IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 16, Issue 1 Ver. XI (January. 2017), PP 14-18
www.iosrjournals.org

Recent Advances in the Field of Nanotechnology: A Review

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Abstract: *New science and technologies are making their way into all aspects of dental practice and have changed traditional approaches to diagnosis, risk assessment, prevention and many other procedures. The impact of nanotechnology on the field of dentistry is creating major changes with respect to improvement of health, diagnosis and proper use of natural resources. Nanotechnology has its greatest effect on restorative dentistry by contributing to the enhancement of previously established clinical systems with the help of nanostructures such as nanoparticles, nanotubes, nanorods, quantum dots, dendrimers, nanospheres, nanofibers, etc. Nanotechnology improves the understanding of the pathophysiologic basis of disease, conveys extra refinements in diagnosis, and yields more efficient treatment and preventive properties.*

Keywords: *Nanoparticle, Nanotechnology, Nanodentistry*

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I. Introduction

Recent Advances In The Field Of Nanotechnology: A Review

Nanotechnology is the creation of functional materials, devices and systems through control of matter on the nanometer length scale and exploitation of novel phenomena and properties (physical, chemical, biological) at that length scale.

Nanotechnology has applications in many fields like

- Medicine includes Diagnosis, Drug delivery &Tissue engineering
- Chemistry and environment includes Catalysis, Reduction of energy consumption, Increasing the efficiency of energy production, Energy, Recycling of batteries Filtration
- Information and communication includes Novel semiconductor devices, Quantum Computers
- Heavy Industry includes Aerospace, Vehicle manufacturers, Refineries, Consumer goods, Foods

Types of nanotechnologies

Nanopharmaceuticals-Application include Cancer, Antiviral agents, Arteriosclerosis, Lung disease and diabetes, Gene therapy, Tissue engineering, Tissue cell repair

Nanodevices- Application include delivery of diagnostic and therapeutic agents

They can be generally divided into three potent molecular technologies:

- Nanoscale materials and devices to be applied in advanced diagnostics and biosensors, targeted drug delivery and smart drugs.
- Molecular medicine through genomics, proteomics, artificial biobotics (microbial robots)
- Molecular machines and medical nanorobots aid in immediate microbial diagnosis and treatment and enhancement of physiological functions

Tissue Engineering

Nanotechnology can help to reproduce or to repair damaged tissue. "Tissue engineering" makes use of artificially stimulated cell proliferation by using suitable nanomaterial-based scaffolds and growth factors. Tissue engineering will eventually replace todays conventional treatments, such as transplantation of organs or artificial implants.[1]

Biopharmaceutics

Nanotechnology offers new delivery solutions in two areas:

- Drug encapsulation
- Functional drug carriers.

The advantage of using encapsulation materials at the nanoscale is that they present better solutions for the delivery of certain drugs. Functional drug carriers are another type of drug delivery that uses nanomaterials to carry drugs to a particular location in the human body.[2] For instance, certain nanostructures (fullerenes/buckyballs, den-drimers and nanoshells) can be used to target specific cells and subsequently release the pay load as they enter the cells (cells can absorb materials that are <100 nm, hence the importance of developing nanoproducts.

Magnetics

- Magnetically controlling the release of drugs by the help of nanoparticles is another method whereby drug delivery is benefited from nanotechnology.
- This usually consists of magnetic fluids which bind with and concentrate the drugs at the site of their delivery.
- Magnetic fluid usually consists of magnetic nanoparticles floating in both organic and inorganic fluid.
- Magnetic nanoparticles consist of iron based compounds of nanometer size. However before these can be used within the body they have to be coated with materials that are biodegradable, non toxic and biologically stable.[3]
- These nanoparticles must also be compatible to the internal environment of the cell.
- Magnetic nanoparticles have the ability to be attracted to distant magnetic fields, so it concentrates drugs at the site of the solid cancer tumor. This feature may also help in thermotherapy.
- Future progress depends on the sharing of knowledge about tools and techniques, as well as on the exchange of expertise on the atomic and molecular interactions along the new scientific frontier.
- This is a truly multidisciplinary area of research and development, in which materials, scientists, medical researchers, and mechanical and electronic engineers must work together with biologists, physicists and chemists.

