicating the usage of machine tools in making smaller machine tools, eventually creating tools all the way down to the atomic level. (Gribbin & Gribbin, 1997)

Feynman's idea was overlooked until the mid-1980s, when the MIT educated engineer K Eric Drexler introduced the term "nanotechnology, (Gribbin & Gribbin, 1997) which was later defined by Norio Taniguchi as follows: Nanotechnology mainly consists of the processing, separation, integration, and deformation of materials by one atom or one molecule.

Today, Nanotechnology is understood by the following 4 approaches

I. **The Bottom Up Approach:** Seeks to arrange smaller components into more complex assemblies, the covalent bonds of which are extremely strong. (Das et al., 2007)

II. **The Top Down Approach:** Seeks to produce smaller devices by using larger ones in achieving precision in structure and assembly. (Das et al., 2007) These solid state materials can also be used to create devices known as NEMS (Nanoelectromechanical systems) which are used in cancer diagnosis.

III. **The Functional Approach:** Seeks to develop components of a desired functionality without regard to how they might be assembled.

IV. **The Biomimetic Approaches:** Seeks to apply biomolecules for applications in nanotechnology. (Ghalanbor et al., 2005)

The subfields anticipate what inventions nanotechnology might yield, or attempt to propose an agenda. (Kubik et al., 2006)

The applications of nanotechnology are varied. They include medicine, environment, energy, information and technology, heavy industry and consumer goods. In the field of dentistry, the integration of nanotechnology has given rise to a new stream 'nanodentistry'. (Uysal et al., 2010) Nanotechnology has its influences in the following ways in dentistry. (Figure, 1)

1. BOTTOM UP APPROACH

a. Nano Anesthesia

Nanotechnology uses millions of active analgesic micrometer sized dental nanorobots in a colloidal suspension for local anaesthesia On reaching the dentin, the nanorobots, within 100 seconds, are said to enter dentinal tubular holes that are 1 to 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. (Freitas Robert, 2000)

b. Hypersensitivity Cure

Reconstructive dental nanorobots selectively and precisely occlude selected tubules in minutes, using native

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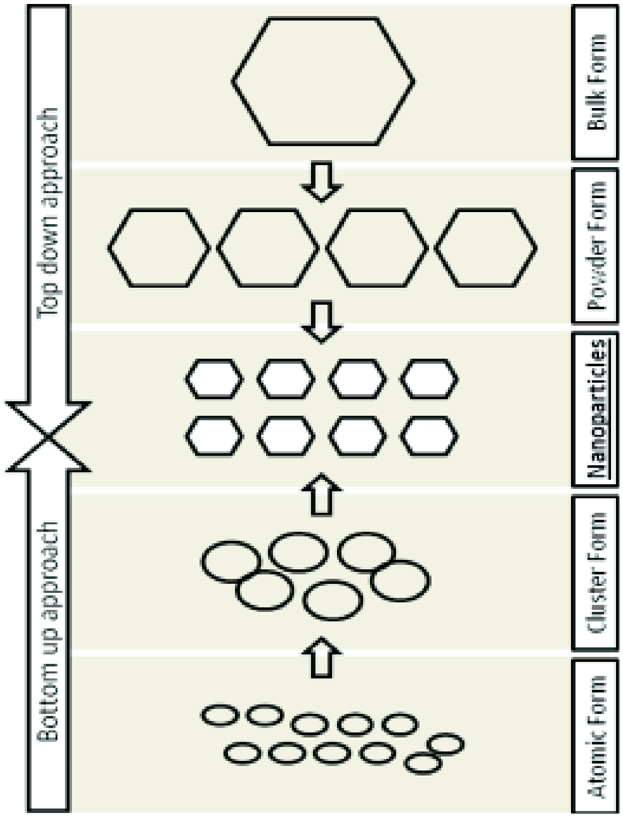

Figure 1: Nanoparticles as Seen in This Figure Are The Minute Components Used in Both Top Down and Bottom Up Approaches to Achieve Adequate Clinical

biological materials, offering patients a quick and permanent cure for hypersensitivity caused by the changes in pressure transmitted hydrodynamically to the pulp. (Nagpal et al., 2011)

c. 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. (Freitas, 2000)

d. Detifrobots

Nanorobotic dentifrice (dentifrobots) delivered by mouthwash or toothpaste patrol 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.

