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NANO ROBOTICS - ITS TIME FOR CHANGE

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ABSTRACT

Nanodentistry is an emerging field with significant potential to yield new generation of technologically advanced clinical tools and devices for oral healthcare. The growing interest in the future of dental applications of robotic dentistry is leading to the emergence of a new field called Nanorobotics in dentistry. Nanorobotics holds promise for advanced diagnostics, targeted drug delivery with biosensors. Robots can supposedly induce oral analgesia, desensitize tooth; manipulate the tissue to realign and straighten irregular set of teeth and to improve durability of teeth The purpose of this article is to review the phenomenon of nanotechnology as it might apply to dentistry as a new field called nanodentistry.

KEYWORDS: Nanorobotics; nanodentistry; nanotechnology

INTRODUCTION

"Nano" is derived from the Greek word which stands for "dwarf". Nanotechnology is the science of manipulating matter, measured in the billionths of metres or nanometre, roughly the size of two or three atoms. It is distinguished primarily by the scale at which it acts, one billionth of a metre or one ten thousand the width of human hair. In simple terms, it is engineering at the atomic or molecular level. Nanotechnology, which is accomplished by manipulating matter at the atomic level, is actually measured in nanometres, roughly the size of two or three atoms. Nanotechnology is an extremely diverse and multidisciplinary field, ranging from novel extensions of conventional physics to completely new approaches based upon molecular self-assembly, to developing new materials and machines with nano scale dimensions.[1] The growing interest in the future of dental applications of nanotechnology lead to the emergence of nanodentistry which involves the maintenance of oral health by the use of nano materials, biotechnology and dental nanorobotics.[2]

HISTORY

The first observations and size measurements of nanoparticles were made during the first decade of the 20th century by Zsigmondy, 1914.[3] The Nobel Prize winning physicist Richard Feynman, at an American Physical Society meeting in 1959, was received with speculation when he gave a talk, "There's Plenty of Room at the Bottom" in 1959, in which he explored the implications of matter manipulation. Four decades ago, the manipulation of single atoms and molecules seemed illusive; however, he predicted that the time would inevitably come when the atomically precise manipulation of matter would be possible. The true founder of nanotechnology was, though, Eric Drexler, who published in 1986 'Engines of Creation The Coming Era of Nanotechnology'.[4] He states that in the near future this kind of technology will be used to assembly atoms and molecules in order to build nano circuits and nano machines. The way average instruments can build average machines out of compound pieces, molecular instruments will create connections between molecules in order to create pinions, engines, manipulating arms and minute covers that will be assembled into complex machines. The first scientist who described the medical applications of nanotechnology and nano robots was Robert Freitas Jr. In an article published by the Journal of American Dental Association, he defined nano medicine as the science and technology of diagnosing, treating and preventing disease and traumatic injury; of relieving pain; and of preserving and improving human health, through the use of nano scale-structured materials, biotechnology and genetic engineering, and eventually complex molecular machine systems and nano robots. In the same article, Freitas introduced the concept of nano dentistry,

which he defines as the science and technology that will make possible the maintenance of near-perfect oral health through the use of nanomaterials, biotechnology, including tissue engineering and nano robotics.[5]

