**TINY MIRACLE WITH ENORMOUS POTENTIAL – NANOBOTS**

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**ABSTRACT**

**Nanorobots is a science and engineering involved in design, synthesis, characteristics and application of materials and devices. These nanorobots allow precision interactions with nanoscale objects or can manipulate with nanoscale resolution. Dental nanobots were first introduced by Robert Freitas in 1994. The manipulation of matter at the molecular and atomic levels is known as nanotechnology. It has the potential to revolutionize the domains of medicine and dentistry. Nanodentistry may soon be able to maintain near-perfect dental health with the help of nanorobotics, nanomaterials, and biotechnology. However, like with any breakthrough, there is a possibility of misuse. Time, economic and technological resources, and human needs will all influence the course of this revolutionary growth. This article examines the current state of nanotechnology, nanaomedicine, and nanodentistry, as well as their future therapeutic applications.**

**KEYWORDS: NANOROBOTS, NANODENTISTRY , DENTIFIROBOTS, NANOMEDICINE, FUTURE APPLICATIONS.**

**INTRODUCTION**

Nanorobotics is the technology of creating machines or robots at

or close to the microscopic scale of a nanometer (10–9 meters).

 The growing interest in the application of nanotechnology in dentistry is leading to the emergence of a new field called nanodentistry. An emerging branch of technological research, involving the use of nanotechnology for designing and constructing nanorobot, will indeed play an indispensable role in medical science and dentistry.

Nanorobotic application is unlimited, with most engrossing applications in dentistry. The construction of dental nanorobots could be aimed to destroy caries-causing bacteria or to repair tooth for hypersensitivity, by tiny workers which are directed by computer in their tasks.

Specific mechanisms like to crawl or swim through human tissue with navigational precision in acquiring energy, to sense and manipulate their surroundings with the goal of achieving safe cytopenetration in real time can be designed. Dental nanorobots will bring notable benefits even in oral health, to achieve painless, quick, and high-precision dental treatment.

 Nanorobots induce oral analgesia, desensitize tooth, manipulate the tissue to realign and straighten irregular set of teeth and to improve durability of teeth. Further, nanorobots are used to do preventive, restorative, curative procedures.

 Treatment opportunities in dentistry may include local anesthesia, dentition renaturalization, and permanent hypersensitivity cure, complete orthodontic realignments during single office visit, and continuous oral health maintenance using mechanical dentifrobots.[1]

 Recent advances in the field of nanorobots prove that nanodentistry has strong potential to revolutionarize dentistry to diagnose and treat diseases.

**PRINCIPLES OF NANOROBOTS**

1. Powering- it is done by metabolizing glucose and oxygen and externally supplied acoustic energy. It is usually controlled by onboard computers

2. Communication- is obtained by acoustic signaling and navigational network installed in the body. It helps to keep track of various devices in the body and communicates with the dentist.

3. Excretion- after it has completed its work, it is usually retrieved when they effuse themselves via the human excretory channels

**MANUFACTURING DONE BY TWO TYPES OF NANOBOTS**

Two approaches for manufacturing medical nanorobots are suggested according to researcher Adriano Cavalcanti from the Center for Automation of Nanobiotech (CAN) in Brazil.

 1. Organic nanorobots (Also known as bionanorobots): Manufactured using proteins and polynucleotides.

2. Inorganic nanorobots: Manufactured using metals or diamonds.

 Metals have double benefit

 Ex: silver serve as the base of a nanorobot and has an antibacterial effect. Diamond - has high strength h and high performance.

**VARIOUS APPLICATIONS IN MEDICINE FIELD**

Nanobots will play an important role in medicine, such as a “nanodoctor” inside the body including pharmaceutics, diagnostics, gene therapy, and dentistry.

**In dentistry, nanorobots are gaining importance via**

• Bring about oral analgesia

• Tooth desensitization

• Manipulating the tissue to realign and straighten irregularly arranged teeth

• To enhance the durability of teeth

• Also employed to do preventive, restorative, curative procedures

i.e., Dental nanorobots could be used to kill caries-causing bacteria or to repair tooth blemishes where decay has developed, by employing a computer to direct these tiny workers in their tasks.

