

NANOROBOTICS – HEADWAY TOWARDS DENTISTRY

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ABSTRACT

Nano-robots are controllable machines or materials or particles at the nano (10⁻⁹) meter or molecular scale that are composed of nano-scale 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. Even if the field of nanorobotics is fundamentally different than that of 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. A roadmap towards the progression of Nanorobotics in dentistry is proposed.

Key words: *Nanorobotics, Nanodentistry, Nanotechnology*

INTRODUCTION

Nanorobotics is manipulating matter at nanometer level and application of same to dentistry is called as Nanodentistry. Nanotechnology holds promise for advanced diagnostics, targeted drug delivery and biosensors. In the long term, nanorobots will allow instant diagnosis and extermination, individual cell surgery in vivo and improvement of natural physiological function. Current research is focusing on fabrication of nanostructures, nanoactuators & nanomotors, along with means to assemble them into larger systems, in great numbers.

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; manipulate the tissue to re-align and straighten irregular set of teeth and to improve durability of teeth. Further it is explained that how nanorobots are used to do preventive, restorative, curative procedures & Major tooth repair.

Nanodental techniques involve many tissue engineering procedures for major tooth repair. Mainly nanorobotics manufacture and installation of a biologically autologous whole replacement tooth that includes both mineral and cellular components which leads to complete dentition replacement therapy [1].

MECHANISM OF ACTION OF NANOROBOTS

The powering of the nanorobots can be done by metabolizing local glucose and oxygen for energy & externally supplied acoustic energy. Other sources of energy within the body can also be used to supply the necessary energy for the devices.

They will have simple onboard computers capable of performing around 1000 or fewer computations per second. This is because their computing needs are simple.

Communication with the device can be achieved by broadcast-type acoustic signaling.

A navigational network may be installed in the body, providing, High positional accuracy to all passing nanorobots that interrogate them, wanting to know their location.

This helps physician to keep track of the various devices in the body. These nanorobots will be able to distinguish between different cell types by checking their surface antigens. They are accomplished by the use of chemo tactic 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 exfuse themselves via the usual human excretory channels. These can also be removed by active scavenger systems.

POTENTIAL APPLICATION IN DENTISTRY

- 1.) **Nanodiagnostics:** – is the use of nanodevices for the early disease identification or predisposition at cellular and molecular level. In in-vitro diagnostics, nanomedicine could increase the efficiency and reliability of the diagnostics using human fluids or tissues sample by using selective nanodevices, to make multiple analyses at sub cellular scale, etc. In vivo diagnostics, nanomedicine could develop devices able to work inside the human body in order to identify the early presence of a disease, to identify and quantify toxic molecules, tumor cells [2, 3].
- 2.) **Nanoanaesthesia:** - In the era of Nanodentistry, to induce local anesthesia, dental professional will instill a colloidal suspension containing millions of active analgesic micrometer sized dental nanorobotic particles on the patient's gingivae. After contacting the surface of the crown or mucosa, the ambulating nanorobots reach the dentin by migrating into the gingival sulcus and passing painlessly through the lamina propria or the 1-3 micrometer thick layer of loose tissue at the cemento dental junction.
On reaching the dentin, the nanorobots enter dentinal tubule holes that are 1-4 micrometers in diameter and proceed toward the pulp, guided by a combination of chemical gradients, temperature differentials and even positional navigation, all under the control of the onboard nanocomputer, as directed by the dentist[2].

