Avens Publishing Group
J Bioelectron Nanotechnol
July 2016 Volume:1, Issue:1

Open Access Research Article

Journal of
Bioelectronics and Nanotechnology

The Application in Dentistry - Nanorobotics

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Submission: 26 May, 2016
Accepted: 25 July, 2016
Published: 30 July, 2016

Reviewed & Approved by: Dr. Baoqiang Li, Harbin Institute of Technology, China

Keywords: Nanorobot; Dentistry; Application

Abstract

Nanorobots are any type of active structure capable of actuation, sensing, manipulation, propulsion, signaling, information process, intelligence and swam behavior at nanoscale. Nanorobotic systems are expected to be used in many different areas that range from medical to environmental sensing to space and military applications. Nanorobotics have arisen from the fictional world of the 'Fantastic voyage`. From precise drug delivery to repairing cells and fighting tumor cells, nanorobots are expected to revolutionize the medical industry in future. Nanorobotic application is unlimited, with most interesting applications in dentistry. This paper will look into the various nanorobotic applications in dentistry and its future implications.

Introduction

Definition: Nanorobot can be defined as intelligent systems with overall dimensions at or below the micrometer range that are made of assemblies of nanoscale components with individual dimensions ranging between 1 to 100 nm.

History of Nanorobotics: Nanorobotics is a relatively new field that grew out of the merging of robotics and nanotechnology during the late 1990s and early 2000s. The term nanorobot started being used by the robotic community in the late 1990s. The term nanotechnology was coined by Prof Eric k Drexler. Two of the pioneers in the field of nanorobotics are Eric k. Drexler and Robert A. Freitas. Drexler described the concept of molecular machinery and molecular manufacturing while Freitas developed the concept of medical nanorobotics. Robotic devices able to perform task at nanoscale are called nanorobots. The field of nanorobotics studies the design, manufacturing, programming and control of nanorobotic system. Nanorobots are also referred as nanobots or nanites. Prior to late 1990s the limited amount of scientific work on nanorobotics focused on concept generation, design and modeling. Thorough computational and experimental studies on nanorobotics started being published only after late 1990s. As with the robotic field, nanorobotics became known to large audience through science fictions movies, TV series and books. Issac Asimov in his 1966 book` Fantastic voyage` described a miniscule submarine able to travel through the human blood stream while Michael Crighton in 2002 in his popular book `Prey` introduced a swarm of intelligent nanorobots that threatens human kind [1].

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 rooms at the bottom` in 1959, in which he explored the implication of matter manipulation. Applications began in the 1980 s with the invention of the scanning tunneling microscope and the discovery of carbon nanotubes and fullerenes [2].

Nanorobot which are incapable of replication and those which are capable of unconstrained replication in the natural environment are found in many science fiction stories, such as Borg nanoprobes in Star Trek. The word nanobot (also nanite, nanogene, or nanoant) are often used to indicate this fictional context and are an informal or even a perjorative term. The word nanorobot is the correct technical term in the nonfictional context of serious engineering studies. Nanorobots capable of replication outside of a restricted factory environment does not form a necessary part of a purported productive nanotechnology, and that the process of self- replication, made could be inherently safe. They further assert that free-foraging replicators are in fact absent from their current plans for developing and using molecular manufacturing [3].

Dental Nanorobot: Carbon will likely be the principal element comprising the bulk of a medical nanorobot, probably in the form of diamond or diamondoid/fullerence nanocomposites. Many other light elements such as hydrogen, sulfur, oxygen, nitrogen, fluorine, silicon etc. will be used for special purposes in nanoscale gears and other components [3]. The dental nanorobot have a nanocomputer

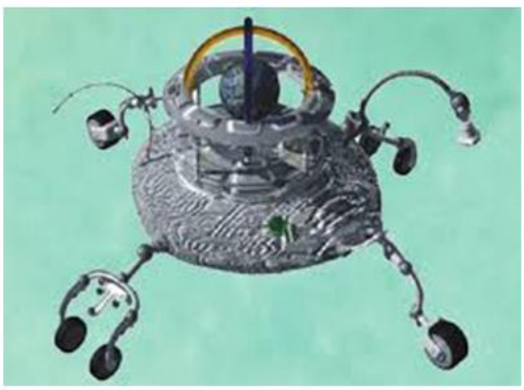

Figure 1: Dental Nanorobot.

ISSN: 2475-224X

Figure 2: Nanoimplant.

which will execute planned missions, receive and process signals, communicate with other nanocomputers and it respond to external control and monitoring devices and also possess the knowledge to ensure the correct functioning of nanomechanical devices. Based on the biomimetism and place of action, researchers have designed various shapes for medical nanorobots. Freitas considers that intravascular nanorobot have a sphere shape, resembling blood cells and leucocytes. The best design for medical nanorobot should be that of flagellated bacteria for good movement through the blood flow-Martel. Dental nanorobots have a spider like body as they need to be quick in fulfilling their tasks. These nanorobots are manufactured out of diamondoid structures. Diamondoid molecules are circular saturated hydrocarbons with a diamond like structure. Diamondoids have unique properties due to the exceptional atomic structure. They are chemically and thermally stable, can self assembly, more resistant, but lighter than steel (Figure 1) [4].