UNDERSTANDING NANOROBOTS

Nanorobots are theoretical microscopic devices measured on the scale of nanometres (1nm equals one millionth of 1 millimetre). When fully realized from the hypothetical stage, they would work at the atomic, molecular and cellular level to perform tasks in both the medical and industrial fields that have heretofore been the content of science fiction. Nano robots are so tiny that they can easily traverse the human body. Nano robots would constitute any active structure (nano-scale) capable of actuation, sensing, signalling, information processing, intelligence, and swarm behaviour at nano-scale. The nano robots are invisible to the naked eye, techniques like scanning electron microscopy (SEM) and atomic force microscopy (AFM) are being employed to visualize these nano-scaled devices. These nano robots provide benefits in numerous areas such as synthesis of new materials with advanced properties like production technology, information technology, medical applications, transportation, etc. Medical nano robots represent microscopical objects artificially manufactured, endowed with intelligence capable of free diffusion inside the human body and which can interact with human body cells or can manipulate them, with a nanometric resolution in order to fulfil tasks in the medical field. As a regular robot, a medical nano robot can be manufactured out of thousands of mechanical parts, made out of nano materials such as carbon nano tubes, metallic nano conductors and diamondoid materials.[6,7] Unlike regular robots, medical nano robots will have invisible dimensions to the human eye, but compound parts will have molecular sizes 1-10nm. Scientists report the exterior of a nano robot will likely be constructed of carbon atoms in a diamondoid structure because of its inert properties and strength. Super-smooth surfaces will lessen the likelihood of triggering the body's immune system, allowing the nano robots to go about their job unimpeded. Glucose or natural body sugars and oxygen might be a source for propulsion and the nano robot will have other biochemical or molecular parts depending on its task.[8] It has increased strength, because of the main component used is carbon in the form of diamond or fullerene composite. The power of glucose can be done by metabolising glucose, oxygen and externally supplied acoustic energy. They can be controlled by onboard computers capable of performing thousand or more computations. A broad cast type acoustic signal helps in communication with these devices, it basically consists of sensors, actuators controlled by light or electric signals, control, power, communication and interfacial signals across facial scales. A navigational network may be installed in the body which provides, positional accuracy to passing nanorobots to know their location. These nanorobots are good at differentiating different cell types in the body based upon their surface antigens. They are accomplished by the use of chemotactic sensors keyed to the specific antigens on the target cells. When the task of the nanorobots is completed, they can be retrieved by allowing them to expel themselves via the usual human excretory channels. These can also be removed by active scavenger systems.[9] It is Freitas (1999) who described how medical nano robots might use specific motility mechanisms to crawl or swim through human tissues with navigational recession; cyto pentration and use any of multitude of techniques to monitor, interrupt or alter nerve impulse traffic in individual nerve cells.[10] According to present day theories, dental nano robots should have at least two means of communication: both with the doctor who coordinates it, and with the other nano robot he teams up with and the two possible ways of communicating between nano robots are being considered: either by means of light signals through optical nano sensors[6] or by chemical signals through chemical nano sensors (i.e. nano robots monitoring glucose level).[11] As to the possible ways of communication between nano robots and the doctor who coordinates them, research scientists incline towards acoustic signals, allowing rapid rates of data transfer, or electromagnetic radio waves, considered useful in detecting the current status of the nano robots inside the patient.[6,11]

Two perspectives of approaching nanodentistry are:

1. Building up particles by combining atomic

elements, i.e., bottom up approach.[12, 13]

2. Using equipment to create mechanical nanoscale objects, i.e., top down approach.[14]

MEANS OF APPROACH

Biochip

The joint use of nano electronics, photolithography, and new biomaterials, can be considered as a possible way to enable the required manufacturing technology towards nano robots for common medical applications, such as for surgical instrumentation, diagnosis and drug delivery.[15] Indeed, this feasible approach towards manufacturing on nanotechnology is a practice currently in use from the electronics industry. So, practical nano robots should be integrated as nano electronics devices, which will allow tele-operation and advanced capabilities for medical instrumentation.

Nubots

Nubot is an abbreviation for "nucleic acid robots." Nubots are synthetic robotics devices at the nanoscale. Representative nubots include the several DNA walkers reported by different groups and universities like Ned Seeman's group at NYU, Niles Pierce's group at Caltech, John Reif's group at Duke University, Chengde Mao's group at Purdue, and Andrew Turberfield's group at the University of Oxford.

Positional nanoassembly

Nano factory Collaboration, founded by Robert Freitas and Ralph Merkle in 2000, is a focused ongoing effort involving 23 researchers from 10 organizations and 4 countries that is developing a practical research agenda specifically aimed at developing positionally-controlled diamond mechano-synthesis and a diamondoid nanofactory. that would be capable of building diamondoid medical nanorobots.

Bacteria Based

This approach proposes the use biological microorganisms, like *Escherichia colibacteria*. Hence, the model uses a flagellum for propulsion purposes. The use of electromagnetic fields are normally applied to control the motion of this kind of biological integrated device, although his limited applications.

