

NANODENTISTRY INNOVATION FOR TODAY AND TOMORROW WORLD



Medical Science

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ABSTRACT

Nanodentistry is an upcoming field with significant capacity to yield new generation of technologically advanced clinical tools and devices for oral healthcare. Feynman's early visualization in 1959 gave birth to the idea of nanotechnology. He found it as an inevitable development in the advancement of science and said that there is plenty of room at the bottom. An outlook on future about "nanodentistry" developments such as detifrobots, prosthetic dental implants and personalized dental healthcare is presented. The field of nanotechnology has tremendous potential, which if harnessed efficiently, can bring out significant change and provide benefits to the human society. The most substantial contribution of nanotechnology to dentistry till date is in Implant and restorative (composite) dentistry. The future holds in store an era of dentistry in which every procedure will be performed using equipments and devices based on nanotechnology. This article reviews the current status and the possible clinical applications of nanotechnology in dentistry for today and tomorrow world.

Introduction

Nano is derived from greek word 'dwarf', the little old man. Nanotechnology is the science of manipulating matter measured in the billionths of meters or nanometer, roughly the size of 2 or 3 atoms or one billion of a meter.¹

The term nanotechnology was first introduced by Richard Feynman in 1959 to the scientific approach of creating functional materials, devices and systems through control of atoms in a dinner talk, inadvertently introduced the concept with his great words, "There is plenty of room at the bottom".^{2,3,4,5} In his historic lecture, he concluded saying, "this is a development which I think cannot be avoided".³

Nanotechnology and the discipline of nanomaterials have a capability to provide benefits in numerous areas such as synthesis of new materials with advanced properties, early disease identification at cellular and molecular level, production technology, electronics, ecology and energy conservation, nanobiosystems, medical appliances, transportation, economy, etc.^{5,6}

The purpose of this article is to review current practicality and achievements of nanotechnology in dentistry and to provide an insight into what the future holds, highlighting the ethical and safety concerns associated with the use of nanotechnology.

Current research is directed towards the making of wide array of different nanoscale structures. The techniques of fabrication of the structures can be divided into 2 approaches: "top-down" and "bottom-up".¹

Bottom up:

Nano anesthesia, hypersensitivity care, Dental durability and cosmetics, Detifrobots, Tooth repositioning/Orthodontic nano robots, Local drug delivery, cancer diagnosis, therapeutic nanotechnology, Major tooth repair

Top down:

Nanotechnology for composite, nanotechnology for GIC, Improving Endodontics, Nano Composite Denture Teeth, Nano-solution, Nanocapsulation, Plasma Layer Application, Prosthetic Implant, Nano Impression Materials, Nano Titanium Implants, Nano Needles, Biodegradable Nanofibers, Wound Dressing, Bone Replacing Materials and Nano Tissue Engineering

VARIOUS APPLICATIONS OF NANOTECHNOLOGY IN DENTISTRY

Bottom up approach:

Nano In Oral Anesthesia Induction

In the era of nanodentistry to induce oral anesthesia, dental

professional will introduce a colloidal suspension containing millions of active analgesic micro sized dental nanorobots 'particles' on the patient's gingival.⁵ 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-dental junction.³

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

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.^{7,8}

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 guided by chemical gradients, temperature differentials, all under the control of nanocomputer.^{7,9}

Detifrobots

Nanorobotic dentifrice (dentifrobots) delivered by mouthwash or toothpaste patrol all supragingival and subgingival surfaces at least once a day metabolizing trapped organic matter into harmless and odorless vapors, performing continuous calculus debridement and identifying and destroying pathogenic bacteria residing in the plaque and elsewhere, while allowing the 500 species of harmless oral microflora to flourish in a healthy ecosystem.⁹

Dental durability and cosmetics

Tooth durability and appearance may be improved by replacing upper enamel layers with covalently bonded artificial materials such as pure sapphire and diamond which can be made more fracture resistant as nanostructured composites, possibly including embedded carbon nanotubes.⁴ Nanorobotic dentifrice (dentifrobots) 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.⁷

Tooth repositioning/ Orthodontic nano robots

Orthodontic nanorobots could directly manipulate the peri-

odontal tissues including gingiva, periodontal ligament, cementum and alveolar bone, allowing rapid painless tooth straightening, rotating, and vertical repositioning in minutes to hours, in contrast to current molar uprighting techniques which require weeks or months for completion.^{4,7,8}

Diagnosis of oral cancer and other diseases

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.

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 and four salivary mRNA biomarkers (SAT, ODZ, IL-8, and IL-1b) can detect oral cancer with high specificity and sensitivity.

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.

Treatment of oral cancer

Nanomaterials For Brachytherapy

BrachySil™ (Sivida, Australia) delivers 32P, clinical trial.