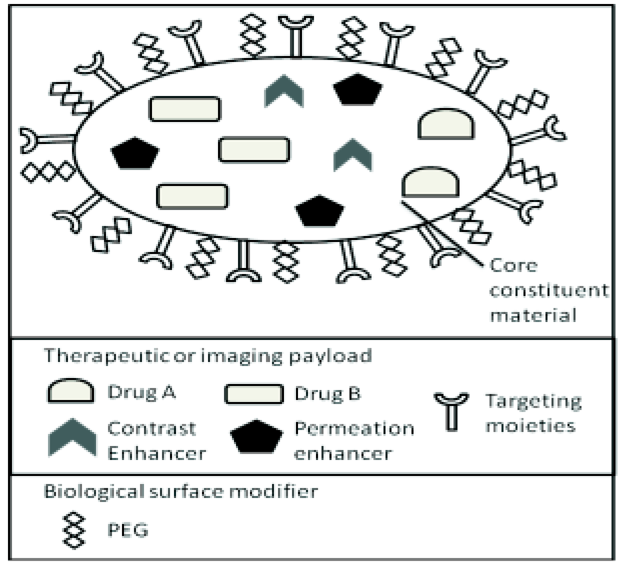

Figure 2: Multifunctional Nanoparticle Illustrating The Ability to Carry One or More Therapeutic Agents, Biomolecular Targeting Through One or More Conjugated Antibodies or Other Recognition Agents, Imaging Signal Amplification By Way of Coencapsulated Contrast Agents, And Biobarrier Avoidance Exemplified By an Endothelial Tight-Junction Opening Permeation Enhancer And By Peg For The Avoidance of Macrophage Uptake

(Freitas, 2000)

e. Orthodontic Nanorobots

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. (Shetty et al., 2013)

f. Cancer Diagnosis

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 - cantilever array 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. (Freitas, 2000)

g. Therapeutic Nanotechnology

Nanotechnologic packaging of therapeutics will provide the ability to co-localize delivery of multiple and complimentary therapeutic agents. (Patil Mallanagouda , Singh Mehta Dhoom & Guvva Sowjanya, 2008) (Refer Figure, 2).

Additionally, materials that now require injection potentially could be inhaled or swallowed using nano engineered delivery devices, thus improving patient comfort and compliance.

Vaccines may be made more comfortable, by using multitudes of micro- or nanometer-scale needles, to which human nerves are insensitive, rather than a painful injection.

Nanoparticulates also may allow increases in the amount of drug that reaches abnormal cells. They possess a site-specific targeting ability combined with potentially metabolism-specific targeting. It also has the ability to cloak off potentially toxic therapies. Theoretically, the requirement for less total amount of therapeutic agents may allow the safe use of some drugs that are effective but otherwise have unacceptable toxicity profiles.

Nanometer-scale features may allow the practical construction and use of fully implantable and controllable drug delivery devices. (Patil et al., 2008)

2. TOP DOWN APPROACH

a. Nanotechnology for Composites

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 (Patil et al., 2008)

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 the NM filler of the resin, matrix during curing. (Koneti & Dayanand, 2008)
- 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 of 0.6micro meters. (Koneti & Dayanand, 2008)