- 3.) **Natural tooth maintenance:** - The appearance and durability of tooth may be improved by replacing upper enamel layers with covalently bonded artificial materials such as sapphire or diamond, which have 20 to 100 times the hardness and strength of natural enamel.
- 4.) **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 every time.
- 5.) **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.
- 6.) **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 + TCP
 - NanOSS[™] (Angstrom Medica, USA) HA
- 7.) **Nanoencapsulation:** - Nanomaterials, including hollow spheres, core-shell structure, nanotubes and nanocomposite, have been widely explored for controlled drug release. Pinon-Segundo et al [4] studied Triclosan-loaded nanoparticles, 500 nm in size, used in an attempt to obtain a novel drug delivery system adequate for the treatment of periodontal disease. These particles were found to significantly reduce inflammation at the experimental sites. An example of the development of this technology is arestin in which minocycline is incorporated into microspheres for drug delivery by local means to a periodontal pocket [5].
- 8.) **Oral Hygiene and Halitosis:** Properly configured dentifrobots could identify and destroy pathogenic bacteria residing in the plaque and elsewhere, while allowing the 500 or so species of harmless oral micro flora to flourish in a healthy ecosystem. Dentifrobots also would provide a continuous barrier to halitosis, since bacterial putrefaction is the central metabolic process involved in oral malodor.
- 9.) **Diagnosis of oral cancer and other diseases:-**

- a) **Nano Electromechanical 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 [6].
 - b) **Oral Fluid NanoSensor Test (OFNASET):-**The Oral Fluid NanoSensor Test (OFNASET) 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 [7]
 - c) **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 [8].
- 10.) Treatment of oral cancer [9):-**
- a.) **Nanomaterials For Brach therapy:-** BrachySil™ (Sivida, Australia) delivers 32P, clinical trial
 - b.) **Photodynamic Therapy:** - Hydrophobic porphyrins are potentially interesting molecules for the photodynamic therapy (PDT) of solid cancers or ocular vascularization diseases [10].
- 11.) Nanorobotic dentifrice [Dentifrobots):-** 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. These invisibly small dentifrobots [1-10 micron], crawling at 1-10 microns/sec, would be inexpensive, purely mechanical devices, that would safely deactivate themselves if swallowed and would be programmed with strict occlusal avoidance protocol [11].

- 12.) **Targeted cellular destruction:** - Quantum dots can be used as photo sensitizers and carriers. They can bind to the antibody present on the surface of the target cell and when stimulated by UV light, they can give rise to reactive oxygen species and thus will be lethal to the target cell.
- 13.) **Nanoneedles:** - Suture needles incorporating nano-sized stainless steel crystals have been developed. Nanotweezers are also under development which will make cell-surgery possible in the near future.
- 14.) **Tooth repair :-**Nanorobotic manufacture and installation of a biologically autologous whole replacement tooth that includes both mineral and cellular components, that is, 'complete dentition replacement therapy' should become feasible within the time and economic constraints of a typical office visit through the use of an affordable desktop manufacturing facility, which would fabricate the new tooth in the dentist's office. Chen et al took advantage of these latest developments in the area of nanotechnology to simulate the natural biomineralization process to create the hardest tissue in the human body, dental enamel, by using highly organized micro architectural units of nanorod-like calcium Hydroxyapatite crystals arranged roughly parallel to each other.
- 15.) **Dentin hypersensitivity:** - Natural hypersensitive teeth have eight times higher surface density of dentinal tubules and diameter with twice as large as nonsensitive teeth. Reconstructive dental nanorobots, using native biological materials, could selectively and precisely occlude specific tubules within minutes, offering patients a quick and permanent cure.
- 16.) **Tooth renaturalization:-**Dentition renaturalization procedures may become a popular addition to the typical dental practice, providing perfect treatment methods for esthetic dentistry. This trend may begin with patients who desire to have their old dental amalgams excavated and their teeth remanufactured with native biological materials so that the affected teeth are remanufactured to become indistinguishable from the original teeth.
- 17.) **Dental durability and cosmetics:** - **Durability** and appearance of tooth may be improved by replacing upper enamel layers with covalently bonded artificial materials such as sapphire or diamond [12], which has 20-100 times the hardness and failure strength of natural enamel or contemporary ceramic veneers and good biocompatibility. Pure sapphire and diamond are brittle and prone to

fracture, can be made more fracture resistant as part of a nanostructure composite material that possibly includes embedded carbon nanotubes.

Potential benefits of nanotechnology are its ability to exploit the atomic or molecular properties of materials and the development of newer materials with better properties. Nanoproducts can be made by: building-up particles by combining atomic elements and using equipments to create mechanical nanoscale objects.