Open Technology

A document with a proposal on nanobiotech development using open technology approaches has been addressed to the United Nations General Assembly.[16] According to the document sent to United Nations, in the same way Linux and Open Source has in recent years accelerated the development of computer systems, a similar approach should benefit the society at large and accelerate nano robotics development. The use of nano biotechnology should be established as a human heritage for the coming generations, and developed as an open technology based on ethical practices for peaceful purposes. Open technology is stated as a fundamental key for such aim.

USES OF NANOROBOTICS IN DENTISTRY

Local Anaesthesia

In the era of nano dentistry a colliodal suspension containing millions of active analgesic micron-size dental robots will be instilled on the patient's gingiva. After contacting the surface of crown or mucosa, the ambulating nanorobots reach the pulp via the gingival sulcus, lamina propria and dentinal tubules. Once installed in the pulp, the analgesic dental robots may be commanded by the dentist to shut down all sensitivity in any particular tooth that requires treatment. After oral procedures are completed, the dentist orders the nano robots to restore all sensation, to relinquish control of nerve traffic and to egress from the tooth by similar pathways used for ingress.[2]

Hypersensitivity Cure

Dentin hypersensitivity may be caused by changes in pressure transmitted hydrodynamically to the pulp. This is based on the fact that hypersensitive teeth have eight times higher surface density of dentinal tubules and tubules with diameters twice as large than non-sensitive teeth. Dental nano robots could selectively and precisely occlude selected tubules in minutes, using native biological materials, offering patients a quick and permanent cure.

Bone Replacement Materials

Bone is a natural nanostructure that is composed of organic compounds (mainly collagen) and reinforced with inorganic ones. Nanotechnology aims to emulate this natural structure for orthopaedic and dental applications and, more particularly, for the development of nano bone. Nano crystals show a loose microstructure, with nano pores situated between the crystals. The surfaces of the pores are modified such that they adsorb protein, due to the addition of silica molecules. Bone defects can be treated by using these hydroxyapatite nanoparticles.[17]

Major Tooth Repair

Nano dental techniques involve many tissue engineering procedures for major tooth repair mainly nano robotics manufacture and installation of a biologically autologous whole replacement tooth that includes both mineral and cellular components which leads to complete dentition replacement therapy.

Nanorobotic Dentifrice (Dentifrobots)

Sub occlusal dwelling nano robotic dentifrice delivered by mouthwash or toothpaste could patrol all supra gingival and sub gingival surfaces at least once a day, metabolising trapped organic matter into harmless and odourless vapours and performing continuous calculus debridement. These invisibly small dentifrobots [1-10 micon], crawling at 1-10 microns/sec, would be inexpensive, purely mechanical devices, that would safely deactivate themselves if swallowed and would be programmed for better cleaning of the teeth.

Orthodontic Treatment

Orthodontic nano robots could directly manipulate the periodontal tissues, allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours. A new stainless-steel wire that uses nano technology is being studied that combine's ultra-high strength with good deformability, corrosion resistance and surface finish.

Maintenance of Oral Hygiene

A mouthwash full of smart nano robots could identify and destroy pathogenic bacteria while allowing the harmless flora of the mouth to flourish in a healthy ecosystem.

Cavity Preparation and Restoration

Multiple nano robots working on the teeth in unison, invisible to the naked eye, may be used for cavity preparation and restoration of teeth. The cavity preparation is very precisely restricted to the demineralised enamel and dentin, thus providing maximum conservation of sound tooth structure. Further the devices would identify particles of food, plaque or tartar and lift them from the teeth to be rinsed away. Being suspended in liquid and able to swim about, devices would be able to reach surfaces beyond reach of toothbrush bristles or the fibres of floss. Sub-occlusally dwelling nano robots delivered by dentifrice patrol all supra-gingival and sub-gingival surfaces metabolizing trapped organic matter performing continuous calculus debridement. They prevent tooth decay and provide a continuous barrier to halitosis with good deformability, corrosion resistance, and surface finish.

Photosensitizers and Carriers

Quantum dots can be used as photosensitizers and carriers. They can bind to the antibody present on the surface of the target cell and when stimulated by ultraviolet light, they can give rise to reactive oxygen species and thus will be lethal to the target cell.

