ISSN No: 2455-7803

REVIEW ARTICLE

NANOTECHNOLOGY AND NANODENTISTRY: A FORESIGHT

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ABSTRACT:
Nanotechnology is a scientific field that examines and fabricates objects on a molecular level. Nanomedicine deals with the comprehensive monitoring, control, construction, repair, defense, and improvement of all human biological systems by working at the molecular level with engineered nanodevices and nanostructures; the science and technology of diagnosing, treating, and preventing disease and traumatic injury, as well as relieving pain and preserving and improving human health through the use of molecular tools and molecular knowledge of the human body; and the use of molecular machine systems to address medical problems and using molecular knowledge to maintain and improve human health at the molecular scale. Nanotechnology is a very promising technology, with many good uses; conversely however, used unwisely or placed in the hands of the unwise, it promises massive destruction. Through this review we would like to give a foresight of nanomedicine in its implication in dentistry.
Keywords: Nanotechnology, Nanodentistry, Dental material.

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This article may be cited as: Suveera, Kaur K, Kaur N, Singh G. Nanotechnology and Nanodentistry: A Foresight. Int J Res Health Allied Sci 2016;2(1):9-13.

INTRODUCTION:

Nanotechnology ("nano" is derived from the Greek word for dwarf) is a scientific field that examines and fabricates objects at a molecular level. The name derives from the nanometer, a scientific measurement unit representing a billionth of a meter, three to four atoms wide. Scientists are learning how to connect atoms and molecules together to create nano-scale mechanisms that create small machines that can perform complex tasks. In general, the word "nanotechnology" is used widely to define all techniques or sciences involved at a nanoscale level. It often refers to research or applications whose aim is to create new structures or products with atomic precision, such as carbon nanotubes.[1]
Nanotechnology was first introduced in 1959, in a talk by the Nobel Prize-winning physicist Richard Feynman, entitled "There's Plenty of Room at the Bottom". Feynman proposed using a set of conventional-sized robot arms to construct a replica of themselves, but one-tenth the original size, then using that new set of arms to manufacture an even smaller set, and so on, until the molecular scale is reached.[2]

Objectives of nanotechnology[3,4]

- Get essentially every atom in the right place.
- Make almost any structure consistent with the law of physics that we can specify in molecular details.
- Have manufacturing costs not greatly exceeding the cost of required raw materials and energy.

Nanomedicine[3-5]

Nanomedicine deals with the comprehensive monitoring, control, construction, repair, defense, and improvement of all human biological systems by working at the molecular level with engineered nanodevices and nanostructures; the science and technology of diagnosing, treating, and preventing disease and traumatic injury, as well as relieving pain and preserving and improving human health through the use of molecular tools and molecular knowledge of the human body; and the use of molecular machine systems to address medical problems and using molecular knowledge to maintain and improve human health at the molecular scale.
More precisely, the word has been defined by Robert A Freitas Jr. as: - "the comprehensive monitoring, control, construction, repair, defense and improvement of human biological systems, working from the molecular level, using engineered nanodevices and nanostructures."[6]

Objectives of Nanomedicine[3]

The ultimate objectives of nanomedicine is the eradication of disease. To accomplish this goal requires the convergence of nanotechnology and biotechnology. In turn, nanomedicine is the convergence of many disciplines: biology, chemistry, physics, engineering and material science.

The eradication of disease involves three sub-goals:

1) Using nano-robots, nano-machines or other methods at the molecular level to search and destroy disease causing cell
2) Same as above for the purposes of repairing damaged cells
3) Using pumps or similar technology at the molecular scale as a means of drug

NANOROBOTS[7-9]

Laurent Levy[9] defined nanorobot as an artificially fabricated object able to freely diffuse in the human body and interact with specific cell at the molecular level by itself. They are used for the purpose for maintaining and protecting the human body against the pathogens.

Stresses induced by disease and infection generally leads to changes in the chemical content of the cell. The cellular chemistry is now well understood from this aspect and could be exploited in order to trigger a reaction of the nanorobots. They can be coated with different agents depending upon their application or tissue destination. The external shell is a crucial point because it has to be recognized as a part of the body so it should be inert coating and be able to release different size molecules so that pore size can be tuned permitting release of different size molecules (tunable porosity). The main element used will be carbon in the form of diamond/fullerene nanocomposites because of the strength and chemical inertness of these forms.[10] Many other light elements such as oxygen and nitrogen can be used for the special purposes. The powering of nanorobots can be done by metabolizing local glucose and oxygen for energy. In a clinical environment another opinion would be to externally supply acoustic energy. Other sources of energy within the body can also be used to supply the necessary energy for the devices. They will have a simple onboard computers capable of performing around thousands or fewer computations per second. Communication with the device can be achieved by broadcast type acoustic signaling.

