Review Article

Indian Journal of Dental Education
Volume 7 Number 1, January - March 2014

Nanodentistry: A Beginning of a New Era in Dentistry

Eram Perwez

Abstact

Evolving is an ongoing process that replaces what is existing gradually to something better. With this rapid development in the field of Nanotechnology it won't be wrong if we call it as, Nano Era. Nanotechnology and its application in dentistry have improved the diagnosis, treatment, prognosis and prevention of the dental diseases. It utilizes nanomaterials, nanobiotechnology and nanorobots for the treatment and maintenance of oral health. The purpose of this paper is to review the phenomenon of nonotechnology as it might apply to dentistry as a new field called nanodentistry.

Keywords: Nanodentistry; Nanotechnology; Nanorobots.

Introduction

The ongoing advancements and revolution in the field of dentistry have now emerged with the recent technology called nanotechnology. The term nanotechnology was introduced by Richard Feynman in1959.[1] Nanotechnology also known as molecular engineering, is the production of functional materials and structures in the range of 0.1 to 100 nanometers.[2,3] "Nano" is derived from the Greek word meaning 'dwarf'. One nanometer is one- billionth or 10^{-9} of a meter.[4]

The term nanotechnology when applied to the field of dentistry is called as nanodentistry.[5] Robert A Frietas defines nanodentistry as 'the science and technology that will make possible the maintenance of comprehensive oral health by employing use of nanomaterials, biotechnology including tissue engineering and ultimately dental robotics.'[6,7]

Author's Affilation: *Associate Professor, M.D.S. (Prosthodontics), Faculty of Dentistry, Jamia Millia Islamia, Govt. of India, New Delhi-110025.

Reprints Requests: Dr. Eram Perwez, Associate Professor, M.D.S. (Prosthodontics), Faculty of Dentistry, Jamia Millia Islamia, Govt. of India, New Delhi-110025.

E-mail: erampravez@yahoo.in

This review deals with the application of nanotechnology in various fields of dentistry. New potential treatment opportunities in dentistry includes, administration of local anesthesia, desensitization of teeth, orthodontic alignment of teeth in single visit, drug delivery during periodontal therapies, improvement of tooth durability and its appearance, improved impression materials containing nano fillers, nano structured implants, nano composites and nanoparticles based disinfection of root canals to name a few.[5,8]

History

Late physicist Richard P. Feynman a Nobel Prize winner speculated in 1959, the potential of nanosize devices. In his historic lecture in 1959, he concluded saying, "this is a development which I think cannot be avoided."[9,10] The term "*nanotechnology*" was defined by Tokyo University Science Professor Norio Taniguchi, in a 1974 paper, entitled "On the Basic Concept of 'Nano-Technology', as follows: 'Nanotechnology' mainly consists of the processing of, separation, consolidation, and deformation of materials by one atom or by one molecule." He also discussed his concept of 'nanotechnology' in materials processing, basing this on the microscopic behavior of material. [11] Prof. Kerie E. Dexler a lecturer and researcher of nanotechnology introduced the concept of molecular nanotechnology in his books "Engines of Creation"(1986) and "Unbounding the Future"(1991).[12] The term "Nanodentistry" was first introduced by research scientist Robert Frietas in 2000.[13]

Various Approaches in Nanotechnology

In the production of nanoparticles the approaches that are followed are namely[14]

- ·Top down approach
- Bottom up approach
- Functional approach

Top down approach- means breaking down of a system to smaller sub systems. Mostly nanoscale structures are manufactured by this method. By further miniaturization the nanodimension is entered.[15]

Bottom up approach-method is used for producing nanoscale structures. This approach means piecing together of systems to give rise to more complex systems.[16,17]

Functional approach-it disregards the method of producton of a nanoparticle. The objective of this approach is to produce a nanoparticle with a specific functionality.[5]

Various Nanoparticles are:[9,18]

Nanopores

Nanotubes

Quantum dots

Nanoshells

Dendrimers

Liposomes

Nanorods

Fullerenes

Nanospheres

Nanowires

Nanobelts

Nanorings

Nanocapsules

Applications of Nanotechnology in Dentistry

Inducing Local Anesthesia: A colloidal suspension containing millions of active analgesic microns – dental nanorobots particles' are instilled on the patient's gingiva. After contacting the crown of mucosa, the ambulating nanorobots reach the dentin, by migrating into gingival sulcus and passing painlessly to the lamina propria. On reaching dentine nanorobots enter dentinal tubules and proceed towards pulp. Guided by combination of chemical gradients, temperature differentials, and even positional navigation, all under the control of nanocomputer as directed by the dentist.[7,19-21]

The diameter of the dentinal tubules increases near the pulp. This facilitates the movement of nanorobots. Once they reach the pulp they are given command by the dentist to shut down all the sensations of that particular tooth that requires treatment. After the procedure is completed, the dentist commands the robots to restore all the sensations. This offers better and speedy action with less patient anxiety and adverse effects of local anesthesia. This anesthetic effect is fast and completely reversible. Hence it offers both patient and dentist comfort.

