10.5005/jp-journals-10052-0026

REVIEW ARTICLE

Nanotechnology in Dentistry

[1]MS Ravisankar, [2]KS Arya, [3]Sunil John, [4]Faisal MA Gaffoor, [5]V Syamkumar, [6]PJ Swathy Anand

ABSTRACT

Nanotechnology is the manipulation of matter at the molecular and atomic levels. Nanotechnology, when integrated into dentistry, gives rise to nanodentistry. Nanodentistry will make possible the maintenance of comprehensive oral health by using nanotissue devices, which will allow controlled oral analgesia, dentin replacement therapy, hypersensitivity cure, orthodontic realignment, etc., in a single visit.

Keywords: Nanodentistry, Nanotechnology, Nan robots.

How to cite this article: Ravisankar MS, Arya KS, John S, Gaffoor FMA, Syamkumar V, Anand PJS. Nanotechnology in Dentistry. Int J Prev Clin Dent Res 2016;3(2):124-127.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Nanotechnology or nanoscience refers to the research and development of an applied science at the atomic, molecular, or macromolecular levels. The prefix nano is defined as a unit of measurement in which the characteristic dimension is one billionth of a unit. The concept of nanotechnology was first elaborated by Richard P. Feynman in 1959. He suggested that nanomachines, nanorobots, and nanodevices ultimately could be used to develop a wide range of atomically precise microscopic instrumentation and manufacturing tools.[1] In 1980, K. Eric Drexler popularized the word nanotechnology. He conceptualized building machines on the scale of molecules, a few nanometers-wide-motors, robot arms, and computers, far smaller than a cell. Nanomaterials are those materials with components less than 100 nm in at least one dimension. These include atoms clusters, grains, fibers, films, nanoholes, and composites from these combinations. Nanomaterials in one dimension are termed as sheets, in two dimensions as nanowires and nanotubes, and as quantum dots in three dimensions.[2]

GENERATIONS OF NANOTECHNOLOGY

First generation: Passive nanostructures
- Dispersed and contact nanostructures – Aerosols, colloids
- Products incorporating nanostructures – Coatings, nanoparticle-reinforced composites, polymers, ceramics, nanostructure metals

Second generation: Active nanostructures
- Bioactive, health effects – Targeted drugs, biodevices
- Physicochemical active – Amplifiers, actuators, adaptive structures, 3D transistors

Third generation: Systems of nanosystems
Guided assembling, 3D networking and new hierarchical architectures, robotics, evolutionary
Fourth generation: Molecular nanosystems
Molecular devices by design, atomic design, emerging functions.

NANOTECHNOLOGY IN DENTAL SCIENCES

Application of nanodentistry can be categorized as
- Nanodentistry as a bottom-up approach
- Nanodentistry as a top-down approach

Nanodentistry as a bottom-up approach
- Inducing anesthesia
- Hypersensitivity cure
- Tooth repair
- Nanorobotic dentifrice (dentifrobots)
- Orthodontic nanorobots

Nanodentistry as a top-down approach
- Salivary diagnostics
- Nanoceramic technology
- Nanotechnology for glass ionomer cement
- Nanoporous silica-filled composite
- Nanoneedles
- Nanobone replacement materials – Ostim® (Osartis GmbH, Germany) HA, VITOSS® (Orthovita Inc., USA) HA+ TCP, nanOss™ (Angstrom Medica, USA) HA.

NANOTECHNOLOGY IN DIAGNOSTIC SCIENCE

Salivary diagnostics is powered by nanotechnologies. Oral fluid is a perfect medium to be explored for health and disease surveillance.

