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Review article

Nanotechnology in Dentistry - A Review.

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ABSTRACT

Dentistry has seen many era of revolution in past, making it more reliable and comfortable for the patients. It is undergoing yet another change in helping mankind, this time with the help of nanotechnology combined with Nonomaterial's, Biotechnology and Nanorobotics. Nanodentistry will make possible the maintenance of comprehensive oral health by employing nanotissue devices which will allow precisely controlled oral analgesia, dentine replacement therapy, permanent hypersensitivity cure, complete orthodontic realignment etc, all in single office visit.

1. Introduction

Nanotechnology era is fast approaching which was unheard two decades ago. All disciplines of human life will be impacted by advances in nanotechnology in the near future. The growing interest in this field is giving emergence to new field called Nanomedicine, a science & technology of diagnosing, treating & preventing diseases, and preserving & improving human health, using nanoscale structured materials. Once one considers other potential applications of nanotechnology to medicine, it is not difficult to imagine what nanodentistry would look like. This article provides an early glimpse of nanodentistry applications to explain their potentially far-reaching impacts on clinical dental practice.

2. Thinking Early by a Physicist

Physicist Richard P Feynman [1] in 1960, had the first notion of how nanotechnology could be applied to medicine. In his historic lecture in 1959, he concluded saying, "this is a development which I think cannot be avoided."

3. Nanotechhology- The Real Meaning

'Nano' is derived from nan(n)os, the Greek word for 'dwarf, little old man'. A nanometer is 10-9 or one billionth of a meter. Nanotechnology is about manipulating matter, atom by atom. Just as robots assemble cars from a set of predefined parts, nano-robots will assemble things from atomic & molecular building blocks.

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4. Various Nanotechnology Products

(a) Nanocream- Nano Aluminium Oxide Fibres

Nano-structural aluminium oxide fibers provide added strength and improved performance to metals, plastics, polymers and composite materials. The large number of hydroxyl groups available on the nanofibers generates a positive charge in water solution such that it will attract and retain negatively charged particles including bacteria, virus, organic & non-organic colloids and negatively charged macromolecules.

(b) Nano Filtration

Use in purification of water for medical and dental purposes. Filter sterilization of medical serum, biological fluids & other pharmaceutical products. Sintering aid of the ceramics Fiber-reinforced plastics

© Nanoporous Silica-Filled Composite [2]

Nanoporous silica filled composite is a fairly new material still in experimental form, proven to increase wear resistance in posterior applications. Nano sized porous silica fillers allow the monomer to inter- penetrate it, through a capillary force; the monomer is drawn in and out of the filler, reinforcing the composite and increasing the durability of the bowing between the two phases. By impregnating organic monomer into the pores & adding a light cure system a solid organic/inorganic nanostructure is formed.

(d)Nanoadhesive – Poss [3]

Polyhedral Oligomeric Silse Squiox (Poss) enables the design of additives that make plastics that are unusuallylightweight, durable, heat-tolerant and environment friendly. Poss combines organic & inorganic materials in molecules with an average diameter of 1.5 nanometers. They can be used as either additives or replacements for traditional plastics. Current applications of Poss include dental adhesives in which a strength resin provides a strong interface between the teeth and the restorative material. In addition, tests have shown that Poss materials are much more resistant to radiation damage and erosion than conventional polymers.

5. Apllications of Nanorobotics to Dentistry [4], [10]

It is Freitas [5] who described how medical nanorobots might use specific motility mechanisms to crawl or swim through human tissues with navigational recession; cytopentration (for example, pass-through plasma membranes such as the odontoblastic process without disrupting the cell, while maintaining clinical biocompatibility) and use any of a multitude of techniques to monitor, interrupt or alter nerve impulse traffic in individual nerve cells.

These nanorobotics functions may be controlled by an on-board nanocomputer that executes pre-programmed instructions in response to total local robots via acoustic signals (as are used in ultrasonography) of other means similar to an Admiral commanding a fleet.

6.Nano In Oral Anesthesia Induction

To induce oral anesthesia in the era of nanodentistry, dental professional will instill a colloidal suspension containing millions of active analgesic micrometer sized dental nanorobots 'particles' on the patient's gingivae. After contacting the surface of the crown of mucosa, the ambulating nanorobots reach the dentin by migrating into the gingival sulcus and passing painlessly through the lamina propria or 1-3 micrometer thick layer of loose tissue at the cemento-dentinal junction.

On reaching the dentin, the nanorobots enter dentinal tubule holes that are 1 to 2 micrometer in diameter and proceed towards the pulp, guided by a combination of chemical gradients, temperature differentials and even positional navigation; all under the control of the on-board nanocomputer as directed by the dentist.

There are many pathways to choose from. Tubule diameter increases near the pulp, which may facilitate nanorobots' movement; although cirumpulpal tubule openings vary in number and size.

Tubule branching patterns may present a significant challenge to navigation because they exhibit an intricate and profuse canalicular anastomosing system that crisscrosses the intertubular dentin with dentinal branching density most abundant in locations where tubule density is low.

Assuming a total path length of about 10 mm from the tooth surface to the pulp and a modest travel speed of 100 micrometers per second, nanorobots can complete the journey into the pulp chamber in approximately 100 seconds.

The presence of natural cells that are constantly in motion around and inside the teeth - including human gingival and pulpal fibroblasts, cementoblasts at CDJ, bacteria inside dentinal tubules, odontoblasts near the pulpal or dentinal border and lymphocytes within the pulp or lamina propria [6] suggests that such journeys should be feasible by cell sized nanorobots of similar mobility.