Nano Robots in Cancer Detection and Treatment

Cancer can be successfully treated with current stages of medical technologies and therapy tools. However, a decisive factor to determine the chances for a patient with cancer to survive is: how earlier it was diagnosed; which means, if possible, a cancer should be detected at least before the metastasis has begun. Another important aspect to achieve a successful treatment for patients is the development of efficient targeted drug delivery to decrease the side effects from chemotherapy. Considering the properties of nano robots to navigate as blood borne devices, they can help on such extremely important aspects of cancer therapy. Nano robots with embedded chemical biosensors can be used to perform detection of tumour cells in early stages of development inside the patient's body. Integrated nano sensors can be utilized for such a task in order to find intensity of E-cadherin signals. Therefore a hardware architecture based on nano bioelectronics is described for the application of nano robots for cancer therapy. Analyses and conclusions for the proposed model are obtained through real time 3D simulation.

Nanocomposites

Nanoproducts Corporation has successfully manufactured nonagglomerated discrete nanoparticles that are homogeneously distributed in resins or coatings to produce nanocomposites.[18] The nanofiller used includes an aluminosilicate powder having a mean particle size of 80 ran and a 1:4 M ratio of alumina to silica and a refractive index of 1.508.

ADVANTAGES

- Superior hardness
- Superior flexural strength, modulus of

elasticity and translucency
- 50% reduction in filling shrinkage
- Excellent handling properties
- Trade name: Filtek O Supreme Universal Restorative P Lire Nano O

Nanoneedles

Nanosized stainless-steel crystals incorporated into suture needles have been developed. Cell surgery may be possible in the near future with nanotweezers, which are now under development.

Nanosolution

Nanosolutions produce unique and dispersible nanoparticles, which can be used in bonding agents. This ensures homogeneity and ensures that the adhesive is perfectly mixed everytime. Trade name: Adper O. Single Bond Plus Adhesive, Single Bond.

Impression Materials

Nanofillers are integrated in vinylpolysiloxanes, producing a unique addition of siloxane impression materials. The material has better flow, improved hydrophilic properties and enhanced detail precision. Trade name: Nanotech Elite H-D.

Nanoencapsulation

SWRI [South West Research Institute] has developed targeted release systems that encompass nanocapsules including novel vaccines, antibiotics and drug delivery with reduced side effect.[19]

Dental implants: Structure, Chemistry and Biocompatibility

The determining factors for successful osseo-integration are surface contact area and surface topography. However, bone bonding and stability also play a role. Bone growth and increased predictability can be effectively expedited with implants by using nanotechnology. The addition of nano scale deposits of hydroxyapatite and calcium phosphate creates a more complex implant surface for osteoblast formation.[20] Extensive research on the effects and subsequent optimization of micro topography and surface chemistry has produced ground-breaking strides in material engineering. These new implants are more acceptable, because they enhance the integration of nano-coatings resembling biological materials to the tissues.

Bionic Mandible

The bionic mandible is helpful to reconstruct the entire mandible similar to normal mandible in function and sensation. It is not far from achieving, just like the first bionic arm constructed on Sullivan by Todd Kuiken and his team using nanotech-enabled robotic myoelectric prosthetic limb.[21]

POSSIBLE DIFFICULTIES IN THE PATH OF NANODENTISTRY

- Precise positioning and assembly of molecular scale part
- Economical nanorobot mass production technique
- Biocompatibility
- Simultaneous coordination of activities of large numbers of independent micron-scale robots
- Social issues of public acceptance, ethics, regulation and human safety

CONCLUSION

Nano robots will change dentistry, health care and human life more profoundly than other developments. Nano dentistry holds the promise to lead to an earlier diagnosis, better therapy and improved follow-up care, making the health care more effective and affordable. Nano dentistry will also allow a more personalised treatment for many diseases, exploiting the in-depth understanding of diseases on a molecular level. Although research into nano robots is still in its preliminary stages, the promise of such technology is endless. Nano robots applied to dentistry hold a wealth of promise for treating disease very rapidly. There will be times when the dentist will not be present for the treatment and leave the job to the assistant and the dentrirobots of his clinic. In future, dentist employment opportunities may demand a degree in nano robotics. This is going to be true soon.

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