Nanorobotics - A Novel Shift Towards An Era of Hands Free Dentistry

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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. Predicting the future of any major technology is difficult. Nanorobotics is the technology of creating machines or robots at or close to the microscopic scale of a nanometre (10−9 m). More specifically, nanorobotics refers to the hypothetical nanotechnology engineering discipline of designing and building nanorobots; devices ranging in size from 0.1 to 10 μm and constructed of nanoscale or molecular components. With the modern scientific capabilities, it has becomepossible to attempt the creation of nanorobotic devices and interface them with the macro world for control. There are countless such machines that exist in nature and there is an opportunity to build more of them by mimicking nature. When we gain access to hold the nanorobots, we will be able to treat very rapidly a number of diseases. Their first useful application was in medicine to identify and destroy cancer cells but the most interesting applications may be in dentistry. Dental nanorobots could be constructed to destroy caries causing bacteria or to repair tooth blemishes where decay has set in, by using a computer to direct these tiny workers in their tasks. The present article aims to provide an early glimpse on the impact and future implication of nanorobotics in dentistry.ng the future of any***

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"Nanorobotics"

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1. Introduction

In today's era and age where every second the worlds of science and medicine are evolving, emerging technologies and newer methodologies are not only highly desired but also the need of the hour. Much in the same way, in the field of dentistry the concept of "Nanorobots" is a path breaking one and this new nano scale technology has the potential to transform dental practice by advancing all aspects of dental diagnostics, therapeutics and cosmetic dentistry into a new paradigm of state-of – the-art patient care beyond traditional oral care methods and procedures. In 1959, Richard Feynman introduced the concept of nanotechnology, however, The true founder of nanotechnology was, Professor Eric Drexler, who published in 1986the book "Engines of Creation-The Coming Era of Nanotechnology" in which he introduced the molecular technology which he called nanotechnology.[1]"Nano" is a word derived from Greek meaning "dwarf." One Nano is $10^{-9}$of a meter. Nanotechnology can be defined as the science of manipulating matter, measured in the billionths of meters or manometer, roughly the size of two or three atoms. It is distinguished primarily by the scale at which it acts one billionth of a meter or one ten thousandth the width of human hair. In simple terms, it is engineering at the atomic or molecular scale.[2]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 nanoscale dimensions.[3]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 nanomaterials, biotechnology and dental nanorobotics.[4]

2. What is Nanorobotics?

Nanorobotics is the technology of creating machines or robots at or close to the microscopic scale of a nanometre (10^{-9} m). More specifically, nanorobotics refers to the hypothetical nanotechnology engineering discipline of designing and building nanorobots; devices ranging in size from 0.1 to 10 mm and constructed of nanoscale or molecular components. With the modern scientific capabilities, it has become possible to attempt the creation of nanorobotic devices and interface them with the macro world for control. There are countless such machines that exist in nature and there is an opportunity to build more of them by mimicking nature.

According to nanorobotic theory "nanorobots are microscopic in size, it would probably be necessary for very large numbers of them to work together to perform microscopicand macroscopic tasks".[5]

3. History of Nanorobots

Richard Zsigmondy studied nanomaterials in the early 20th century, and later discoveries culminated in ideas presented by Nobel Prize winning physicist Richard Feynman in a lecture called "Plenty of Room at the Bottom" in1959, in which he explored the implications of matter manipulation.[6]Applications began in the 1980s with the invention of the scanning tunnelling microscope and the discovery of carbon nanotubes and fullerenes.[7]

The first scientist who described the medical applications of nanotechnology and nanorobots was Robert Freitas Jr. In an article published by the Journal of American Dental Association, he defined nanomedicine 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 nanoscale – structured materials, biotechnology and genetic engineering, and eventually complex molecular machine systems and nanorobots" In the same article, Freitas introduced the concept of nanodentistry, 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 nanorobotics".[8]

4. Architecture of Nanorobots

Nanorobots are theoretical microscopic devices measured on the scale of nanometres (1 nm equals one millionth of 1 mm). 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 until now been the stuff of science fiction. Nanomedicine's nanorobots are so tiny that they can easily traverse the human body. Scientists report the exterior of a nanorobot 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 nanorobots to go about their business unimpeded. Glucose or natural body sugars andoxygen might be a source for propulsion and the nanorobot will have other biochemical or molecular parts depending on its task. [9]