Once installed in the pulp and having established control over nerve impulse traffic, the analgesic dental nanorobots may be commanded by the dentist to shut down all sensitivity in any tooth that requires treatment.

Nanorobotic analgesics offer greater patient comfort, reduced anxiety, no-needle, greater selectivity and control ability of the analgesic effect, fast and completely reversible action and avoidance of most of side effects and complications.

7.Nano in Tooth Repair

Nanodental techniques for major tooth repair may evolve through several stages of technological development, first using genetic engineering, tissue engineering and regeneration, and later involving the growth of whole new teeth in-vitro and their installation. [7]

Ultimately, the nanorobots manufacture and installation of a biologically autologous whole replacement that includes both mineral and cellular components, that is, complete dentition replacement therapy should become feasible within the time and economic constrains 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.

8.Nano In Dentition Renaturalization Procedures

Dentition renaturalization procedure may become a popular addition to the typical dental practice providing perfect treatment methods for aesthetic dentistry. Demand will grow for full coronal renaturalization procedures, in which all fillings, crowns and other 20th century modifications to the visible are removed with the affected teeth remanufactured to be come indistinguishable from the neighbouring original teeth.

9.Nano In Dental Hypersensitivity

Dental hypersensitivity is another pathological phenomenon that may be amenable to nano-dental treatment . Changing pressure transmitted hydrodynamically to the pulp may cause dental hypersensitivity. Many therapeutic agents provide temporary relief for this common painful condition, but reconstructive dental nanorobots using native biological material could selectively and precisely occlude specific tubules within minutes offering patients a quick and permanent cure.

10.Nano In Tooth Repositioning

Orthodontic nanorobots could directly manipulate the periodontal tissues including gingivae, periodontal ligament, centum and alveolar bone allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours. This is in contrast to current molar up righting techniques, which require weeks or even months to complete. [8]

11.Durability and Appearance

Tooth durability and appearance 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 failure strength of natural enamel, or contemporary ceramic veneers as well as good biocompatibility. Pure sapphire and diamond are brittle and prone to fracture resistant as part of a nanostructure composite material that possibly includes embedded carbon nanotubes.

However, a sub-occlusion dwelling nanorobotic dentifrice delivered by a mouthwash or toothpaste could patrol all supragingival and gingival surfaces, at least once a day, metabolizing trapped organic matter into harmless and odorless vapors and performing continuous calculus debridement.

These almost invisible (1 to 10 micrometer) dentifrobots, perhaps numbering 1000 to 100000 per mouth and crawling at 1 to 10 micrometer per second might have the mobility of tooth but would be inexpensive purely mechanical devices that safely deactivate themselves, if swallowed. Moreover, they would be programmed with strict protocol to avoid occlusal surfaces. 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. Dentif-robots also would provide a continuous barrier to halitosis since bacterial putrefaction is the central metabolic process involved in oral malodor.[9] With this kind of daily dental care available from an early age, conventional tooth decay and gingival disease will disappear.

12.Nano in Diagnosis of Oral Cancer and Other Diseases

12.1.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. [11]

12.2. 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. [12]

12.3.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. [13]

13. Nano in Treatment of Oral Cancer [14]

13.1.Nanomaterials For Brachytherapy:

BrachySilTM (Sivida, Australia) delivers 32P, clinical trial.

13.2.Drug Delivery Across The Blood-Brain Barrier:

More effective treatment of brain tumours, Alzheimer's, Parkinson's in development.

13.3.Nanovectors For Gene Therapy

Non-viral gene delivery systems.

13.4.Photodynamic Therapy

Hydrophobic porphyrins are potentially interesting molecules for the photodynamic therapy (PDT) of solid cancers or ocular vascularization diseases.

14. Nano Inorthodontic Treatment

Orthodontic nanorobots could directly manipulate the periodontal tissues, allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours. [14]

15. The Path to Nanodentistry

Nano technological advances should be viewed in the context of other expected developments relevant to oral health in the coming decades. Biological approaches such as tissue and genetic engineering will yield new diagnostic and therapeutic approaches much sooner than nanotechnology. At the same time continual refinement of traditional methods, developments of advanced restorative materials and new medications and pharmacological approaches will continue to improve dental care.

Trends in oral health and disease also may change the focus on specific diagnosis and treatment modalities. Deeper understanding of the causes and pathogenesis of other disease processes such as periodontal disease, developmental craniofacial defects, and malignant neoplasm should make prevention a viable approach. The role of the dentist will continue to evolve along the lines of currently visible trends. The best technical abilities, professional judgment and strong interpersonal skills are the hallmark of the contemporary dentist.

16. Conclusion

Nanodentistry still faces many significant challenges in realizing its tremendous potential. Basic engineering problem from precise positioning and assembly of molecular-scale parts to economical mass production techniques to biocompatibility and the simultaneous coordination of the activities of large number of independent micrometer-scale robots. In addition, there are larger social issues of public acceptance, ethics, regulation and human safety that must be addressed before molecular nano-technology can enter the modern medical armamentarium. However, there is equally powerful motivation to surmount these various challenges such as the possibility of providing high quality dental care to 80% of the world's population that currently receives no significant dental care. Time, specific advances, financial and scientific resources and human needs will determine which of the applications to be realized first.

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