Implantable Materials

The possibility of repairing and replacing human tissues is another remarkable application of nano-technology in the biomedical sciences. Scientists are developing a new generation of nanoscale biostructures that solve some of the problems related to the repair and replacement of tissues in the body (the most common problems are immune rejection and invasive surgery). Nano-technology offers new biocompatible nanomaterials and coatings that should increase the adhesion, durability and lifespan of implants.[4]

Other areas of application of nanoscale biostructures include bone repair, bioresorbable materials and smart materials. In the case of bone repair, calcium phosphate apatite (CPA)and hydroxyapatite (HAP), for instance, are two nanoceramic materials that can be used since they have the ability to conform to and bond with bone. Bioresorbable materials have the advantage of having the capacity to disintegrate without human intervention. For instance, these nanomaterials can be used in sutures and orthopedic fixation devices but, more importantly, they could be used as temporary implants, which would avoid subsequent surgery owing to their biodegradable nature Finally, smart materials are nanomaterials that have the ability to react to the environment (e.g., to temperature). These types of applications are usually considered as methods of restoring or enhancing human performance at the mental level (sensory) and physical level (increase strength or restore mobility).[5]

This technology can be used in the following areas:

Tissue repair and replacement, Implant coatings, Tissue regeneration scaffolds, Structural implant materials, Bone repair, Bioresorbable materials, Smart materials, Assessment and treatment devices, Sensory aids, Retinal and cochlear implants.

Implantable Devices

Nanotechnology offers new technologies that enable the monitoring and collection of data in a more efficient way. Nanosized sensors could be used for the monitoring of blood sugar in diabetes. Other applications include the development of sensor microchips to monitor body parameters such as pulse, temperature and blood glucose.[6]

Devices can also be implanted in the human body for specific medical applications. For instance, very small implantable fluid injection systems can be placed in the body to dispense drug on demand for the treatment of diseases such as cancer. The advantages are the ability to target the tumors to be treated and such devices enable a more optimum dosage of medication. Other applications include implantable heart sensors to monitor the heart's activity and the ability to be used as an implantable defribulator.

Finally, some nanodevices are being developed to restore vision and correct hearing dysfunctions. These types of devices are built to collect and interpret information and transform them into electrical signals transferred directly to the nervous system of an individual. Retinal implants use nanodevices to stimulate ilic functional neurons in the retina electrically. Hearing loss is usually caused by the absence or malfunction of

sensory cells in the cochlea (spiral-shaped cavity of the inner ear that contains nerve endings essential for hearing). Cochlear implants function as a substitute for the action of the middle ear, cochlear mechanical motion andsensory cells.

Surgical Aids

Another category of nanodevice that could change the practice of medicine is medical nanodevices that would enable greater precision, better monitoring of physiological and biomechanical parameters and safer & potentially less expensive surgical procedure as because they are less invasive. For instance, a company is developing smart medical instruments (catheters able to measure the blood velocity along a vessel) that use sensors with micro-electromechanical systems (MEMS) technology. Robotic surgical systems are also under development to provide surgeons with unparalleled precision instruments.[7]The great advantage of such technology is that it should provide less-invasive surgical procedures.

Diagnostic Tool

Finally, nanotechnology offers new applications in the area of genetic testing. In particular, these innovative solutions can increase speed and accuracy in the process of identifying genes and genetic materials either for treatment-oriented applications or the development of new drugs.

Few applications:-

T4 bacterial

Virus, an assembly of protein components, is a simple biological "nanomachine". The head is protein membrane, shaped like a kind of prolate icosahedron with 30 facets and filled with deoxyribonucleic acid (DNA). It is attached by a neck to a tail consisting of a hollow core surrounded by a contractile sheath and based on a spiked end plate to which six fibers are attached. The spikes and fibers affix the virus to a bacterial cell wall. The sheath contracts, driving the core through the wall and viral DNA enters the cell. Bacteriophages are being studied in anti-bacterial applications as phage therapy.