Two achievements developed nanotechnology through the scientific method rather than conceptual. First, the invention of scanning tunnelling microscope (STM) by Binnig and Rohrerin 1981, by which the individual atoms were easily identified for the first time. Some of the limitations of this microscopy were eliminated through the invention of the atomic force microscope which could image non – conducting materials such as organic molecules. This invention was integral for the study of carbon Bucky balls, discovered at Rice University in1985-1986 and carbon nanotubes few years later.[10]

5. Mode of Action of Nanorobots

Nanorobots in medicine are used for the purpose of maintaining and protecting the human body against pathogens. They are 0.5-3µmin diameter and are constructed of parts with dimensions in the range of 1 – 100 nm. The main element used is carbon in the form of diamond/fullerene nanocomposite due to its increased strength and chemical inertness. Other light elements such as oxygen, nitrogen can be used for special purposes. The external passive diamond coating provides a smooth, flawless coating and evokes less reaction from the body's immune system. [9]The powering of nanorobots can be done by metabolizing local glucose, oxygen and externally supplied acoustic energy. They can be controlled by on-board computers capable of performing around 1000 or more computations per second. Communication with the device can be achieved by broadcast type acoustic signalling. A navigational network installed in the body, provides high positional accuracy to all passing nanorobots and keep track of the various devices in the body. Nanorobots are able to distinguish between different cell types by checking their surface antigens. Building nanorobots involves sensors, actuators, control, power, communications and interfacial signals across spatial scales and between organic/inorganic as well as biotic/abiotic systems. Nano – actuators can be controlled by light or electrical signals.[11, 12] When the task of the nanorobot is completed, they can be retrieved by allowing them to effuse themselves via the usual human excretory channels. They can also be removed by active scavenger systems.[12]

6. Applications of Nanorobots in Dentistry

The growing interest in the future of dental applications of nanotechnology is leading to the emergence of a new field called nanodentistry. Nanorobots induce oral analgesia, desensitize tooth, and manipulate the tissue to re – align and straighten irregular set of teeth and to improve durability of teeth. Further nanorobots are used to do preventive, restorative& curative procedures.[9]

1) Major Teeth Repair
   Tooth repair by dental nanorobots involve manufacturing and installation of a biologically autologousteethwhich include mineral and cellular components hence providing Complete Dentition Rehabilitation Therapy. Nanodental techniques involve genetic engineering followed by tissue engineering, and finally, tissue regeneration procedures for major tooth repair. Complete dentition replacement was the basis for research byChan et al, who recreated dental enamel, the hardest tissue in the human body, by using highly organized micro architectural units of nanorods.[5, 9]

2) Nanorobotic Dentifrice (Dentifrobots) :-
   Subocclusally dwelling nanorobotic units delivered by mouthwash or toothpaste could be used to patrol all supragingival 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 – 10µm], crawling at 1 – 10 µm/sec, would be inexpensive, purely mechanical devices, that would safely deactivate themselves if swallowed and would be programmed with strict occlusal avoidance protocol.[13]

3) Dentin Hypersensitivity
   Dentin hypersensitivity is a pathological phenomenon caused by changes in pressure transmitted hydro – dynamically 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 as non – sensitive teeth. Reconstructive dental nanorobots selectively and precisely occlude specific dentinal tubules within minutes, using native biologic materials, offering patients a quick and permanent cure from hypersensitivity.[14]

4) Inducing Analgesia
   Induction of analgesia is often one of the first and most important steps of any dental treatment. Advancements achievable in this area with the help of nanorobots is of great importance. Pulpal anaesthesia is achievable by forming a colloidal suspension containing millions of active analgesic micron size dental robots will be instilled on the patient's gingiva. After contacting the surface of the crown or mucosa, the ambulating nanorobots reach dentin by migrating into the gingival

sulcus and pass painlessly through the lamina propria or through 1-3 µm thick layer of loose tissue at the CEJ. Upon reaching the dentin, they enter the dentinal tubules up tol-4 µm depth and proceed toward the pulp guided by a combination of chemical gradient, temperature differentials and positional navigation under nanocomputer control. Thus the migration of nanorobots from tooth surface to the pulp occurs in l00 seconds. Once installed in the pulp, they establish control over nerve impulse; analgesic nano robots commanded by the dentist shutdown all sensitivity in any particular tooth requiring treatment. When the dentist presses the hand held control, the selected tooth is immediately anaesthetized. After the procedure is completed, the dentist orders the nanorobots to restore all sensation and exit from the tooth.[15]Nanorobot analgesia offers greater patient comfort, reduces anxiety, no needles, greater selectivity, controllability of analgesic effect; fast and completely reversible action; avoidance of side effects and complications.[16]

