Review Article

Being Nano is a Boon in Dentistry - An Appraisal on Nanorobots and Nanomaterials Applications in Dentistry

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Abstract

Advanced healthcare is the prime choice nowadays as it conquered the conventional techniques with its overwhelming benefits. Nanodentistry is one such evolving branch of science. The research in this branch is expanding in and out, addressing on the major challenges using smallest of solutions. This review article explains the detail nano-dental robot structure, its parts and phenomenon of action. This article also gives an appraisal of nanomaterials, its applications in dentistry as new field called nanodentistry.

Keywords: Dental nanorobots, Nanodentistry, Nanomaterials, Nanotechnology.

Introduction

In Greek nano means "dwarf." Technically word nano is one-billionth of a meter.[1] A small change in size can bring in a huge difference in function. Hence, nanotechnology has entered the medical field like a boon. Nanotechnology, nanoscience, nanomedicine, and nanodentistry are the terms formed by combining nouns from medical sciences.[2]

Nanodentistry concepts expanding slowly using nanomachines in areas like Local anesthesia, dentine Re-naturalization, permanent dentinal hypersensitivity cure, orthodontic realignments, oral health maintenance, and early caries detection. On the other hand, many studies showed that incorporation of nanomaterials has the superior properties over the conventional dental materials.

History

Nobel laureate Richard P. Feynman first used the term Nanotechnology in his lecture at the Annual meeting of American physical society in 1959.[3] Earlier, Prof.Kerie E. Drexler who was a great researcher and writer in nanotechnology firstly coined the term "Nanotechnology."[2] The true founder of Nanotechnology was though Eric Drexler, who was published the book "Engines of Creation."[4]

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Definitions

Nanotechnology

The branch of science focusing on the manipulation of materials measured on the nanoscale is referred as nanotechnology.[3]

Nanodentistry

Robert Freitas in his article defined the nanodentistry as the science and technology that will make possible the maintenance of near-perfect oral health using nanomaterials, biotechnology, including tissue engineering, and nanorobotics.[4]

Nanorobots in Dentistry

Definition

Nanorobots are those that allow precise interactions with nanoscale objects or can manipulate with nanoscale resolution.[5]

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Synonyms

Nanites, nanomachines, and nanobots are the synonyms of nanorobots.

Parts of nanorobot

- The structural components of nanorobots include manipulating arms (100 nm), sorting rotors for molecular purification (2.10 nm) and glossy hard surfaces made of atomically unblemished diamond. Nanorobots are planned to have a diameter of 0.5–3 microns and parts of dimension 1–10 nm.
- There are four major parts in Nanorobots: Camera, payload, capacitor, and swimming tail (Figure 1). Nanorobots will involve sensors, actuators, control, power, communications and interfacing across spatial scales, and between organic/inorganic as well as biotic/abiotic system.[1,6,7]

Materials used for fabrication of nanorobots

Carbon, sulfur, hydrogen, oxygen, and fluoride are the prime elements comprising to build Nanorobots. Nanomaterials such as carbon nanotubes, metallic nanoconductors, and diamondoid materials are used in their construction. Diamondoid molecules are nothing but circular saturated hydrocarbons formed into diamond shape. They have exceptional properties due to unique atomic structure such as lighter than steel, self-assembly, stability, and resistance.[1,4,7-9]

Differences in shape and structure between medical and dental nanorobots

Intravascular medical nanorobots will bear sphere shape, to mimic blood cells (Figure 2). Martel *et al*. suggested that flagellated bacteria design would be preeminent as medical nanorobot.

Dental nanorobots requires spider like body model to be fast in accomplishing the tasks (Figure 3).[4]

Mechanism of action

Nanorobots would constitute any active structure capable of actuation, sensing, signaling, information processing, intelligence, and swarm behavior at nano scale. The nanorobots are invisible to naked eye, techniques such as scanning electron microscopy and atomic force microscopy are being employed to visualize these nanos scaled devices. It has been planned to give nanorobots a smooth surface that will provide streamlined path during their functioning. It is also thought that glucose, naturally occurring body sugars and oxygen might be a source for propelling the nanodevice in specified direction.[1]

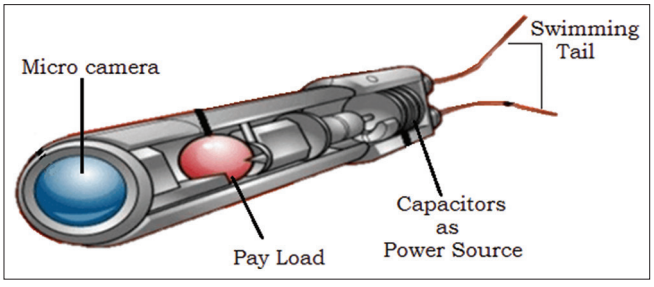

Figure 1: Parts of the nanorobot

Theories behind modes of powering nanorobots

The major modes of powering nanorobots include internal sources and external sources. Metabolism of local glucose, oxygen, patient body heat, and body electrolytes are external energy sources. The acoustic energy released by radioactive particles or solar cells attached to nanorobots body forms internal energy sources.[7]