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. (Wei et al., 2007)

b. **Nanotechnology for Glass Ionomer Cement (GIC)**

Nano Ionomer is a glass ionomer cement whose formulation is based on bonded nanofiller technology. Mechanical properties of nano-ionomer are improved by the combination of fluoroaluminosilicate glass, nanofi llers, and nanofi ller clusters. The nanofi ller components also improve some physical properties of the hardened restorative. It also shows high fluoride release that is rechargeable after being exposed to a topical fluoride source. Additionally, in vitro tests showed that the nano ionomer (Ketac N100) has the ability to create a caries inhibition zone after acid exposure. (Uysal et al., 2010)

c. Improving Endodontics

A novel root end filling material; Nanomaterial enhanced retrofil polymer (NERP) has been developed. It reveals better bond strength and adaptability to the tooth structure as compared to conventional retrofill materials. These promising results are synonymous with in vitro dental antibacterial and micro-leakage studies. Pellets of NERP loaded with an antimicrobial drug, chlorhexidine, displayed sustained drug - release capabilities and confirmed that drug-elution can be manipulated. In particular, the drug-elution studies showed enhanced release as the acidity level of the surrounding environment was reduced, a finding uniquely favorable in cases of apical infection where the environment is mostly acidic. In the latest extracted-tooth-model study, NERP materials were also found to significantly reduce the micro-leakage of bacteria compared to conventional materials, demonstrating their ability to seal effectively. (Chogle et al., 2013)

Further encorporation of nanotechnology in various solutions used for endodontic purposes aids in the prevention of agglomeration,

- Prevents agglomeration,
- They have high dentin bond strength,
- Reinforce the surface hardness of exposed dentin,
- Penetrate dentinal tubules of diameter 5 -10nm to provide additional 'nano retention'. (Mitra et al., 2003)

d. 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. (Kumar & Vijayalakshmi, 2006)

e. Nano Titanium Implants

Nano Titanium is a new form of titanium metal that has been introduced. Patients should experience shorter post surgery healing times and a more reliable integration of these new implants into their body. 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. (Albrektssonet al., 2008)

f. Nano Needles

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. (Shetty et al., 2013)

g. Biodegradable Nanofibres

Bionanotechnology, especially with the powerful electrospinning method to fabricate the nanofibrous scaffold is again believed to be a promising technology. The synthetic aligned matrix along with the advantages of synthetic biodegradable polymers, with the required nanometer-scale dimension and a defined architecture replicating the in vivo like vascular structure, may represent an ideal tissue engineering scaffold, especially for blood vessel engineering. (Mendonça et al., 2008)

h. Wound Dressing

Some medical products containing nano-particles have been raised, notably those for wound dressings. The Biosafety of nanometer-scale materials is the subject of much attention, therefore enhancing the focus on studies of the acute and chronic toxic effects of nano-particles. Self-assembly technology is a strategy for nanofabrication, which calls for designing molecules and supramolecular entities in a way that shape-complementarities cause them to aggregate into the desired structure thus acting as a recognized barrier to full and partial thickness wounds. This method is practiced widely in chemical science and biomedicine. It has been discovered that silver nano crystalline Chitosan dressing yielded in a faster healing process. (Kumar & Vijayalakshmi, 2006)

i. Bone Replacing Materials

The hydroxyapatite nanoparticles have nanocrystallites that show a loose microstructure in which nanopores are situated between the crystallites. This material structure is completed by pores in the micrometer area. Porosity values of around 60 % can be found. The surface of the pores is modified in such a manner, that it literally "hangs on" to the proteins. From the porosity in the nanometer range, most bone replacement material mainly acts on a surface on which proteins can configure. That's why the cells recognize it as body's own material. (Kumar & Vijayalakshmi,2006)

j. Major tooth Repair / Nano Tissue Engineering

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. The pioneer for complete dentition replacement was Chan et al., who recreated dental enamel, the hardest tissue in the human body, by using highly organized micro-architectural units of nanorods. (Shetty et al., 2013)

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. (Kumar & Vijayalakshmi, 2006).

The risk to health and environment from nanoparticles and nanomaterials and the risks posed by molecular manufacturing and social risks need further inverstigation. (Freitas, 2000).

CONCLUSION

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.

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