Drug Delivery Across The Blood- Brain Barrier

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

Nanovectors For Gene Therapy

Non-viral gene delivery systems

Photodynamic Therapy

Hydrophobic porphyrins are potentially interesting molecules for the photodynamic therapy (PDT) of solid cancers or ocular vascularization diseases.^{10,11}

Top down approach:

Nanotechnology for composite

Nanoproducts Corporation has successfully manufactured non agglomerated discrete nanoparticles that are homogeneously distributed in resins or coatings to produce nanocomposites. The nanofiller used include an aluminosilicate powder having a mean particle size of 80 nm and a 1:4 M ratio of alumina to silica and a refractive index of 1.508.¹⁰

Nanotechnology for GIC

Nano Ionomer is a glass ionomer cement whose formulation is based on bonded nanofiller technology. Mechanical properties of nano-ionomer are improved by the combination of fluoroaluminosilicate glass, nanofillers, and nanofiller clusters. The nanofiller components also

improve some physical properties of the hardened restorative. It also shows high fluoride release that is rechargeable after being exposed to a topical fluoride source. Additionally, in vitro tests showed that the nanoionomer (Ketac N100) has the ability to create a caries inhibition zone after acid exposure.⁴

Plasma Layer Application for periodontia

When TiO₂ particle sizes are reduced to nanoscale (20-50nm), and present on human skin in the form of a gel-like emulsion, it has some interesting properties such that when irradiated with

laser pulses, these particles can be optically broken down with accompanying effects.

- Shock wave
- Micro-abrasion hard tissue
- Stimulation of collagen production

Clinical applications:

- Periodontal treatments
- Melanin removal
- Incision of soft tissue without anesthesia
- Caries preparation
- Cutting of enamel & dentin³

NanoTitanium Implant

NanoTitanium is a new form of titanium metal that has been introduced. Patients should experience shorter post surgery healing times and a more reliable integration of these new implants into their body. It is highly compatible with bone and is thought to provide stronger, up to 20 times faster bonding with improved strength, biocompatibility, long life and improved wear and tear.⁴

RECENT ADVANCES IN IMPLANT DENTISTRY

Dental implant therapy has been one of the most significant advances in dentistry in the past three decades. The success and longevity of dental implants are strongly governed by surface characteristics.

Three factors have become key areas for improved implant device topography. Nanoscale surfaces structuring, which would optimize cell colonization; surface chemistry, which attempts to control and optimize the chemical surface properties of an implant material; and wettability, due to the observation that cell adhesion and subsequent activity are generally better on hydrophilic surfaces. Structuring chemistry modification would require nanoscale processes while engineered nanomaterial would play a role in increasing wettability.⁶

Prosthetic Implant

Nanostructured surfaces may control the differentiation pathways into specific lineages and ultimately direct the nature of peri-implant tissues. Furthermore, it is possible to incorporate biologically active drugs such as antibiotics or growth factors during the precipitation of CaP coatings on Ti implants. Compared with titanium alloy covered in micron-sized bumps, about 60% more new cells are grown on the same alloy containing nanometer-scale features, eg: Nanotite™ Nano-Coated Implant.³

Nano 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.¹ The presence of the nanostructure increases the fluidity of the material, especially when pressure is applied.⁴

Nano Titanium Implants

Dental implantology has a long, well documented history reaching back over thousands of years from ancient times and initial modern reports in the early 19th century to the accidental discovery of osseointegration by Branemark in 1952.⁶

Bioactive approaches such as osseointegration involve the direct physiochemical bond formation and most commonly involve the use of titanium implants. Extensive research on the effects and subsequent optimization of microtopography and surface chemistry has produced ground-breaking strides in materials engineering such as the widely used Osseotite dental implant, Straumann with SLActive, Astra Tech with its OsseoSpeed.^{5,6,12}

Nano Needles

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.¹ Suture needles with nano sized stainless steel crystals have been developed. Nano tweezers are also under development which will make cell surgery possible in the near future. This means that properties such as elastic modulus, mechanical properties and thermal expansion are comparable to ferritic steels (such as low alloyed carbon steels or chromium steels) while properties such as corrosion resistance is more comparable to austenitic stainless steels.^{4,13,14}

Wound Dressing, Bone Replacing Materials

Products Manufactured by South West Research Institute: Medical appendages for instantaneous healing

- Biodegradable nanofibres—delivery platform for haemostatic
- Wound dressings with silk nanofibres in development
- Nanocrystalline silver particles with antimicrobial properties on wound dressings [Acticoat™, UK] Bone Replacement Materials will assist in the repair and regenerations of cellular tissue in the bone. Hydroxyapatite nanoparticles used to treat bone defects are
- Ostim_ (Osartis GmbH, Germany) HA
- VITOSSO (Orthovita, Inc, USA) HA ?TCP
- NanOSSTM (Angstrom Medica, USA) HA¹²

BARRIERS TO NANOTECHNOLOGY

- Feasibility of mass production technique
- Precise positioning and assembly of molecular scale parts
- Manipulating and coordinating activities of various micro-scale robots
- Development of biofriendly nanomaterial
- Biocompatibility with all intricate of the human body
- Ethical issues
- Public acceptance needed
- Regulation and human safety⁶

Conclusion

Nanotechnology is such a new and exciting area of science, so there are many ways in which it can progress. It is an emerging field with a significant potential to yield new generation of technologically advanced clinical tools and devices for oral health-care. Nano-enabled technologies thus provides an alternative and superior approach to assess the onset or progression of

diseases, to identify targets for treatment interventions as well as the ability to design more biocompatible, microbe resistant dental materials, and implants. Major advances are also expected in the field of preventive dentistry and imitating processes that occur in nature (biomimetic).

For all these things to happen, nanodentistry needs to overcome the various barriers or challenges for its application and yield more effective therapies and preventive properties. As every coin has two sides, same implies for nanotechnology, as well. Nanotechnology also carries a significant potential for misuse and abuse on a scale and scope never seen before.

Time, specific advances, financial and scientific resources and human needs will determine which of the applications to be realized first.

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