Nanotechnology has improved the properties of various kinds of fibers. ^[21] Polymer nanofibers with diameters in the nanometer range, possess a larger surface area per unit mass and permit an easier addition of surface functionalities compared to polymer microfibers [13, 14], Polymer nanofibers materials have been studied as drug delivery systems, scaffolds for tissue engineering and filters. Carbon fibers with nanometer dimensions showed a selective increase in osteoblast adhesion necessary for successful orthopedic/dental implant applications due to a high degree of nanometer surface roughness [15].

Nonagglomerated discrete nanoparticles are homogeneously manufactured in resins or coatings to produce nanocomposite. The Nanofillers used include an aluminosilicate powder having a mean particles size of about 80 nm and 1:4 M ratio of alumina to silica. Advantages - superior hardness, flexible strength, modulus of elasticity, translucency and esthetic appeal, excellent color density, high polish, and polish retention, and excellent handling properties[16] (Filtek O supreme Univrasl Restorative Pure Nano O). Heliometer, micro filled composite resin, a close examination of this composite suggests that a form of nanotechnology was in use years ago, yet never recognized. Nanosolutions produce unique and dispersible nanoparticles that can be added to various solvents, paints, and polymers in which they are dispersed homogeneously. Nanotechnology in bonding agents ensures homogeneity and so the operator can now be totally confident that the adhesive is perfectly mixed every time. Nanofillers are integrated in the vinylsiloxanes, producing a unique addition siloxane impression material. Better flow, improved hydrophilic properties, hence fewer voids at margin and better model pouring, enhanced detail precision [17].

DISCUSSION

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 on a microscopic level by enabling us to battle decay where it begins with bacteria. Construction of a comprehensive research facility is crucial to meet the rigorous requirements for the development of nanotechnologies.

Researchers are looking at ways to use microscopic entities to perform tasks that are now done by hand or with equipment. This concept is known as nanotechnology. Tiny machines, known as nanoassemblers, could be controlled by computer to perform specialized jobs.

The nanoassemblers could be smaller than a cell nucleus so that they could fit into places that are hard to reach by hand or with other technology. Used to destroy bacteria in the mouth that cause dental caries or even repair spots on the teeth where decay has set in, by use of computer to direct these tiny workers in their tasks.

Role of periodontitis will continue to evolve along the lines of currently visible trends. For example, simple self-care neglect will become fewer, while cases involving cosmetic procedures, acute trauma, or rare disease conditions will become relatively more commonplace.

Trends in oral health and disease also may change the focus on specific diagnostic and treatment modalities. Increasingly preventive approaches will reduce the need for cure prevention a viable approach for the most of them.

Diagnosis and treatment will be customized to match the preferences and genetics of each patient. Treatment options will become more numerous and exciting. All this will demand, even more so than today, the best technical abilities, professional skills that is the hallmark of the contemporary dentist and periodontist. Developments are expected to accelerate significantly.

Nanometers and nanotubes, technologies could be used to administer drugs more precisely. Technology should be able to target specific cells in a patient suffering from cancer or other life-threatening conditions.

CHALLENGES FACED BY NANODENTISTRY

- 1.) Design cost very high.
- 2.) Electrical systems can create stray fields which may activate bioelectric-based molecular recognition systems in biology.
- 3.) Hard to Interface, Customize and Design, Complex
- 4.) Social challenges of ethics, public acceptance, regulation and human safety.
- 5.) Precise positioning and assembly of molecular scale part
- 6.) Biocompatibility

- 7.) Nanorobots can cause a brutal risk in the field of terrorism. The terrorism and anti groups 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.

PROBLEMS FOR RESEARCH IN NANOTECHNOLOGY IN INDIA

- 1.) Painfully slow strategic decisions
- 2.) Sub-optimal funding
- 3.) Lack of engagement of private enterprises
- 4.) Problem of retention of trained manpower

CONCLUSION

The visions described above may sound unlikely , implausible , or even heretic. Yet , the theoretical and applied research to turn them into reality is progressing rapidly. Nanorobotics will change dentistry, health care & human life more profoundly than other developments[18].

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