**IN PERIODONTAL POINT OF VIEW**

1. ORAL HYGIENE AND HALITOSIS : Nanorobotic dentifrice is mainly kept sub occlusally (dentifrobots). These dentifrices keeps an eye on supragingival and subgingival surface at least once a day and destroys pathogenic bacteria in plaque and food. These bacteria are destroyed by the nanorobots. After the bacteria is trapped, these nanorobots metabolizes the trapped organisms into harmless and odorless vapors and later deactivate themselves if swallowed.
2. Nanoscale particles are added in the conventional dentifrices like mouthwashes and toothpastes and helps in-

  Repelling the deposition of bacterial biofilm

  Prevents early remineralization of carious lesion

  Helps in deposition of minerals which is lost by tooth called

 enamel remineralization

The nanoparticles that are usually added in the dentifrice are silver nanoparticles and triclosan loaded nanoparticles**.**

1. **MANAGEMENT OF DENTINAL HYPERSENSITIVITY**

The most commonly faced dental problem by the patients is Dentinal hypersensitivity which is another area where Nanorobots are useful. Nanorobots are utilized to selectively and precisely occlude tubules in minutes, by making use of native biologic material, thus benefiting the patients with a rapid and permanent cure.[2]

The choice of material is Nanohydroxyapatite (n-HAP). It is gaining importance in the field of dentistry, mainly ascribed to its structural similarity to the crystals of the tooth enamel, and is a biocompatible and bioactive material.

n- HAP-containing toothpaste was found to be advantageous in decreasing dentin hypersensitivity and can be prescribed for dentinal hypersensitivity management. Wang et al in their study reported that nano-hydroxyapatite formulations (with or without home-care product association) were as effective as the other treatment approaches in decreasing dentin hypersensitivity[3].

1. **DIAGNOSIS OF ORAL CANCER**

• Nanoelectromechanical systems(NEMS*):* Nanotechnology-based NEMS biosensors that exhibit exquisite sensitivity and specificity for analyte detection,

down to single molecule level are being developed. They convert (bio) chemical to electrical signal.[9]

• Oral fluid nanosensor test(OFNASET*):* The oral-fluid nanosensor test technology is used for multiplex detection of salivary biomarkers for oral cancer. It has been demonstrated that the combination of two salivary proteomic biomarkers (thioredoxin and IL-8) and four salivary mRNA biomarkers (SAT,

ODZ, IL-8, and IL-1b) can detect oral cancer with high specificity and sensitivity.[10]

• Optical nanobiosensor*:* The nanobiosensor is a unique fiberoptics-based tool which allows the minimally invasive analysis of intracellular components,

such as cytochrome C, which is a very important protein to the process which produces cellular energy and is well-known as the protein involved in apoptosis,

or programmed cell death.[11]

1. **Treatment of oral cancer**:

Nanotechnology in field of cancer therapeutics has offered highly specific tools in the form of multifunctional dendrimers and nanoshells. The unique property of dendrimers, such as their high degree of branching, multivalence, globular structure and well-defined molecular weight make them promising

in cancer therapeutics. Nanoshells are miniscule beads with metallic outer layers designed to produce intense heat by absorbing specific wavelengths of radiations that can be used for selective destruction of cancer cells leaving aside intact and adjacent normal cells.

• Nanomaterials for brachytherapy*:* BrachySilTM (Sivida, Australia) delivers 32P, clinical trial.

• Photodynamic therapy*:* Hydrophobic porphyrins are potentially interesting molecules for the photodynamic therapy (PDT) of solid cancers or ocular

diseases.