Desensitization of Teeth: The hypersensitive teeth have dentinal tubules with surface densities eight times higher than the non sensitive teeth. Dental nanorobots selectively and precisely occlude selected tubules in minutes, using native biologic material offering quick and permanent cure to the patient. [7,19-22]

Teeth Alignment: Nanorobots directly manipulate the periodontal tissues, allowing rapid and painless tooth straightening, and repositioning within minutes to hours. The orthodontic wires are coated with inactive fullerene- like tungsten disulfide nanoparticles, known for their excellent dry lubrication properties, a reduction in this friction was observed by Redlich.[19-23] Optiflex that is impregnated with the nano composite materials is revolutionary in orthodontics, making the orthodontic realignments possible in a single visit.

Implants: The most common cause of failure of implant is the insufficient formation of bone around the biomaterial immediately after the implantation, with coating of nano particles over the dental implants, adhesion and integration of surrounding tissues is improved.[24] The nanostructured materials can exhibit enhanced mechanical, electrical, magnetic, optical properties compared with the conventional counterparts.[25]

Impression Materials: Nano fillers are integrated in vinyl poly siloxanes, producing unique impression materials with better flow, improved hydrophilic properties and better detail reproduction.[26]

Nanocomposites: The discrete nanoparticles are homogeneously distributed in resins or coatings to produce nanocomposites. The nano fillers include alumino silicate powder having a mean particle size of 80 nm. These filler particles are compatible with dental composites; hence greater amount of filler can be added to the resin matrix. [27,28] This offers superior hardness, flexural strength, modulus of elasticity, and translucency. This material exhibits superior handling properties.[19]

Diagnosis of Oral Cancer: Exosome found in saliva is a marker whose level is elevated in malignancy. This marker is studied by using various nanostructures such as nanoscale cantilevers, nano tubes, quantum dots, dendrimers and nanoshaells.[29-33]

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.[34]

Oral Fluid NanoSensor Test (OFNASET): The Oral Fluid NanoSensor Test (OFNASET) technology is used or 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.[35]

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.[36]

Treatment of Oral Cancer[37]

Nanomaterials for Brachtherapy-BrachhySil™ (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- Hydrpphobic porphyrins are potentially increasing molecules for the photodynamic therapy (PDT) of solid cancers or ocular vascularization diseases.[38]

Nanoencapsulation

SWRI (South West Research Institute) has developed targeted release systems that encompass nano capsules including novel vaccines, antibiotics, and drug delivery with reduced side effects.

At present, targeted delivery of genes and drugs to human liver have been developed by Osaka University in Japan (2003). Engineered Hepatitis B virus envelope L particles were allowed to form hollow nanoparticles displaying a peptide that is indispensible for liver-specific entry by the virus in humans. Future specialized nanoparticles could be engineered to target oral tissues, including cells derived from the perodontium.[19]

Various nanomaterials like hollow spheres,core shell structure, nanotubes and nano composites have been explored widely for controlled drug release.[37] Pinon–

Segundo *et al* 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 in which minocycline is incorporated into microspheres for drug delivery by local means to a periodontal pocket.[39]

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 everytime.

Nanoparticles have also been used as sterilizing solutions in the form of nanosized emulsified oil droplets that bombard pathogens.[40]

Types of Nanoparticles are:

Nanomeric: These are monodisperse non aggregated and non agglomerated silica nanoparticles. They reduce the interstitial spacing and increase the filler loading.

Nanoclusters: these are zirconia silica particles (2-20nm) and zirconyl salts (from 75nm) which are spheroidal agglomerated particles.[41]

The latest genenration of bonding agents are self etching, one step materials. The silica nanofillers contributes to high bond strength performance while providing a stable , dispersed filled adhesive that prevents particle settling, eliminating the need to be shaken prior to use.[42]

Trade name- Adper O Single Bond Plus Adhesive Single Bond.[19]

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. Trade name- Sandvik Bioline, RK91™ needles (AB Sandvik, Sweden). [19]

Nanorobotic Dentifrice (Dentifrobots)

Subocclusal dwelling nanorobotic dentifrice delivered by mouth wash 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 dentiforobots [1-10µ], crawling at 1-10µ/sec, would be inexpensive, purely mechanical devices, that would safely deactivate themselves if swallowed and would be programmed with strict occlusal avoidance protocol.[19]

Tooth Replacement

The nanorobtic manufacturing and installation of the whole tooth that includes both mineral and cellular components can be made possible by the use of genetic engineering, tissue engineering and tissue regeneration. This would fabricate a new tooth in vitro in the dental office and later it is implanted in the jaws.