Chrysalis

Poisoning, asphyxiation, drowning, all require cell-by-cell repair, perhaps too extensive for macrophages. A chrysalis first envelopes the patient, then enters in between all his cells. It disassembles the patient, surrounding each cell with its own repair machinery and vascular system.

The geometry already preserves information about locations of the patient's cell. If necessary, though, morphogen chemical gradients could also retain this information. A patient would swell upto 10 times original diameter. After repair, the chrysalis withdraws the same way it entered.

Dna Repair Machine

Floating inside the nucleus of a human cell, an assembler built repair vessel performs some genetic maintenance. Stretching a supercoil of DNA between its lower pair of robot arms, the nanomachine gently pulls the unwound strand through an opening in its prow for analysis.[8]

Upper arms, meanwhile, detach regulatory proteins from the chain and place them in an intake port. The molecular structures of both DNA and proteins are compared to information stored in the database of a larger nanocomputer positioned outside the nucleus and connected to the cell-repair ship by a communications link. Irregularities found in either structure are corrected and the proteins are reattached to the DNA chain, which recoils into its original form. The molecular structures of both DNA and proteins are compared to information stored in the database of a larger nanocomputer positioned outside the nucleus and connected to the cell-repairchip by a communications link. With a diameter of only 50 nanometers, the repair vessel would be smaller than most bacteria and viruses, yet capable of therapies and cures well beyond the reach of present-day physicians.[9]

With trillions of these machines coursing through a patient's bloodstream, "internal medicine" would take on new significance. Disease would be attacked at the molecular level, and such maladies as cancer, viral infections and arteriosclerosis could be wiped out.

Nanorobots

Nanorobots are defined as "Computer controlled robotic devices constructed of nanometer scale components to molecular precision, usually microscopic in size". Nanorobots are devices, which exert a precise control over matter. Each nanorobot measures 650 nm in length and 160 nm in diameter. The biomolecule has a diameter of 120 nm. Each obstacle has a diameter of 120 nm. The organ inlets are 400 nm in height and Width with inlet orifices 720 nm in diameter.

Various Nanotechnology Products

(a) Nanocream- Nano Aluminium Oxide Fibres

Nano-structural aluminium oxide fibers provide added strength and improved performance to metals, plastics, polymers and composite materials. The large number of hydroxyl groups available on the nanofibers generates a positive charge in water solution such that it will attract and retain negatively charged particles including bacteria, virus, organic & non-organic colloids and negatively charged macromolecules.

(b) Nano Filtration

Use in purification of water for medical and dental purposes. Filter sterilization of medical serum, biological fluids & other pharmaceutical products.

(c) Nanoporous Silica-Filled Composite

Nanoporous silica filled composite is a fairly new material proven to increase wear resistance in posterior applications. Nano sized porous silica fillers allow the monomer to inter- penetrate it, through a capillary force; the monomer is drawn in and out of the filler, reinforcing the composite and increasing the durability of the bowing between the two phases. By impregnating organic monomer into the pores & adding a light cure system a solid organic/inorganic nanostructure is formed.

(d)Nanoadhesive – Poss

Polyhedral OligomericSilseSquiox (Poss) enables the design of additives that make plastics that are unusually lightweight, durable, heat-tolerant and environment friendly. Poss combines organic & inorganic materials in molecules with an average diameter of 1.5 nanometers. They can be used as either additives or replacements for traditional plastics. Current applications of Poss include dental adhesives in which a strength resin provides a strong interface between the teeth and the restorative material. In addition, it has been shown that Poss materials are much more resistant to radiation damage and erosion than conventional polymers.

Types of nanotechnologies

Broadly, nanotechnologies consist of three mutually overlapping and progressively more powerful molecular technologies:

- Nanoscale-structured materials and devices that can be fabricated for advanced diagnostics and biosensors, targeted drug delivery and smart drugs
- Molecular medicine via genomics, proteomics, artificial biobotics (microbial robots)
- Molecular machine systems and medical nanorobots allow instant pathogen diagnosis and extermination, and efficient augmentation and improvement of natural physiological function.