1. **MAJOR TOOTH REPAIR/NANOTISSUE ENGINEERING**

Replacement of the whole tooth, including the cellular and mineral components, is referred to as complete dentition replacement. This therapy is possible through a combination of nanotechnology, genetic engineering, and tissue engineering. Complete dentition replacement was the basis for research by Chan et al., who recreated dental enamel, the hardest tissue in the human body, by using highly organized microarchitectural units of nanorods.

1. **NANOANESTHESIA :**

 A colloidal suspension containing millions of active analgesic microns to which dental nanorobots particles are infused on the patient’s gingiva. Once they lie in proximity to the mucosa or crown, the ambulating nanorobots reach the dentin, by migrating into the gingival sulcus and passing painlessly to the lamina propria or through a 1-3 micrometer thick layer of loose tissue at the CEJ. On reaching the dentin, nanorobots enter the dentinal tubules up to 1-4micron depth and move towards the pulp directed by a combination of chemical gradients, temperature differentials, and even positional navigation, all under the control of a nanocomputer as guided by the dentist. Time taken for nanorobots to reach the pulp from the tooth surface is approximately 100 seconds thereby giving a quick relief of sensitivity.

 i.e., Tooth surface ---100 seconds --------------------------pulp

Upon reaching the pulp, they are given an order by the dentist to shut down all the sensations of that particular tooth that requires treatment. Once the procedure is completed, the dentist orders the robots to reinstate all the sensations.

Advantages

 Renders better and speedy action

Reduced patient anxiety as it doesn’t use needles

 Reduced adverse effects/complications of local anesthesia.

 Anesthetic effect is fast and completely reversible thus offering both patient and dentist comfort.

1. **SURGICAL NANOROBOTICS:**

A surgical nanorobot, programmed or guided by a dentist, could act as a semiautonomous onsite surgeon inside the human body. Such a device could perform various functions, such as searching for pathology and then diagnosing and correcting lesions by nanomanipulation, coordinated by an onboard computer, while maintaining contact with the supervising surgeon via coded ultrasound signals.[15]

The earliest forms of cellular nanosurgery are already being explored today. For example, a rapidly vibrating (100 Hz) micropipette with a <1 micron tip

diameter has been used to completely cut dendrites from single neurons without damaging cell viability.

Axotomy of roundworm neurons was performed by femtosecond laser surgery, after which the axons functionally regenerated. A femto laser acts like a pair

of ‘nanoscissors’ by vaporizing tissue locally while leaving adjacent tissue unharmed.

1. **BONE REPLACEMENT MATERIALS**:

These can be used in maxillofacial injuries requiring bone graft, cleft patient

and osseous defect in periodontal surgeries.

• Hydroxyapatite nanoparticles used to treat bone defects are

 Ostim® (Osartis GmbH & Co KG, Obernburg, Germany) HA.

• VITOSSO (Orthovita, Inc., Great Valley Parkway Malvern,

 PA 19355, USA) HA and TCP.

• NanOSSTM (Angstrom Medica, USA) HA.

1. **LOCAL DRUG DELIVERY:**

Local drug delivery helps to improve the regenerative capacity of damaged tissues and also helps to treat periodontal disease. These provide therapeutic molecules that could be loaded in carriers such as scaffolds to allow sustained and controlled release. The drug concentration is improved due to sustained release into the periodontal pocket. The materials used as drug delivery are:

 Nanoparticles: TRICLOSAN nanoparticles, MINOCYCLINE nanoparticles, CALCIUM LOADED nanoparticles, ZINC LOADED nanoparticles

 Nanogels: introduce quantum dots to PDL cells

 Nanofibers: Poly e-caprolactone containing metronidazole [4]

1. **QUANTUM DOTS:**

These are usually tiny semi-conductors that are stable, non-toxic and glow brightly when stimulated by UV light. These provide promising nanostructures in diagnostic application, healing of inflamed periodontal tissue and also in treatment of cancer. The quantum dots that are usually used are lead free and cadmium free quantum dots. The mechanism of these quantum dots is:

Nanostructures gets attached to the antibody and attacks the target cell which is stimulated by UV light which gives out reactive oxygen and destroys the particular target cell. ([12]

 Study selection should be based on the advantages and disadvantages of these nanorobots which include:

 **Advantages**

These nanorobots has a lot of advantages which include:

 Superior hardness, translucency, flexure strength are good

 Faster and accurate diagnosis of oral disease

 Faster elimination of disease

 Less fatigue

 Durability (i.e.) it can remain operational for years, decades or centuries.