With the latest developments in the area of nanotechnology Chen et al attempted to stimulate the natural biomineralization process to create the hardest tissue i.e dental enamel by using highly organized micro architectural units of nanorod like calcium hydroxyl appetite crystals arranged roughly parallel to each other.[43]

Dental Durability and Cosmetics

The esthetics and durability of the teeth can be improved by the use of covalently bonded artificial materials such as sapphire and diamond that helps in replacing superficial enamel layers. These materials have 20-100 times the hardness, failure strength and good biocompatibility when compared to enamel and ceramic veneers. Pure sapphire and diamond can be made fracture resistant as a part of nanostructured composite material that possibly includes embedded carbon nanotubes. [42,44]

Photosensitizers and Carriers

Quantum dots are tiny particles about the size of a protein molecule or a short sequence of DNA measuring only few nanometers. It can bind to the antibody present on the surface of the target cell. When it is stimulated by UV light, it gives rise to the reactive oxygen species and thus will be lethal to the target cell. Hence they can be used as photosensitizers and carriers. [33, 37]

Bone Replacement Materials

Bone is composed of organic compounds mainly collagen and reinforced with inorganic ones. It is a natural nanostructure. Nanocrystals show loose microstructure, with nanopores situated between the crystals. The pores adsorb proteins by the addition of silica molecules due to the modified surface. Bone defects can be treated by using hydroxyappetite nanoparticles. Hydroxyappetite crystals used to treat bone defects are[19]:

- ·Ostim ® (Osartis GmbH, Germany) HA
- VITOSS ® (Orthovita, Inc.,USA) HA+TCP
- NanOss™(Angstrom Medica, USA) HA

Conclusion

The future of nanodentistry seems to be bright as the current ongoing developments in the field of nanotechnology looks promising. Among all the emerging technologies, this seems to be a very promising one .The applied research to turn it into reality is progressing rapidly. Nanotechnology in dentistry has to face many challenges regarding the use of in vivo nanorobots before it is incorporated into daily dental practice.

References

1. Feynman RP. There's Plenty of Room at the Bottom, Reinhold. New York: 1961.
2. Kirk RE, Othmer DF, Kroschwitz J, Howe-Grant M. *Encyclopedia of Chemical Technology*, 4th Ed. New York: Wiley; 1991, 397.
3. Sumita BM, Brian NH. An Application of Nanotechnology in Advanced Dental Materials. *JADA*. 2003; 134: 1382-1390.
4. Kaehler T. *Nanotechnology:Basic Concepts and Definitions. Clinical Chemistry*. 1994; 40(9):1797-1799.
5. Sivaramakrishnan SM and Neelakantan P. Nanotechnology in Dentistry- What does the Future Hold in Store? *Dentistry, An Open Access Journal*. 2014; 4(2).
6. Singla G, Vasudev K, Puri N. Nanodentistry – The Future Ahead. *BFUDJ*. 2010; 1(1): 43-45.
7. Frietas RA. Nanodentistry. *JADA*. 2000; 131: 1559-1565.
8. Ingle E, Gopal S. Nanodentistry: A Hype or Hope. *J Oral Health Comm Dent*. 2011; 5(2): 64-67.
9. Freitas R.A. Nanomedicine // Basic Capabilities. Georgetown, TX: *Landes Bioscience*. – 1999; 1: 345-47.
10. Rocco Castoro. Think Small. U F expects big things from the science of small, nanotechnology // *The POST* 2005; 2:25-27.
11. Taniguchi N. On the basic concepts of nanotechnology In: Proc. Intl. Conf. Prod. Eng. Part ii, Tokyo, Japan Society of Precision Engineering. 1974; 18-23.
12. Drexler KE. New era of nanotechnology. Engines of creation: The coming era of nanotechnology. New York: Anchor Press; 1986, 99–129.
13. Mikkillineni M, Rao AS, Tummala M, Elkanti S. Nanodentistry: New Buzz in Dentistry. *Eur J Gen Dent*. 2013; 2(2): 109-113.
14. Rodgers P. Nanoelectronics. Nature Nanotech; 2006.
15. Ashley S. Nanorobot Construction Crews. *Scientific American*. 2001; 285(3): 76-77.
16. Dexler KE. Nanosystems. Molecular Machinery, Manufacturing and Computation.

New York: John Wiley and Sons; 1992; 990-998.