Modes of communication with nanorobots

Two possible modes include light signals using optical sensors and the other is by chemical signals. They can be controlled by high-speed computers capable of performing around 1000 or more computations per second. Preferable mode would be acoustic signaling navigational network installed in nanorobots. It helps in communication that would provide high positional accuracy to all passing nanorobots, rapid rates of data transfer and help in keeping track of various devices in body.[7]

Elimination

After completion of the task nanorobots are retrieved by allowing them to effuse themselves via the usual human excretory route. These can also be removed by active scavenger system.

Advantages of nanorobots

They provide benefits in various fields of science such as synthesis of new materials with advanced properties,

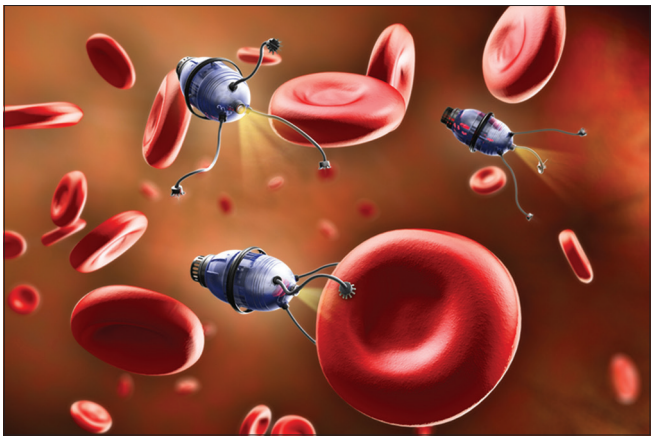

Figure 2: Structure of nanorobot

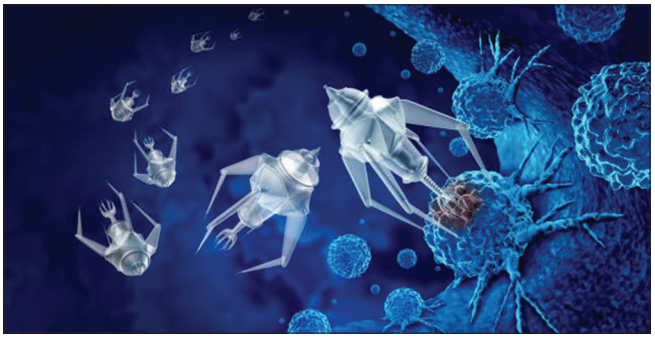

Figure 3: Structure of dental nanorobot

production technology, information technology, medical applications transportation, and drug delivery.[5] Nanorobotic surgeries are excellent option in amalgamating surgeon's skills due to their miniature instrumentation, precise control.[2]

Dental nanorobots are helpful in diagnosing, interceptive, preventive, curative, and restorative procedures. In addition, nanorobots can address the tooth hypersensitivity, induce oral analgesia, and perform malocclusion corrections.[6]