 HIV, cancer and other harmful diseases are also under progress for curing. Nanorobots will treat and find disease and restore lost tissues at cellular

level in reduced span of time[12]

1. **IMPRESSION MATERIALS**

Nanofillers are integrated into vinylpolysiloxanes, producing a unique siloxane impression material that has a better flow, improved hydrophilic properties, and enhanced precision detail ***(Kumar and Vijayalakshmi, 2006*)[12]**

**13. 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 development11.

**14. NANOCOMPOSITES**

Microfillers in composites and microcore materials have long been in use. Although the filler particle size cannot be reduced below 100 nm, nanocomposite particles are minute enough to be synthesized at the molecular level. These nanoparticles improve the compressive strength of the material. Filler particles of submicron size, such as zirconium dioxide, are also necessary to improve

polishability and esthetics. However, when particles of this size are used, the material may be more prone to brittleness and cracking or fracturing after curing.

To address this issue, hybrid composites and composites containing a wider distribution of filler particles have come into use. Although these composites display a better balance of strength and esthetics, they are weak due to nanoparticle clumping or agglomeration.

 This problem can be overcome by incorporating a proprietary coating process during the particle manufacturing procedure, thereby eliminating weak spots and providing consistent strength throughout the entire “fill” of the core build-up. Additionally, the even distribution of nanoparticles results in a smoother, creamier consistency and improves flow characteristics.

Once the material is cured to its hardened state, these properties contribute to the dentin-like cutability and polishability of the material (***Kumar and Vijayalakshmi, 200613; Abhilash, 2010)*[12]*.***

**15. Dental implants: structure, chemistry, and biocompatibility**

The determining factors for successful osseointegration 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 nanoscale deposits of hydroxyapatite and calcium phosphate creates a more complex implant surface for osteoblast formation (***Albrektsson et al., 200816; Goene et al., 2007***). Extensive research on the effects and subsequent optimization of microtopography and surface chemistry has produced ground-breaking strides in material engineering. These new implants are more acceptable, because they enhance the integration of nanocoatings resembling biological materials to the tissues.

**16. APPLICATION OF CARBON NANOTUBES (CNT) IN ORAL REGENERATIVE MEDICINE**

There is no doubt that dentistry is one of the branches of medicine most interested in the application of new knowledge acquired from the recent advances in tissue engineering and, particularly, in the field of nanotechnology. Important areas such as implantology, periodontics, and oral and maxillofacial surgery can benefit tremendously from the development of new nanomaterials.

 In the past few years, CNT combined with biopolymers have been novel potential biomaterials that may aid in the restoration of bone defects in dentistry. Currently, much information about the synthesis, characterization, and properties of CNT is available; however, more *in vitro* and *in vivo* studies are needed for a better comprehension of their effects on bone repair/regeneration.

 In **2010**, **Mendes *et al18****.* evaluated the effects of single-walled CNT (SWCNT) associated with sodium hyaluronate (HY-SWCNT) on bone repair/ regeneration of tooth sockets in rats. Treatment of sockets with this nanomaterial increased the formation of bone trabeculae approximately 3-fold and decreased the number of cell nuclei, thus indicating that the healing process was advanced in comparison with that in control sockets. Also, the expression of type I collagen was increased by 46% in treated sockets after 7 days of tooth extraction. This is an important finding, since, during the bone healing process, the collagen fibrils form osteoid, which allows for the deposition of crystals of carbonated hydroxyapatite responsible for mineralization of the bone matrix (**Bouletreau *et al.*, 2002**).