17. Herzog A. Of Genomics, Cyborgs, and Nanotechnology: A Look into the Future of Medicine. *Connecticut Medicine.* 2002; 66(1): 53-54.
18. Iijima S, Brabec C, Maiti A. Structural flexibility ofcarbon nanotubes .*Journal Chemistry and Physiology*.1996; 104(5): 2089-92.
19. Sarvana KR and Vijayalakshmi R. *Nanotechnology in Dentistry*. *Ind J Res.* 2006; 17(2): 62-65.
20. Whitesides GM, Love JC.The Art of Building Small. *Scientific American*. 2001; 285(3): 33-41.
21. Patil P, Mehta DS, Guvva S. Future impact of Nanotechnology on Medicine and Dentistry. *J of Indian Society of Periodontology*. 2008; 12920: 34-40.
22. Verma SK, Prabhat KC, Jain A. A Critical Review of the Implication in Modern Dental Practice. *National J of Maxillofacial Surgery*. 2010; 1(1):41-44.
23. Redilch M, Katz A,Rapopport L,Wagnerb HD, Feldmanb Y. Improved Orthodontics Stainless Steel Wires Coated with inorganic fullerne-like nanoparticles of WS2 Impregnated in electrodes Nickel-Phosphorous Film. *Dent Mater*. 2008; 24: 1640-1646.
24. Park. Current and Future Applications of Nanotechnology. Cambridge, UK: The Royal Society of Chemistry; 2007.
25. Simon Z , Watson PA. Biomimetic Dental Implants-New Ways to Enhance Osseo integration. *J Can Dent Assoc*. 2002; 68: 286-288.
26. Rao KVP, Kumar JS. Nanotechnology in Dentistry. *KDJ*. 2013; 36(1): 56-59.
27. `Jung M, Sehr K , Klimek J. Surface Texture of Four Nano- filled and One Hybrid Compoosite After Finishing. *OpER Dent.* 2007; 32: 45-52.
28. `Ozak TS, Ozkan P. Nanotechnology and dentistry. *European J of Dentistry.* 2013; 7(1): 145-151.
29. Khosla R. Nanotechnology in Dentistry. *Famdent Practical Dentistry Handbook.* 2009; 69-84.
30. Weiss R. Nanomedicine's promise is everything but tiny. *Washington Post.* 2005.
31. Kairemo K, Erba P, Bergstorm K , Pauwel's EJ, Nanoparticles in Cancer. *Curr Radiopharm.* 2008; 1: 30-36.
32. Kanaparthy R, Kanaparthy A. The Changing Face of Dentistry: Nanotechnology. *Int J of Nanomedicine*. 2011; 6: 2799-2804.
33. Shetty NJ, Swati P, David K, Nanorobots : Future in Dentistry. *The Saudi Dental Journal*. 2013; 25: 49-52.
34. Li Y, Denny P , Ho CM. The Oral Fluid MEMS / NEMS Chip (OFNMC): Diagnostic and Transitional Applications. *Adv Dent and Res.* 2005; 18: 3-5.
35. Gau V, Wong D, Oral Fluid Nanosensor Test (OFNASET) with advanced electrochemical –based molecular analysis platform. *Ann NY Acad Sci.* 2007; 1098: 401-10.
36. Song JM, Kasili PM, Griffin GD, Vo-DinhT. Detection of cytochrome C in a singlecell using an optical nanobiosensor. *Anal Chem.* 2004; 76(9): 2591-2594.
37. Piñón-Segundo E, Ganem-Quintanar A, Alonso-Pérez V, Quintanar-Guerrero D. Preparation and characterization of triclosan nanoparticles for periodontal treatment. *Int J Pharm.* 2005; 294: 217–32.
38. Vargas A, Pegaz B, Debefve E. Improved photodynamic activity of porphyrin loadedinto nanoparticles: in vivo evaluationusing chick embryos. *Int J Pharm.* 2004; 286(1-2): 131-45.
39. Paquette DW, Hanlon A, Lessem J, Williams RC. Clinical relevance of adjunctive minocycline microspheres in patients with chronic periodontitis: secondary analysis of a phase 3 trial. *J Periodontol*. 2004; 75: 531–6.
40. Archana Nagpal, Jasjit Kaur, Shuchita Sharma, Aarti Bansal, Priyanka Sachdev. Nanotechnology – the era of molecular dentistry. *Indian J Dent Sci*. 2011; 3(5) .
41. Mitra SB, Wu D, Holmes BN. An application of nanotechnology in advanced dental materials. *J Am Dent Assoc.* 2003; 134(10): 1382-90.
42. Raybachuk AV, Chekman IS Nebsesna TY. Nanotechnology and Nanoparticles in Dentistry. *Indian J Dent Rest*. 2009; 17: 62-69.
43. Chen Y, Jung G-Y, Ohlberg DAA, *et al*. Nanoscale molecular-switch crossbarcircuits. *Nanotechnology*. 2003; 14: 462.
44. Yunshin S, Park HN, Kim KH. Biologic evaluation of Chitosan Nanofiber Membrane for guided bone regeneration. *Journal Periodontology*. 2005; 76(1778): 84-85.