



NANOTECHNOLOGY IN DENTISTRY

Dental Science

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KEYWORDS

Nanotechnology' refers to the projected ability to construct items from the bottom up, using techniques and tools which are being developed to make high performance products. This theoretical capability was envisioned as early as 1959 by physicist Richard Feynman.^[2] The word nanotechnology was coined by Norio Taniguchi, and introduced by Prof. K. Eric Drexler.^[3]

Nanomedicine and nanodentistry

The unique quantum phenomena that happen at the nanoscale, draw researchers from many different disciplines to the field, including medicine, chemistry, physics, engineering, and others.^[4] Nanotechnology when incorporated into biology is referred as "nanobiotechnology" or "nanomedicine. Nanomedicine is defined as the science and technology of diagnosing, treating and preventing disease, relieving pain and stabilizing, and improving human health, using nanoscale structured materials. Because of the growing importance of applications of nanotechnology in dentistry, a new field called nanodentistry is evolving.^[5] The term "nanodentistry" was first popularized in 2000 by research scientist Robert Freitas.^[3] The scientists in the field of regenerative medicine and tissue engineering are continually looking for new ways to apply the principles of cell transplantation, material science, and bioengineering to construct biological substitutes that will restore and maintain normal function in diseased and injured tissue.^[4]

Generations of nanotechnology:

- **First generation:** Passive (steady function Nanostructures)
Eg: Nanostructured coating invasive; noninvasive diagnostic for rapid patient monitoring.
- **Second generation:** Active (evolving function nanostructures)
Eg: Reactive nanostructured materials and sensors, targeted cancer therapies.
- **Third generation:** Integrated nanosystems
Eg: Artificial organs built from nanoscales; evolutionary Biosystems.
- **Fourth generation:** Heterogeneous nanosystems
Eg: Nanoscale genetic therapies; molecules intended to self-assemble themselves.^[4]

Applications of nanotechnology in field of medicine and dentistry: NANOMEDICINE**Nanodiagnostics**

Nanodiagnostic devices are used for early disease identification at the cellular and molecular levels by using selective nanodevices in collecting human fluids and tissue samples and by making multiple analyses at the subcellular level and may be introduced into the body to identify the early existence of a disease.^[6]

Stem cell labels and tracers

Nanotechnology provides a variety of direct stem cell labeling options, as well as facilitates the use of other important techniques such as reporter genes.^[5]

Nanorobotic microbivores

Microbivores are the artificial phagocytes that patrol the bloodstream

and digest the unwanted pathogens including bacteria, viruses or fungi. The microbivores would achieve complete clearance of even the most severe septicemic infections in hours or less because the pathogens are completely digested into harmless sugars and amino acids.^[7,8]

Surgical nanorobotics

It is coordinated by an onboard computer along with the supervising surgeon by means of coded ultrasound signals. E.g., Femtolaser, which act like a pair of nanoscissors, vaporizes tissue locally and leave the adjacent tissue unharmed.^[7,9]

Nanogenerators

They are self-powered implantable medical devices, sensors, and portable electronics, which convert mechanical energy from human body movement, muscle stretching, or fluid flow into electricity.^[1]

Regenerative medicine

Nanotechnology makes it possible to interact with cell components, to influence the cell proliferation and differentiation, and to control the production and organization of the extracellular matrices. Structured nanoparticles like dendrimers and nanoshells are used to target specific tissues and organs.^[5]

NANODENTISTRY

Nanodentistry is an off shoot of nanomedicine. Application of nanomedicine to dentistry has led to the emergence of a branch of science called nanodentistry. Emergence of nanodentistry will aid in the maintenance of perfect oral health care through the use of nanomaterials, biotechnology and nanorobotics.^[7]

Oral fluid nanosensor test (OFNASET)

The OFNASET is a portable, automated, user-friendly, integrated system that will detect the salivary proteins and nucleic acid targets in the saliva.^[10]

Nanoneedles and nanoanaesthesia

The new of revolutionary nanodentistry will have a colloidal suspension consisting of nanorobots measuring micron size with active analgesic properties. When these moving nanorobots are injected into patient's gingiva, they reach the pulp through gingival sulcus and dentinal tubules. These are controlled by the dentist to block all the sensation in that particular tooth. Once the procedures are completed, the dentist orders to restore all the sensation and to exit from the nerve pathways.

Nanoneedles are used to execute the surgery on a single living cell and are nano-meter wide in dimension. Trade name: Sandvik Bioline, RK 91™ needles.^[11]

As nanocomposites

Nanoparticles improve the compressive strength of the material used. Filler particles of submicron size, like zirconium dioxide, are also essential to improve composites polishing ability as well as esthetics. However, when particles of this size are used, the material may be

more prone to brittleness, cracking and fracturing after curing. To overcome it, hybrid composites and composites containing a wider distribution of filler particles are used. Although these composites exhibit a better strength and esthetics, they are weak due to nanoparticle clumping or agglomeration. This problem can be overcome by incorporating a proprietary coating particle during their manufacturing procedure, thereby eliminating weak spots and providing consistent strength throughout the entire "fill" of the core build-up. In addition, the even dispersal of the nanoparticles results in a smoother, creamier consistency, and improves its flow characteristics. Once the material is cured to its hardened state, the properties contribute to the dentin like polishability.^[11,12]