Thus, an augmented expression of collagen type I in HY-SWCNT-treated sockets further suggests that the healing process is accelerated in these sockets (**Mendes *et al*., 2010**). No evidence of toxicity was observed in this study (Mendes *et al.*, 2010) . Similar methodology was used to investigate the effects of HY-SWCNT on bone repair/regeneration of tooth sockets of rats under conditions in which bone repair/regeneration was hindered. It is well-known that diabetes alters bone metabolism by reducing both neoformation and resorption, prolonging the process of bone tissue repair/regeneration. Thus, the effects of HY-SWCNT were tested in rats with type I diabetes, induced by streptozotocin (**Sá *et al.*, 2013**).

It was found that, 14 days after tooth extraction, the bone repair/regeneration was approximately 3.3-fold higher in tooth sockets of diabetic rats treated with the nanomaterial. The treatment markedly increased the formation of bone trabeculae and reduced the number of cell nuclei, reaching values similar to those observed in non-diabetic rats. Therefore, the treatment with HY-SWCNT was able to restore the bone repair/regeneration process in tooth sockets of diabetic rats **(Sá *et al.*, 2013).**

In summary, both of the above-described studies **(Mendes *et al.*, 2010; Sá *et al.*, 2013)** verified that HY-SWCNT have great potential use for bone regenerative procedures in dentistry, in normal and adverse metabolic states. Corroborating these findings, **Usui *et al.* (2008)** conducted a series of experiments implanting MWCNT into different types of bone in mice. First, they implanted MWCNT subperiosteally into the skull to evaluate bone-tissue compatibility. At 1 and 4 wks post- surgery, there were no significant signs of incompatibility.

 These authors then implanted MWCNT into tibial defects to examine their influence on bone healing during 4 weeks and found a bone formation pattern similar to that of the control group, suggesting that the nanomaterial did not inhibit bone regeneration. More importantly, MWCNT particles promoted immediate HA crystallization on their surfaces, acting as a core for initial HA crystallization.[6]

**17. IN ORTHODONTICS**

The treatment generally involves a frictional type of force which provides the desired movement. in a study published by Katz, a reduction in friction has been reported by coating the orthodontic wire with inorganic fullerene-like tungsten disulfide nanoparticles which are known for their dry lubrication properties. it has been reported thatorthodontic nanorobots could directly manipulate the periodontal tissues, allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours.

**18. TOOTH DURABILITY AND APPEARANCE:**

Nanodentistry has given material that is nanostructured composite material, sapphire which increases tooth durability and appearance. Upper enamel layers are replaced by covalently bonded artificial material, such as sapphire. This material has 100 to 200 times hardness and failure strengththan ceramic. Like enamel, sapphire is a some what susceptible to acid corrosion. Sapphire has best standard whitening sealant, cosmetic alternative. New restorative nanomaterial to increase tooth durability is nano-composites. This is manufactured by nanoagglomerated discrete nanoparticles that are homogeneously distributed in resins or coatings to produce nanocomposites.

The nanofiller includes an aluminosilicate powder having a mean particle size of about 80 nm and a 1:4 ratio of alumina to silica.

The nanofiller has a refractive index of 1.503, it has superior hardness, modulous of elasticity, translucency, esthetic appeal, excellent color density, high polish and 50% reduction in filling shrinkage.

They are superior to conventional composites and blend with a natural tooth structure much better.

**19. POTENTIAL FUTURE APPLICATIONS**

**Dentifrobots**

Dentifrobots are nanorobots that identify and destroy pathogenic oral bacteria and prevent putrefaction, thus maintaining a healthy oral ecosystem and minimizing halitosis. They are usually made up of nanosized hydroxyapatite molecules, delivered either through mouthwash or toothpaste, and can be deactivated if ingested accidentally by the patient.[13]

Dentin hypersensitivity is relatively common and is provoked by changes in pressure that are hydrodynami­cally transferred to the pulp. The dentinal tubules of a hypersensitive tooth are twice the diameter and have eight times the surface density of non-sensitive teeth.