These nanorobots will be able to distinguish between different cell types by checking their surface antigens. This is accomplished by the use of chemotactic sensors keyed to the specific antigens on the target cells. When the task of nanorobots is completed they can be retrieved by allowing them to effuse themselves via the usual human excretory channels.

NANODENTISTRY

Robert A Freitas defines Nanodentistry as the science and technology that will make possible the maintenance of comprehensive oral health by employing use of nanomaterials, biotechnology including tissue engineering and ultimately dental nanorobotics.[6]

Applications of nanorobotics to dentistry:

Freitas has described how medical nanorobots might utilize specific motility mechanism to crawl or swim through human body tissues with navigational precision, acquire energy, sense and manipulate their surroundings, achieve safe cytopenetration (for example pass through plasma membrane such odontoblastic process without disrupting the cells), and employ any of a multitude of techniques to monitor, interrupt or alter nerve impulse traffic in individual nerve cells. These nanorobot functions may be controlled by an onboard nanocomputer executing preprogrammed instructions in response to local sensor stimuli. Alternatively the dentist may issue strategic instructions by transmitting his orders directly to in vivo nanorobots via acoustic signals (ultrasound).[6]

Although new technical advancement are taking place in nanodentistry but still it is a theoretical concept. Many development have been made in this field like the use of nanocomposites, nanobonding agents etc but still many others are yet to be made in the coming future.

IMPLICATION IN DENTAL MATERIAL

A. NANOCOMPOSITES[11-15]

Nanotechnology is of great interest for the development of dental materials. **Mitra S**[15] developed a dental composite with long-lasting aesthetics that mimic natural teeth, yet has the strength and wear-resistance of hybrid composites. The team found that by creating high-strength nanocomposite particles, well below the wavelength of visible light, there is considerable latitude in adjusting the optical properties of the material, while retaining the mechanical integrity required for high stress-bearing restorations.[16] Nanotechnology is also very interesting with regard to developing biocompatible or bioactive materials, such as coatings for dental implants and bioceramics

Composite with nanofillers[13-14]

Nanofillers are very different from traditional fillers and require a shift from a top-down to a bottom-up manufacturing approach. To make filler particles of the mechanically strong composites of today (such as macrofills, hybrids and microhybrids) one starts from dense, large particles (mined quartz, melt glasses, ceramics) and comminutes them to small particle size. Nanocomposites consequently display high polish retention after toothbrush abrasion. When these materials undergo toothbrush abrasion, only nanosized particles are plucked away, leaving the surfaces with defects smaller than the wavelength of light. The visual appearance retains a high gloss and is consistent with the smooth surfaces displayed other than universal restoratives. Nanofillers also offer advantages in optical properties. In general, it is desirable to provide low visual opacity in unpigmented dental composites. This allows the clinician to construct a wide range of shades and opacities and, thus, provide highly esthetic restorations.

Hybrid nanocomposites[14]
Inorganic-organic hybrid materials can be used as monomer matrix in dental restoratives to diminish their polymerisation shrinkage and improve their wear resistance and biocompatibility. Inorganic-organic hybrids with tailor-made properties can be created by means of sol-gel processing of hydrolytically condensable, organically modified trialkoxysilanes, which contain radically polymerisable methacrylate groups or cyclic groups capable of ring-opening polymerisation.

Metal oxide – polymer composites[17]
Material scientists at Southwest Research Institute (SwRI) have developed a novel restorative material to be used by the dentists for tooth fillings, inlays, and crowns. The material, a polymer composite made from tantalum oxide and silica nanoparticle fillers incorporated in a liquid crystal monomer matrix, retains the desirable properties of existing composite restoratives but avoids there major shortcomings.[18]

B. IMPRESSION MATERIALS[19]
Impression materials are available with nanotechnology application. Nanofillers are integrated in the vinylpolysiloxanes, producing a unique addition siloxane impression material, with advantages of better flow, improved hydrophilic properties hence fewer voids at margin and better model pouring and enhanced detail precision.

C. BONDING AGENTS[20]
Pentron Clinical Technologies have introduced the first commercial dental product based on polyhedral oligomeric silsesquioxane or POSS. They incorporated 10% by weight of 5 nm diameter spherical silica particles through a process that prevents agglomeration$_{17}$. As discrete particles, their extremely small size keeps them in colloidal suspension. Reinforced with nano particles this adhesive of the 6th generation guarantees high stress absorption and durable marginal tightness even under extreme loads. They are very tolerant to varying moisture degrees on dentine and only has to be applied in one layer.