Nano glass ionomer cement (GIC)

By using bonded nanofillers and nanocluster fillers, along with FAS glass newer type of GIC was formulated using nanotechnology along with its fluoride releasing property. Advantages of this material are: superb polish, excellent esthetics, higher wear resistance, It is faster, easier to mix and dispense.^[13]

Nano-ceramics

The Organically Modified Ceramic nano-particles comprise a polysiloxane backbone. The good resistance to microcrack propagation might be related to the strengthening effect of the nanoceramic particles. Propagating cracks are either more often reflected or absorbed by the nanoceramic particles.^[14]

Nano bond (Bonding agents) and nanosolutions

The new bonding agents are prepared from nanosolutions which contain homogenous nanoparticles dispersed in the solution. Silica nanofillers are stable and do not cluster in the solution so provide the superior bond strength values.^[15,16,17]

Coating agents

These agents contain light activated nanosized fillers which can be used as coating over the composite, glass ionomer cements, jacket crowns and veneers. Incorporation of nanofillers provide superb polish on the restorations which prevents staining, increases abrasion and wear resistance.^[18]

Impression materials

Impression materials Nanotech Elite H-D from the company Zhermack is available with nanotechnology application. Here, nanofillers are perfectly blended with vinylpolysiloxanes, resulting in a unique addition siloxane impression material having added advantages of: Decreased viscosity, lesser voids in the impression, better handling properties, enhanced detail recording, high tear resistance, resistance to distortion, heat resistance.^[13]

Nano-composite denture teeth

New type of denture tooth, fabricated of nanocomposite resin, has recently, been, developed as a highly polishable, stain and impact resistant material. It consists of uniformly dispersed nano-sized filler particles. It has advantages such as lively surface structure, available in different shades, matching the morphology of natural teeth, multifunctional use for all standard set-up techniques and extraordinary esthetics.^[19]

Tooth repair/nanotissue engineering (biomimicry)

This is achieved through the combined utilization of approaches like nanotechnology, genetic engineering, and tissue engineering. Chan *et al.* re-formed dental enamel, the hardest tissue in the human body, by using particularly organized micro architectural units called nanorods.^[5]

Nano bone fibers

These have a tensile strength 100 times that of steel (polyphosphazene nanofibers). These are assuming great interest in local drug delivery system because of their superior properties. Treatment of dentinal hypersensitivity Nanorobotic dentifrices (dentifrobots) Periodontal drug delivery.^[7]

Laser plasma application for periodontia

When TiO₂ particle sizes are reduced to nanoscale (20-50 nm diameter particles), and present on the 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 like shock wave, microabrasion hard tissue, stimulation of collagen production and has been proven effective in a

number of dental treatments including: Periodontal treatment, melanin pigment removal and incision of soft tissue without anesthesia.^[17]

Dental implants

Nanotechnology applied to implants can enhance the osseointegration, bone growth and ultimately increase the prognosis of the implant. These implants are surfaced with nanoscale deposits of hydroxyapatite and calcium phosphate, which create a suitable medium for osseointegration by activating the osteoblasts. These have proven to accomplish osseointegration by 150% thereby decreasing the length and number of appointments.

Treatment of dentinal hypersensitivity

Changes in pressure transmitted to the pulp hydrodynamically are the main cause of dentinal hypersensitivity. Nanorobots selectively and accurately block these dentinal tubules using native materials, thus offering quick and permanent relief to the patient.^[17]

Nanorobotic dentifrices (dentifrobots)

Nanorobotic dentifrices, either by mouthwash or toothpaste cover all subgingival surfaces and metabolize trapped organic matter into harmless and odorless vapors. These nanorobot dentifrices calledentifrobot scan identify and destroy pathogenic bacteria that exist in the plaque and oral cavity. Invisibly small dentifrobots (1-10 μ), crawling at 1-10 μ/s, have the advantages of being inexpensive and safe as they are purely mechanical devices that would safely deactivate themselves if swallowed.^[5]

Bone regeneration

Bone regeneration requires three essential elements: Osteoconductive matrix (scaffold), osteoconductive signals, osteogenic cells that can respond to these signals, and an adequate blood supply. Nanotechnology delivers new useful tools to engineer the scaffold's internal surfaces and to create devices used in drug delivery with carefully controlled spatial release patterns. Different techniques to successfully seed scaffolds along with cells can be roughly divided into two main groups, i.e. either attaching the cells to the internal scaffold surface or distributing them in the scaffold porosity with the help of a gel-like vehicle. Injectable gels comprising of cells could also be used directly in non-load bearing presentations. It has been detected that the presence of calcium within the matrix favors the osteogenic differentiation of the appropriate progenitor cell.

Bone replacement materials

Bone is said to be a natural nanostructure which is composed of organic compounds mainly of collagen. Nanotechnology targets to imitate this natural structure for development of nanobone, which can be used in dental applications. Various Hydroxyapatite nanoparticles used to treat bone defects are: Ostim® (Osartis GmbH, Germany) HA, Vitosso (Orthovita, Inc., USA), HA + TCP, Nano SSTM. (Angstrom Medica, USA) HA.^[5]

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