[1,3]Reader, [2,5,6]Senior Lecturer, [4]Professor

[1,4]Department of Conservative Dentistry and Endodontics Noorul Islam College of Dental Science, Thiruvananthapuram Kerala, India

[2,3]Department of Periodontics, Noorul Islam College of Dental Science, Thiruvananthapuram, Kerala, India

[5,6]Department of Public Health Dentistry, Noorul Islam College of Dental Science, Thiruvananthapuram, Kerala, India

Corresponding Author: MS Ravisankar, Reader, Department of Conservative Dentistry and Endodontics, Noorul Islam College of Dental Science, Thiruvananthapuram, Kerala, India, Phone: +919497004568, e-mail: msrendo@gmail.com

Oral Fluid Nano Sensor Test – The envisioned product is called the Oral Fluid NanoSensor Test (OFNASET). The OFNASET is a handheld, automated, easy-to-use integrated system that will enable simultaneous and rapid detection of multiple salivary proteins and nucleic acid targets.[3] This salivary biomarker detector can be used in the office of a dentist or another health care provider for point-of-care disease screening and detection.

NANOCERAMIC TECHNOLOGY

The organically modified ceramic nanoparticles comprise a polysiloxane backbone. Methacrylic groups are attached to the backbone via silicon–carbon bonds. These nanoceramic particles can be best described as inorganic–organic hybrid particles where the inorganic siloxane part provides strength and the organic methacrylic part makes the particles compatible and polymerizable with the resin matrix. The good resistance to micro-crack propagation might be related to the strengthening effect of the nanoceramic particles. Propagating cracks are either more often deflected or absorbed by the nanoceramic particles.

COMPOSITION

Methacrylate-modified polysiloxane, dimethacrylate resin, fluorescence pigment, UV stabilizer, stabilizer, camphorquinone, ethyl-4 (dimethylamino) benzoate, barium-aluminum borosilicate glass, methacrylate functionalized silicon dioxide nanofiller, iron oxide, titanium oxide, and aluminum sulfosilicate pigments.

Indications – Direct restorations of all cavity classes in anterior and posterior teeth.

Contraindications – Known allergy to methacrylate resins or any other of the components.

Commercially available nanoceramic – Ceram X duo.

NANOTECHNOLOGY FOR GLASS IONOMER CEMENT (GIC)

Composites have provided for an esthetic restorative; however, a number of problems are associated with using dental composites, with the primary ones being polymerization shrinkage, intolerance to moisture, and lack of essential bonding to dentin and enamel.[4] Glass ionomers are required to meet physical, chemical, biological, and esthetic requirements, same as other materials used in the mouth. It has adequate strength, abrasion resistance, good color stability, and is dimensionally stable. By using bonded nanofillers and nanocluster fillers, along with fluoroaluminosilcate (FAS) glass, a newer type of GIC was formulated using nanotechnology along with its fluoride-releasing property. The glass ionomers setting mechanism is an ionic reaction that occurs between a basic, acid-reactive FAS glass and a polycarboxylic acid functional polymer in the presence of water. The reaction of the carboxylic acid functional groups with the basic glass results in a chemical reaction that neutralizes the acidic parts and subsequently generates distinct metal carboxylate salts. The GI reaction can be clearly monitored as a function of time by utilizing an infrared (IR) spectroscopic technique. A second signature reaction associated with Resin modified glass ionomer (RMGI) materials is the free radical polymerization of methacrylate functional monomers, oligomers, and polymers. Upon free radical generation via a light cure mechanism, these double bonds are consumed during the polymerization process. Subsequently, the absorbance associated with these double bonds decreases linearly as a function of their decreasing concentration. The consumption of double bonds is extremely rapid under this set of conditions with a majority being converted within 4 minutes of light exposure. Additional free radical polymerization occurs during the next 24 hours; however, it is relatively minimal when contrasted to the significantly slower GI reaction process. Thus, the IR analysis clearly demonstrates that glass ionomer restorative material with nano formula which can be light cured is a true RMGI material that undergoes both GI and free radical reactions similar to other RMGI compositions.

NANO LIGHT CURING GLASS IONOMER RESTORATION

This is composed of a two-part system, aqueous paste (acidic polyalkenoic acid, reactive resins, and nano fillers), nonaqueous paste (FAS glass, reactive resins, and nano fillers), filler content (69%), 27% FAS glass (acid and free radically reactive), 42% methacrylate functionalized nano fillers (acid and free radically reactive) and GIC nano primer. Nano primer is a one-part, visible light-cure liquid specifically designed for use with GIC nano restorative. It is composed of the Vitrebond copolymer, HEMA, water, and photoinitiators. The primer is acidic in nature. Its function is to modify the smear layer and adequately wet the tooth surface to facilitate adhesion of nanorestorative to the hard tissue. In use, nano primer is applied to the surface for 15 seconds, and air dried. The primer is then light cured for 10 seconds. Adequately air drying followed by light curing of the primer before placement of GIC Nano restorative provides adhesion to the tooth structure.[5] Commercially available – Ketac™ N100 Light Curing Nano-Ionomer Restorative.