Application of Nanorobots in Dentistry

Nanocomposites: The latest advances in composite resin are the implementation of nanoparticle technology into restorative material. Nanotechnology has enabled the production of nano-dimensional filler particles, which are added either singly, or as nanoclusters into composite resin. Nanofillers are different from traditional fillers. Nanotechnology allows nano sized filler particles that are compatible with dental composite so that a greater amount of filler can be added into composite resin matrix. Nanoparticles produces composite with a smooth surface after polishing with superior esthetic feature. These particles are easy to shape and have high degree of strength and resistance to abrasion. The fillers in nanocomposites have higher translucence since they are smaller than the wavelength of light, allowing more esthetic restoration with a vast range of color options. Artifical teeth made of nanocomposites have been produced. Nanocomposite artificial teeth are more durable than acrylic teeth.

Digital dental imaging: With nanotechnology there is an advance in digital imaging. In digital radiographs obtained by nanophosphor scintillators, the radiation dose is diminished and high quality images are obtained [5].

Diagnosis and treatment of oral cancer: Nano Electro Mechanical System (NEMS) convert bio chemical to electrical signal and cantilever array sensor is an ultrasensitive mass detection technology that can be used for the detection of the 10-12 bacteria, viruses and DNA; these are extremely useful in detection of oral cancer. Nanomaterials for brachytherapy like "Brachysil" (Sivida, Boston and Perth, Australia) deliver 32P are in clinical trial [2].

Nanorobotic dentifrice: A subocclusal-dwelling nanorobotic dentifrice delivered by mouthwash or toothpaste could patrol all supragingival and subgingival surfaces at least once a day, metabolizing trapped organic matter into harmless and odorless vapors and performing continuous calculus debridement [6].

Impression materials: Nanofillers are integrated in vinyl polysiloxanes, producing a unique addition of siloxane impression materials.

Nanoneedles: Suture needles incorporating nano-sized stainless steel crystals have been developed (trade name: Sandvik Bioline, RK 91 needles, AB Sandvik, Sweden). Nano tweezers are also under development, which will make cell surgery possible in near future [7].

Dentinal hypersensitivity: Hypersensitivity is caused by changes in pressure transmitted hydro dynamically to the pulp. The use of nanorobots that selectively and precisely occlude tubules in minutes, by using local, native materials, thus offering patients a quick and permanent cure [8].

Orthodontic treatment: During orthodontic treatment the orthodontic appliances need to be wear for weeks and it will cause discomfort for the patients who are concerned about the aesthetics, orthodontic nanorobots are able to manipulate directly the periodontal tissues which include gums, periodontal ligament, cementum and alveolar bone allowing a quick and painless straightening, rotating or vertical position within minutes to hours [4].

Dental implants: One of the reasons for the failure of dental implants is the insufficient bone formation around implant, for sufficient bone formation, surface of implant need to be altered, which includes nanoscale topography for better and faster osseointegration of implants. Bone growth and increased predictability can be expected with nanotechnology. The addition of nanoscale deposits of hydroxyapatite crystals and calcium phosphate creates a more complex implant surface for osteoblast formation. These implants are more acceptable because they enhance the integration of nanocoatings resembling biological materials to the tissues (Figure 2) [9,10].

Nanoanesthesia: Dental treatments often involve the injection of local anesthesia which has longer duration of action and varying degrees of efficiency, patient discomfort and complication. Nanodentistry works on a colloidal suspension containing millions of active analgesics dental nanorobotic particles that can be instilled on patients gingival. These nanorobot, after contacting the surface of crown or mucosa, reaches the dentin by migrating into the gingival sulcus and pass painlessly to the target site. Once reaching the dentin, the nanorobots enter the dentinal tubule and proceed towards pulp, guided by a combination of chemical gradients, temperature differentials, and positional navigation, all under control of onboard nanocomputers directed by the dentist. The analgesic dental robot may be commanded by the dentist to shut down all sensitivity in

ISSN: 2475-224X

any particular tooth that requires treatment. After completion of treatment, dentist orders the nanorobot to restore all sensation, to replenish control of nerve traffic [11].

Nanosolutions: Nanosolutions consist of dispersible nanoparticles, which are used as components in bonding agents.

Advantages: Higher enamel and dentin bond strength, higher stress absorption, higher shell life, durable marginal seal, no separate etching required, fluoride release [12].

Nanoencapsulation: South West Research Institute (SWRI) developed targeted release system which will cover nanocapsules including novel vaccines, antibiotic and drug delivery with reduced side effects.

Other products developed by SWRI include:

A) Protective clothing and mask, using antipathogenic nanoemulsions and nanoparticles.