Applications in Dentistry

1. Nanodiagnostics: Nanodevices can be inserted into human body to detect the disease at cellular and molecular level. Specific nano devices are available for *in vivo* analysis to gather human fluids and create several investigations at subcellular level[1,10]
2. Nanoanesthesia: Nanorobots in contact with the surface of crown or mucosa can reach the pulp through the gingival sulcus, lamina propria, and dentinal tubules. Once in pulp, they shut down all sensations by establishing control over nerve impulse traffic in any tooth that requires treatment. The anesthesia is fast acting, reversible with no side effects or complications associated with tissue[10]
3. Surgical nanorobots: Surgical nanorobots, directed by a dentist are visualized to act as on-site surgeons such a device is expected to perform various activities such as diagnosis and treatment planning of atypical lesions with proper nanomanipulation and organization by computers through coded ultrasound signals[7]
4. Personalized treatment: Dentist will perform routine examinations that will include the use of high-resolution imaging devices to better envision the subsurface tomography of each tooth. Individualized treatment plan with advanced technology in nanorobotics delivers most efficient biologically based therapy to promote remineralization naturally and removes the bacteria in the target area[7]
5. Major tooth repair/nano tissue engineering: Tooth restore include constructing the biologically autologous whole replacement teeth using tissue engineering, genetic engineering that involves both the cellular and mineral parts of tooth. It is proved that along with tissue and genetic engineering, nanotechnology plays an important role in natural biomineralization process to produce the hardest tissue in the body and replacement therapy of tooth[2,6]
6. Tooth appearance and durability: Sapphire, a non-constructed composite material has been obtained from nano dentistry, which enhances the durability and aesthetics. This material is 100–200 times harder than the ceramic. And it is very effective whitening sealant and cosmetic substitute. The ratio of alumina to silica with refractive index of 1.503 has excellent physical properties to conventional materials[1]
7. Orthodontic treatment: Nanorobots in orthodontics allows painless tooth rotating, up righting and vertical repositioning, also rapid tissue repair. Nanotechnology could provide a new way to reduce friction during tooth movement. A new stainless-steel wire that uses nanotechnology is under study which combines ultra-high strength with the good deformability, corrosion resistance, and surface finish[4]
8. Dental implants: The contact surface area and surface topography determined as the successful factors for osteointegration along with the other factors such as bonding of bone and its stability. The application of nanotechnology on the dental implants had inevitably increased the bone growth and its effectiveness. The nano technology has produced innovative step in material engineering through advanced research in improving the surface topography and chemistry of dental implants[6]
9. Bone replacement materials: The most biocompatible nanostructure of bone composed of organic compounds mainly collagen and reinforced with inorganic ones. Specifically for the growth of nano bone for its applications in the field of orthopedic and dental aims in the development of nanotechnology. The surface microstructure is designed in such a way that they absorb the protein due to the supplement of silica molecules[10]
10. Dentin hypersensitivity: Dentinal hypersensitivity is one of the most common clinical problems encountered. Discrepancies of hydrodynamics in the pulp cause hypersensitivity. Reconstructive dental robots using native biological materials could selectively and precisely occlude specific tubules within minutes, offering a quick, and permanent cure[2,7]
11. Treatment of oral cancer: Nanotechnology had offered the best treatment modality for cancer patients with precise tools in the form of multifunctional dendrimers and nano shells. The intense head generated by engrossing the definitive wavelength of radiation can be utilized for target destruction of cancer cells leaving the normal cells intact. The unique property of dendrimer such as this high degree of branching, multivalence, globular structure, and well-defined molecules weight make them promising in cancer therapeutics.[1,7]

Nanomaterials

Nanomaterials are defined as those materials, involving parts that are <100 nm in at least one dimension.[1] Nanomaterials will be used for more widely and will yield superior results and when combined with biotechnology, laser, and digital guided surgery will thus provide excellent dental care. Salivary glands can be a gateway to the body for the delivery of precise molecular therapy using nanosized particles-based drug delivery system with fewer side effects.[11]

Nanoparticles: Different types of nanoparticles have been shown to mimic the host tissues.[11] Nanoparticles because of its nano filler size are widely accepted in modern dentistry. Nanofillers have improved esthetic, physical, and mechanical properties of dental materials. The nanoscale size of nanoparticles has profound effect in relation to repairing and regenerating

lost tissues at molecular level. Their low toxicity, low filler content, antimicrobial properties, and enhanced protein-surface interactions can be used for various dental applications.[11]

Nanoparticles regarding their size can penetrate cell membrane readily, leads to damage to, and inactivity of, the bacteria.[11] Nanoparticles are attractive for medical purposes that are based on their important and unique features such as their surface-mass ratio that is much larger than that of the other particles, their quantum properties and their adsorbing capacity and carrying other compounds such as drugs, probes, and proteins.[11]

Properties of nanomaterials, such as active surface area, chemical reactivity, and their biological activity, can be dramatically varies from those micro sized particles, indeed the biocidal effectiveness of metallic nanoparticles has been suggested due to their size and their high surface-volume ratio.[12] Studies shown that some nanoparticles such as silica have been detected to cross the blood-brain barrier in mice although without apparent negative effects of toxicity.[13] There are several types of nanoparticles available in dentistry.

For example: Silver nanoparticles, iron oxide nanoparticles, gold nanoparticles, Copper oxide nanoparticles, hydroxyapatite nanoparticles, calcium fluoride nanoparticles, calcium phosphate nanoparticles, silica nanoparticles, zirconium nanoparticles, and zinc oxide nanoparticles.[14,15]

Among all these silver nanoparticles are most widely used in dentistry. Antimicrobial property of silver is widely accepted; thus, silver nanoparticles are combined with different materials that results in additional antimicrobial effects that ultimately leads to decrease in biofilm production and maintain better oral health.[12]

In addition to antimicrobial property, biocompatibility is another vital property of the biomaterials. Incorporation of nanomaterials did not induce any cytotoxicity and substantially enhance the antimicrobial potency of primer and adhesive.[13,16] In addition, silver nanoparticles incorporated into polymers used as tissue conditioners, and as denture bases has shown the satisfactory results in the treatment for denture stomatitis.[11] Silver nanoparticles have demonstrated unique interactions with bacteria and fungi species.[12,17]