NANOPOROUS SILICA-FILLED COMPOSITE

Nanoporous silica-filled composite is 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 and adding a light-cure system, a solid organic/inorganic nanostructure is formed.[6]

Nano needles: Suture needles incorporating nano-sized stainless steel crystals have been developed. Trade name: Sandvik Bioline, RK 91TM needles (AB Sandvik, Sweden).[7]

Nanomaterials for periodontal drug delivery: Drugs can be incorporated into nanospheres composed of a biodegradable polymer, thus allowing for timed release of the drug as the nanospheres degrade. Recently, triclosan-loaded nanoparticles were found to be effective in achieving reduction of inflammation.[8] A nanostructured 8.5% doxycycline gel was observed to exhibit favorable results following experimental periodontal disease in rats.[9]

A BIO MIMETIC ROOT CANAL

Decay that destroys the tough enamel covering of the tooth can also progress into the deeper dentin layer and even into the pulp. When pulp becomes infected, traditional treatments involve removal of all infected or damaged tissues, followed by filling the root canal and replacing the dentin and enamel with synthetic materials.[10] Two approaches are being pursued to regenerate the tooth's internal structures. Direct application of TGF-beta family proteins (BMP-2, -7, TGF-beta 1) onto exposed healthy pulp has stimulated dentin formation in animal studies. A potentially more versatile approach has been used *in vitro* to grow pulp-like tissue in a three-dimensional (3D) scaffolding material. A combination of cultured human pulp cells (fibroblasts) grown in a poly glycolic acid (PGA) matrix produced new tissue histologically resembling pulp.

Nanoparticulate-based disinfection in endodontics: The nanoparticles evaluated on endodontics include chitosan, zinc oxide, and silver.[11] The efficacy of chitosan and zinc oxide nanoparticles against *Enterococcus fecalis* have been attributed to their ability to disrupt the cell wall. In addition, these nanoparticles are also able to disintegrate the biofilms within the root canal system.[12] Silver nanoparticles are being evaluated for use as root canal disinfecting agents and has been shown that 0.02% silver nanoparticle gel is able to kill and disrupt *E. faecalis* biofilm.[13]

HYPERSENSITIVITY

Dentin hypersensitivity may be caused by changes in pressure transmitted hydrodynamically to the pulp. There are many therapeutic agents for this common painful condition that provide temporary relief, but reconstructive dental nanorobots could selectively and precisely occlude selected tubules in minutes, using native biological materials, offering patients a quick and permanent cure.[14]

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.[15] 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 microflora to flourish in a healthy ecosystem. It is used as a mouthwash containing full of smart nanomachines to identify and destroy pathogenic bacteria while allowing the harmless flora of the mouth to flourish in a healthy ecosystem.

NANOTECHNOLOGY 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 new teeth *in vitro* and their installation.[16] 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 that would fabricate the new tooth in the dentist's Office.

NANOTECHNOLOGY IN SURGICAL INTERVENTION

Inducing Anesthesia

To induce oral anesthesia in nanodentistry, a colloidal suspension containing millions of active analgesic micron-size dental nano robots will be installed on the patient's gingiva. After contacting the surface of the crown or mucosa, the ambulating nano robots reach the dentin by migrating into the gingival sulcus and passing painlessly through the lamina propria or the 1- to 3-micron thick layer of loose tissue at the cementodentinal junction. Upon reaching the dentin, the nano robots enter the 1- to 4-micron diameter dentinal tubule holes and proceed toward the pulp, guided by a combination of chemical gradients, temperature differentials, and even positional navigation, all under onboard nano computer control. Assuming a total path length of about 10 mm from tooth surface to pulp, and a modest travel speed of 100 microns/seconds nano, robots can complete the journey into the pulp chamber in 100 seconds. 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 particular tooth that may require treatment. When the dentist presses the icon for the desired tooth on the handheld controller display, the selected tooth immediately numbs.[17] After the oral procedures are completed, the dentist orders the nano robots (via the same acoustic data links) to restore all sensation, to relinquish control of nerve traffic, and to egress from the tooth by similar pathways used for ingress, followed by aspiration. Nano robotic analgesics offer greater patient comfort and reduced anxiety, no needles, greater selectivity and controllability of analgesic effect, fast and completely reversible switchable action, and avoidance of most side effects and complications.