B) Medical appendages for instantaneous healing, for example biodegradable nanofibers delivery system for haemostatic and wound dressing with silk nanofibers.

C) Bone targeting nano carriers.

D) Calcium phosphate based biomaterial will be developed which will support the growth of cartilage and bone cells [13].

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 orthopedic and dental applications and more particularly, for the development of nanobone. Nanocrystals show a loose microstructure, with nanopores 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 [14].

Dental caries: The use of tooth paste with nanosized calcium carbonate enable remineralisation of early lesions. Some studies suggest the bacteriostatic effect of silver, zinc oxide and gold nanoparticles on streptococcus mutants. Compared to other nanoparticles silver nanoparticles had an antimicrobial effect in lower concentration and lower toxicity [5].

Durability and appearance: Replacing upper enamel layers with covalently bonded artificial materials such as sapphire or diamond can improve the appearance and durability of teeth. Pure sapphire and diamond are brittle and are prone to fracture; it can be made fracture resistant as a part of nanostructured composite material that possibly includes embedded carbon nanotube [6].

Nanovector: Calcium phosphate nanoparticles serve as a good nanovector to deliver target genes to fibroblast for periodontal regenerative purposes.

Mouth washes: Mouth washes containing nano-calcium fluoride show higher solubility and reactivity [15].

Nanotech floss: It is an ultra-thin ultra-glide, completely non-shredding floss with excellent tensile strength. The unique nanostructure of dental tape allows for the addition of flavors and delivery of medications [16].

Challenges Faced by Nanodentistry

Biocompatibility: It is essential to develop biofriendly nanomaterial and ensure compatibility with all intricate of human body. Smaller particles are more bioactive and toxic. Their ability to interact with other living system 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 many biochemical reactions like the creation of free radicals that damage cells. While the body has built- defense for natural particles it encounters, the danger of nanotechnology is that it is introducing new types of particles.

Basic engineering problems: There is a problem in the feasibility in the mass production technique. Precise positioning and assembly of molecular scale part is a challenge for them. Manipulating and coordinating activities of large number of independent microscale robot simultaneously is a difficult task. Even though the field of nanorobotics is fundamentally different from that of the macro robot due to the differences in scale and material, there are many similarities in the design and control technique that eventually could be projected and applied [17].

Cost factor: Nanotechnology will dramatically reduce the cost and increase the capabilities. The uses of nanotechnology in aerospace, construction, agriculture, steel, environment, medicine, transportation etc reduces the labour cost and also saves a lot of time. New application expected to emerge in next decade will range from very low cost, long life and high efficiency devices. Nanomedicine will revolutionize the way we diagnose and treat the disease with substantially lower cost [18].

Social issues of public acceptance: Continued advancement of nanotechnology research, and eventual integration of nanotechnology into consumer products and useful applications, will depend heavily on the public acceptance of nanotechnology. Governments around the world must take a proactive stance to ensure that environmental, health and safety concerns are addressed as nanotechnology research and development moves forward in order to assure the public that nanotechnology products will be safe [19].

Ethics: The dominance of the drastic opposition of utopian dreams and apocalyptic night mares in the debate on the future perspective of nanotechnology holds the risk of undesirable conflicts and unnecessary black lashes. Hence the present state of debate on nanotechnology calls for the development of more balanced ethical views [20].

Human safety: Nanotoxicity is still a new field but there is possibility that some nanomaterials may present health risk. The properties that allow nanomaterials to penetrate the body in new ways are not necessarily bad, but in fact may be beneficial, such as in the development of targeted cancer therapies. It is also crucial to bear in mind that not all nanomaterials are created equal toxicity will likely vary depending not only on the material, but also vary based on the particle size [21].

Advantages

1) Nanorobots will restore lost tissue at cellular level.

ISSN: 2475-224X

2) Nanorobotic probes are mainly useful for monitoring, diagnosing and fighting sickness.

3) Ability to detect neuro-electric signals and stimulate bodily systems.

Disadvantages

1) Clusters of different nanorobots are harmful.

2) Installation cost is high.

3) Maintenance is difficult [22-26].

Future: Nanorobots is going to play an important role in the future in the medical field. Nanorobotic technology promises huge advances in extending healthy lifespan. Nanorobots are efficient in eliminating every infected cell. Life is going to be easy and simple with the discovery of nanorobots. It will prove boon to dentistry in future decades to come.

Conclusion

Nanorobots are predicted to be wealth of promise, as its application is practically unlimited. Nanodentistry will lead to a effective and better dental treatment. In earlier era nanorobots which remained only in fictions are now becoming a reality. Dentistry has become less stressful to the dental surgeon with the applications of nanotechnology in dentistry. One of the best ways to maintain oral health is by nanodentistry. Nanodentistry maintain oral health using mechanical dentifrobot, complete orthodontic realignment, hypersensitivity cure, etc. Further research and studies in this exciting new field of science can lead to more success in future of nanotechnology.

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