D. DENTIFRICES[2, 21]
Using nanoparticles, **Japan's Sangi Company, Ltd** had manufactured a dentifrice that not only seeks out but actually repairs damage to tooth enamel. Scientists have learned to synthesize hydroxyapatite, a key component of tooth enamel, as nanosized crystals. When nano-hydroxyapatite is used in toothpaste, it forms a protective film on tooth enamel, and even restores the surface in damaged areas. Nanoparticles can assume very different chemical, physical and biological properties than their normal-sized counterparts.

E. MATERIAL TO INDUCE BONE GROWTH[22]
Calcium sulfate has been used to stimulate bone growth for decades; its usefulness to dentists has been limited because it often resorbs before bone is fully regenerated. Many dentists, in fact, use the compound mainly to fill small voids, such as those found in post-extraction tooth sockets and periodontal bone defects, and only as an adjunct to other types of longer lasting bone graft materials.

F. MATERIAL TO INDUCE RADIOPACITY[23]
Bismuth oxide has been used extensively for years in the medical appliance industry to impart X-ray opacity. As parts become smaller and thinner, it is difficult to incorporate bismuth oxide to achieve X-ray opacity without deteriorating the physical properties of the plastic or composite part. Because nanoparticles are so small, they can be incorporated at levels that provide the needed X-ray opacity without significantly affecting rheology, physical properties or surface characteristics. It can be incorporated into specialty polymers and materials for bone implants, dental prosthetic devices, catheters, sutures and surgical instruments to make them detectable by X-rays without the toxicity or carcinogenicity associated with other heavy metals.

G. **IMPLICATION IN ORTHODONTIC WIRES AND SURGICAL TOOLS[24]**
Sandvik Materials Technology has developed a new stainless steel with exceptional properties; called Sandvik Nanoflex, the new steel allows ultra-high strength to be combined with good formability, corrosion resistance and a good surface finish. Because of the combination of properties, Sandvik

Nanoflex is ideally suited to mechanical applications where lightweight, rigid designs are required. A high modulus of elasticity combined with extreme strength can result in thinner and even lighter components than those made from aluminium and titanium.

Applications of Nanotechnology in Tissue Engineering[25,26]

Tissue engineering, as an emerging and rapidly growing field, has received extensive attention. The ultimate goal of tissue engineering as a treatment concept is to replace or restore the anatomic structure and function of damaged, injured, or missing tissue or organs following any injury or pathological process by combining biomaterials, cells, or tissue, biologically active molecules, and/or stimulating mechanical forces of the tissue microenvironment.

Biomaterials are fashioned into three-dimensional scaffolds to provide mechanical support and guide cell growth into new tissues or organs. The scaffolds have to be highly porous to allow seeding of cells at high densities and, upon implantation into the body, to facilitate the infiltration and formation of large numbers of blood vessels for nutrient supply of the transplanted cells and the removal of waste products. The extracellular matrix deposited by the cells confers the physical, mechanical, and functional properties of the tissue or organ. Signals originating from the underlying substrate and the surrounding environment govern the response of the cells and their assembly into desired structure.

The tooth itself is a cranio-facial structure that is the focus of intensive tissue engineering studies. During its formative stages enamel consists of a protein matrix that forms the framework for mineral deposition. The matrix proteins have been identified and cloned and now scientists hope to use this knowledge to replicate the natural enamel-forming process. Amelogenin, produced by specialized cells called ameloblasts, is the major enamel protein, constituting about 90 percent of the matrix material. Amelogenin is believed to play a role in developing enamel by stabilizing newly formed enamel crystals and their subsequent growthThere is compelling evidence that enamel formation begins at the outer edge of the dentinal layer, at the dentino-enamel junction. Crystallite ribbons rise up from the dentin and are separated by globules, or nanospheres of amelogenin. The nanospheres appear to spiral upward around the growing crystallites, eventually degrading and ultimately disappearing as the crystallite ribbons coalesce into solid enamel. The secret to duplicating this process may lie in isolating the progenitor cells that control the mineralization process and putting them in a three-dimensional environment seeded with the necessary signaling molecules.[16]

CONCLUSION

As with any new technical advancement, the same risks and ethical issues present themselves with nanotechnology. As nanotechnology aims to alter structures at the molecular level, it is arguable that we are playing the role of creator and God. Currently, scientists and researchers are trying to model nano-medicine from the basics of pre-existent sources such as DNA. With enough advancement in nano-medicine, it would even be possible to "determine who is predisposed to what disease, and thus allow us to make a pre-emptive strike by way of adjustments in the person’s DNA". With such changes in our genetic structure, how much of us would really remain human? It would give new meaning to the word birth. Nanotechnology is a very promising technology, with many good uses; conversely however, used unwisely or placed in the hands of the unwise, it promises massive destruction.

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Source of support: Nil   **Conflict of interest:** None declared

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