Nanophase materials

Nanophase materials are promising materials for various bioapplications, because human tissues are composed of nanometer components (proteins, inorganics).[10]

Nanophasehydroxy-apatite

The adhesion and proliferation of osteoblasts are significantly greater on nanophasehydroxy apatite (HA) than on conventional HA. Therefore, nanophase HA clearly represents a unique and promising class of maxillofacial implant formulations with improved osseointegrative properties. Apart from nanostructured HA, both nanophase alumina and titania demonstrate the same properties. HA nanoparticles used to treat bone defects are Ostim HA (Osartis GmbH, Germany). Vitosso (Orthovita, Inc) HA, TCP (tricalcium phosphate), and NanOSSTM HA (Angstrom Medica).[11]

Nanophase carbon

Carbon nanofibers have exceptional theoretical mechanlcal properties that, along with possessing nanoscalefiber dimensions similar to crystalline HA found in bone, suggest strong possibilities for use as a maxillofacial implant material.

Various approaches used in nanotechnology

Following approaches have been followed in production of nanoparticles, namely Bottom up approach, Top down approach and functional approach. The functional approach disregards the method of production of a nanoparticle, and the objective is to produce a nanoparticle with a specific functionality.[12]

A). Bottom up technique:-In this technique smaller components are arranged into more complex assembly. This begins by designing and synthesizing custom made molecules that have the ability to self-assemble or self-organize into higher order mesoscale or macroscale structures.[13] Modern synthetic chemistry

has reached the point where it is possible to prepare small molecules to almost any structure. These methods are used today to manufacture a wide variety of useful chemicals such as pharmaceuticals or commercial polymers. Such bottomup approaches are much cheaper than top-down methods, but could potentially be overwhelmed as the size and complexity of the desired assembly increases.

This technique seeks to arrange smaller components into a more complex assembly. The dental procedures employed are Local anaesthesia, Hypersensitivity cure, Nanoroboticdentrifice (dentifrobots), Nano toothpaste, Dental durability and cosmetics, Orthodontic treatment, Photosensitizers and carriers, Diagnosis of oral cancer (nanodiagnosis), Whole tooth replacement, Tooth renaturalization, **N**anodiagnosis, Treatment of oral cancer, Dental biomimetics, Endodontic regeneration, Nanoterminators

B). Top down technique:-In this technique smaller devices are created by using larger ones to direct their assembly. So, small features are made by starting with larger materials patterning and carving down to make nanoscale structures in precise patterns. Complex structures containing hundreds of millions of precisely positioned nanostructures can be fabricated. Materials are reduced to the nanoscale and can suddenly show very different properties, enabling unique applications.[14] As the size of system decreases there is increase in ratio of surface area to volume and number of physical phenomena becomes noticeably pronounced. This technique seeks to create smaller devices by using larger ones to direct their assembly. It includes Pit & fissure sealants, Bone targeting nanocarriers and other products.

The dental procedures employed are Nanocomposites, Nano Light-Curing Glass Ionomer Restorative, Nano Impression Materials, Nano-Composite Denture Teeth, Nanosolutions, Nanoencapsulation, Plasma Laser application, Prosthetic Implants, Nanoneedles, Bone replacement materials, Nanoparticulate based disinfection in endodontics

Functional approach : In this approach, components of a desired functionality are developed without regard to how they might be aassembled. Other approaches followed at Rice University are given as follows:

Wet nanotechnology : Study of biological system that exist mainly in water environment, which include genetic material, membranes, enzymes, and nano-sized cellular components.

Dry nanotechnology: It derives from surface science and physical chemistry focuses on fabrication of structure in carbon, silicon and other organic materials.

Computational nanotechnology: It permits the modeling and stimulation of complex nanometer scale structure, the predictive and analytical power of computation is critical to success in nanotechnology.

Nanotechnology produced goals can be achieved when the scientist is able to manipulate individual atoms, develop nanoscopic machines, called assemblers that can be programmed to manipulate atoms and molecules at will and in order to create enough assemblers to build consumer goods ,some nanomachines called replicators, will programmed to build new assemblies.

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