5) Cavity Preparation And Restoration :-
Multiple nanorobots 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 demineralized enamel and dentin, thus providing maximum conservation of sound tooth structure.[16]

6) 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 the current techniques which require weeks or months to proceed to completion.[17,18]

7) Nanoencapsulation
Nanomaterials, including hollowspheres, core – shell structure, nanotubes and nanocomposite, have been widely explored for controlled drug release. Pinon-Segundo et al. studied Triclosan-loaded nanoparticles, 500 nm in size, used in an attempt to obtain a novel drug delivery system adequate for the treatment of periodontaldisease.[19]These particles were found to significantly reduce inflammation at the experimental sites. An example of the development of this technology is are stin in which minocycline is in corporate into microspheres for drug delivery by local means to a periodontal pocket.[20]

8) Implants
Current trends in clinical dental implant therapy include use of endosseous implant surfaces embellished with nanoscale topography. Nanoscale modification of titanium endosseous implant surface canalter cellular and tissue response thatbenefit dental implant therapy. Three nanostructured implant coatings in use are diamond; which possess improved hardness, toughness, low friction, hydroxyapatite; which possess increased osteoblast adhesion proliferation and mineralization,& graded metalloceramics; which possess ability toovercome adhesion problems.[21]

9) Decay Resistant Teeth
Researchers at the Clarkson advanced materials centre have found a way to use nanotech to help protect almost any teeth or surface from caries. These are done by polishing teeth with silica that is made from nanoparticles. This material is 90,000times smaller than a tiny grain of sand.[22]

10) 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.[23]

Besides these applications there are many more trials and researches being carried out to implement the above mentioned as well as newer applications of this advanced in the field of nanorobotics. However, there are certain challenges being faced in this area as well and some of these challenges have been discussed below.

Challenges faced by Nanorobotics

1) Engineering Challenges
- Feasibility of mass production technique.
- Precise positioning and assembly of molecular scale part.
- Manipulating and coordinating activities of large numbers of independentmicro-scale robots simultaneously.

2) Biological challenges
- Developingbio – friendly nanomaterial ensuring compatibility with allintricaciesof human body.

3) Social challenges
- Ethics.
- Public acceptance.
- Regulation and human safety.

Engineering Challenges: There is a problem in the feasibility of mass production technique. Precise positioning and assembly of molecular scale part is a challenge for them. Manipulating and coordinating activities of large numbers of independent micro –scale robots simultaneously is a difficult task. Even though the field of nanorobotics is fundamentally different from that of the macro – robots due to the differences in scale and material, there are many similarities in design and control techniques that eventually could be projected and applied. Due to the modern scientific capabilities, it has become possible to attempt the creation of nanorobotic devices and interface them with the macro world for control. There are countless such machines which exist in nature and there is an opportunity to build more of them by mimicking nature. Now a days these nano robots play a vital role in the field of Bio Medicine& dentistry, especially in the treatment of cancer. It also helps to remove the defected part in our DNA structure and some other treatments that have the greatest aid to save human lives.[24]

Biological Challenges: It is essential to develop bio friendly nano material and ensure compatibility with all intricate of human body. In general, smaller particles are more bioactive and toxic. Their ability to interact with other living systems increases because they can easily cross the skin, lung, and in some cases the blood/brain barriers. Once inside the body, there may be further biochemical reactions like the creation of free radicals that damage cells. While the body has built-defence for natural particles it encounters, the danger of nanotechnology is that it is introducing entirely new type of particles. Some experts believe that the body is likely to find toxic.[25]

Social Challenges: Highest at risk are workers employed by manufacturers producing products that contain nanoparticles. The National Institute for Occupational Safety and Health (NIOSH) reports over two million Americans are exposed to high levels of nanoparticles. NIOSH publishes safety guidelines and other information for those employed in the nanoindustry.[24]

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