The basic approach to treatment of dentin hypersen­sitivity involves blockage of open dentinal tubules, thus preventing external stimuli from creating fluid movements that trigger pain. Dental nanorobots can selectively identify teeth in minutes and block dentinal tubules by using natural biologic substances, thus of­fering patients a fast and long-lasting cure. [14]

**20. Tooth Reconstruction**

Nanodentistry plays an important role in natural tooth repair through genetic engineering, tissue engineering and regeneration, as well as production and installation a of a whole new tooth *in vitro*.

The use of nanorobotic technology to manufacture and install new teeth with the same mineral and cellular components as the original tooth structure would greatly improve the whole treatment plan.

**21. NANOHAZARDS**

Since nanotechnology is a very recent discovery and is only just being put in to use, there are issues that need to be addressed. As long term effects of nanotechnology are unknown, therefore, potential hazards caused by the nanotechnology might not show for many years. Various factors govern the amount of free Nanoparticles in nature such as their physic-chemical properties, quantity, and time of exposure. Nanomaterials released in the environment can be further modified by, Temperature, pH, different biological conditions, and presence of other pollutants. In this interaction , nanomaterials can alter atmosphere, soil and water and prove to be harmful to human health and the environment[7].

It has been reported that nanomaterials can enter the human body through several ports. Accidental or involuntary contact during production or use is most likely to occur via the lungs and skin, from which a rapid translocation is possible to other vital organs through the bloodstream. Carbon black Nanoparticles have been implicated in interfering with cell signalling. It could also have unwanted effects on the DNA of cells, which could potentially cause genetic defects if this were to happen it would take a lot of time and research to put right. There is a need for developing systemic solutions, monitoring, and recording of the potential hazard as well as finding timely responses in order to achieve safety for human health and the environment5

**ADVANTAGES & DISADVANTAGES OF NANOROBOTS**

 1. Nanorobotics is evolving rapidly progressively in the medical field owing to their effectiveness, and comfort, simultaneously lowering the risk and invasiveness significantly.

 2. Nanorobotics will help in the early diagnosis or prevention or management of the disease.

 Despite their varied applications and numerous advantages, nanorobots have challenges and risks.

**DISADVANTAGES.**

1. Expensive initial design.

2. Difficult to Interface, Customize, and has a complicated design

3. Electrical nanorobots are vulnerable to electrical interference from external sources such as radiofrequency(rf) or electric fields, electromagnetic pulse (EMP), and stray fields from other in vivo electrical devices.[15]

**Are Nanorobots safe?**

The nonpyrogenic nanorobots used *in vivo* are bulk, carbon powder and monocrystal sapphire. Pyrogenic nanorobots are alumina, silica and trace elements like copper and zinc.

If inherent nanodevice surface pyrogenicity cannot be avoided, the pyrogenic pathway is controlled by *in vivo* medical nanorobots.

Nanorobots may release inhibitors, antagonists or down regulators for the pyrogenic pathway in a targeted fashion to selectively absorb the endogenous pyrogens, chemically modify them, then release them back into the body in a

harmless inactivated form.[16]

**Challenges faced by Nanodentistry**

• Precise positioning and assembly of molecular scale part

• Economical nanorobot mass production technique

• Biocompatibility

• Simultaneous coordination of activities of large numbers

of independent micronscale robots

• Social issues of public acceptance, ethics, regulation and

human safety

• Design cost very high

• Electrical systems can create stray fields which may

activate bioelectric-based molecular recognition systems

in biology

• Hard to interface, customize and design, complex

• Nanorobots can cause a brutal risk in the field of terrorism.

The terrorism and antigroups can make use of nanorobots as a new form of torturing the communities as nanotechnology also has the capability of destructing the human body at the molecular level.

**CONCLUSION :**

Nanotechnology is a predicted future in which dentistry and periodontal practice becomes high-tech and more effective looking to manage individual dental health. Research into nanorobotics is still in its primary stages but can be the best promising future in dentistry.

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