CONCLUSION

Nanotechnology will change dentistry, health care, and human life more profoundly than many developments of the past. As with all technologies, nanotechnology carries a significant potential for misuse and abuse on a scale and scope never seen before. Nanodevices cannot be seen, yet carry powerful capabilities. However, they also have the potential to bring about significant benefits, such as improved health, better use of natural resources, and reduced environmental pollution.

REFERENCES

1. Feynman R. There's plenty of room at the bottom. In: Gilbert HD, editor. Miniaturization. New York (NY): Reinhold; 1961. p. 282-296.
2. Nagpal A, Kaur J, Sharma S, Bansal A, Sachdev P. Nanotechnology-the era of molecular dentistry. Indian J Dent Sci 2011;3(5):80-82.
3. Sundaram M. Nanodentistry: A step ahead. JIDAT 2012;4(12): 23-26.
4. Xia Y, Zhang F, Xie H, Gu N. Nano particle reinforced resin based dental composite. J Dent 2008 Jun;36(6):450-455.
5. Chandki R, Kala M, Kumar KN, Brigit B, Banthia P, Banthia R. Nanodentistry: exploring the beauty of miniature. J Clin Exp Dent 2012 Apr;4(2):e119-e124.
6. Gutwein LG, Tepper F, Webster TJ. Increased osteoblast function on nanofibred alumina. The 26th International Conference on Advanced Ceramics and Composites. Cocoa Beach, FL; 2002 Jan. p. 13-18.
7. Kumar SR, Vijayalakshmi R. Nanotechnology in dentistry. Indian J Dent Res 2006;17:62-65.
8. Bhardwaj A, Bhardwaj A, Misuriya A. Nanotechnology in dentistry: Present and future. J Int Oral Health 2014 Feb;6(1):121-126.
9. Botelho MA, Martins JG, Reula RS, Queiroz DB, Reula WS. Nanotechnology in ligature-induced periodontitis: Protective effect of a doxycycline gel with nanoparticles. J Appl Oral Sci 2010 Jul-Aug;18(4):335-342.
10. Rao RN. Advanced Endodontics 2009 Jaypee brothers medical publishers, private limited.
11. Rai MK, Deshmukh SD, Ingle AP, Gade AK. Silver nanoparticles: the powerful nanoweapon against multidrug-resistant bacteria. J Appl Microbiol 2012 May 28;112(5):841-852.
12. Shrestha A, Shi Z, Neoh KG, Kishen A. Nanoparticulates for antibiofilm treatment and effect of aging on its antibacterial activity. J Endod 2010 Jun;36(6):1030-1035.
13. Wu D, Fan W, Kishen A, Gutmann JL, Fan B. Evaluation of the antibacterial efficacy of silver nanoparticles against Enterococcus faecalis biofilm. J Endod 2014 Feb;40(2):285-290.
14. Somerman MJ, Ouyang HJ, Berry JE, Saygin NE, Strayhorn CL, D'Errico JA, Hullinger T, Giannobile WV. Evolution of periodontal regeneration: from the roots' point of view. J Periodontal Res 1999 Oct;34(7):420-424.
15. Frietas RA Jr. Nanodentistry. JADA 2000 Nov;131(11): 1559-1566.
16. Shellart WC, Oesterle LJ. Uprighting molars without extrusion. JADA 1999 Mar;130(3):381-385.
17. Jontell M, Gunraj MN, Bergenholtz G. Immunocompetent cell in the normal dental pulp. J Dent Res 1987 Jun;66(6): 1149-1153.