Concentrations of nanoparticles that are used to agglomerate with the different dental materials play a major role in improving its properties. Increasing in concentration of nanoparticles has negative effect on strength.[17]

Nanomaterials in Dentistry

1. Nanocomposites: Nanofillers are added to traditional composites to improve its properties such as filler loading and superior physical properties.[6] Nanofillers such as nanomeric and nanocluster types are added
2. Nano impression materials: Nanofillers added to polyvinyl siloxanes yields a siloxane impression material with superior properties than its conventional types[3]
3. Nano solutions: This can be made use of dentin bonding agents because of better bond strength[10]
4. Nanoencapsulation: Target drug delivery system has been developed successfully that involves nano capsules containing antibodies, vaccines, and drug delivery[2]
5. Nano adhesives: These materials prevent agglomerations, and these are produced from nano solutions[1]
6. Nanorobotic dentifrices: Properly configured dentifrorobots have the potential to identify and destroy pathogens present in plaque and elsewhere and provide decreased halitosis[7]
7. Orthodontic wire: Nanotechnology with nanoparticles included in orthodontic wire has shown improved qualities such as ultra-high strength, corrosion resistance, and good surface finish[7]
8. Nano needles: Nanosized stainless steel crystals incorporated into suture needles have been developed[6]

*Along with these nanosterilizers, nanosilver fluorides, sealants, and nanocomposite denture teeth are also developed in this nano dentistry.

Synthesis of Nanoparticles

Nanoparticles can be extracted through chemical solutions or from plants extract. The process of nanoparticles synthesis, from the plants extract is called green synthesis.[18,19] It has potential applications in environmental and biomedical fields. Green synthesis aims in decreasing the usage of toxic chemicals.

Green synthesis of nanoparticles includes gold, silver, copper, palladium, platinum, zinc oxide, and titanium dioxide. Green synthesized nanomaterials are of growing interest as they contain flavonoids, tannins, alkaloid, etc. Thus, nanoparticles carrying natural phytochemicals derived from medicinal plants are considered as good alternatives to synthetic chemicals in treating dental problems. The use of biological materials such as plants is usually safe.[20-23]

How are Nanorobots Safe?

The nonpyrogenic nanorobots which are used *in vivo* are Bulk, Carbon powder, monocrystal sapphire, pyrogenic nanorobots are alumina, silica, and trace elements such as copper and zinc. If inherent nanodevice surface pathogenicity cannot be avoided, the pyrogenic pathway is controlled by *in vivo* medical nanorobots. The endogenous pyrogens are absorbed in targeted fashion by releasing of inhibitors and modifying them chemically in a harmless inactivated form back into the body.[7]

Provacations in Designing Nanorobots

Nanomachines manufacturing involves dexterity, it is an exigent task. There are various challenges and risks encountered in this like fixing each nanostructure with precision.[5] Apparently, it requires fine tools and manipulation procedures. Also assembling of nanomachines poses challenges when the parts start moving

relative to each other they will disconnect due to adhesion and static friction which surpasses the strength of material.[5,7]

Limitations of nanorobots[2]

1. Start-up will be a bit pricey
2. Technique sensitive
3. Misuse of nanorobots in the field of terrorism can pose a peril
4. Intricate to customize
5. Biocompatibility issues due to pyrogenicity
6. Community and ethical problems in acceptance of treatment
7. Harmonization of activities in huge number of independent microscale robots.

Enigma For Research in Nanotechnology in India[1,7]

1. Slow strategic decisions
2. Inadequate trained manpower and problem of retaining them
3. Lack of private agencies involvement
4. Inadequate funding.

Conclusion

Nanotechnology has bought dentistry a miniature technology which has the ability to lessen the burden of dentist in near future.[1] Nanotechnology is a relatively new, rapidly, and developing area of science that has great potential in effective development of new devices and nanomaterials that can be used in the management of human health.[3] These views need to be addressed before nanotechnology can be incorporated into armamentarium of modern medicine.[10]

Nanotechnology is part of a predicted future in which dentistry and periodontal practice may become more high-tech and more effective looking to manage individual dental health.[1] Construction of comprehensive research facility is crucial to meet the rigorous requirements for the development of nanotechnologies. Advanced technology in dental materials allows dentists to create durable restorations that match the color of your natural teeth, require less tooth structure removal, and ensure your total health. The combination of continual refinements in conventional treatment modalities and advances in the clinical applications of nanotechnology is promising way to improve the dental care.[14]

Acknowledgment for figures

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2. https://interestingengineering.com/15-medical-robots-that-are-changing-the-world
3. https://www.pinterest.com/pin/362891682444016410/

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