Year : 2006 | **Volume** : 17 | **Issue** : 2 | **Page** : 62-5 Nanotechnology in dentistry

Kumar Saravana R, Vijayalakshmi R
Department of Periodontics, Meenakshi Ammal Dental College and Hospital, Alapakkam Main Road, Maduravoyal, Chennai 600 095, India

Abstract

Nanotechnology is manipulating matter at nanometer level and the application of the same to medicine is called nanomedicine. Nanotechnology holds promise for advanced diagnostics, targeted drug delivery, and biosensors. In the long-term, medical nanorobots will allow instant pathogen diagnosis and extermination, individual cell surgery in vivo, and improvement of natural physiological function. Current research is focusing on fabrication of nanostructures, nanoactuators, and nanomotors, along with means to assemble them into larger systems, economically and in great numbers.

Keywords: Nanotechnology, nanomedicine, "top- down" and "bottom-up", nanorobots, research in India

How to cite this article:
Kumar SR, Vijayalakshmi R. Nanotechnology in dentistry. Indian J Dent Res 2006;17:62-5

How to cite this URL:
Kumar SR, Vijayalakshmi R. Nanotechnology in dentistry. Indian J Dent Res [serial online] 2006 [cited 2007 Apr 12];17:62-5. Available from: http://www.ijdr.in/article.asp?issn=0970-9290;year=2006;volume=17;issue=2;spage=62;epage=5;aulast=Kumar

Introduction

top

Science is undergoing yet another change, in helping mankind enter a new era, the era of nanotechnology. "Nano" is derived from the Greek word for 'dwarf. Nanotechnology is the science of manipulating matter measured in the billionths of meters or manometer, roughly the size of 2 or 3 atoms [1].

In the literature, both a fairly broad as well as a rather narrow concept of nanotechnology are employed [2]. The first signifies any technology smaller than microtechnology. In contrast, the latter stands for the technology to program and manipulate matter with molecular precision and to scale it to 3-D products of arbitrary size.

The basic idea of nanotechnology, used in the narrow sense of the world, is to employ individual atoms and molecules to construct functional structures.

Earlythinking [3]

The late Nobel prize winning physicist Richard P. Feynman in 1959 speculated the potential of nanosize devices as early as 1959. In his historic lecture in 1959, he concluded saying, "this is a development which I think cannot be avoided."

3 steps to achieving nanotechnology-produced goods [4]

1. Scientists must be able to manipulate individual atoms.
2. Next step is to develop nanoscopic machines, called assemblers, that can be programmed to manipulate atoms and molecules at will.
3. Inorder to create enough assemblers to build consumer goods, some nanomachines called replicators, will be programmed to build more assemblers.

Assemblers and replicators will work together like hands, to automatically construct products.

State of the fie Id at present [5],[6],[7]

Current research is not exclusively focused on achieving assemblers. Instead, research is directed towards the production of a wide array of different minuscule structures. The fabrication techniques of these structures can be divided into 2 approaches: "top- down" and "bottom-up".

The 'top-down' techniques that are used to manufacture nanoscale structures are mostly extensions of methods already employed in small-scale assembly at the micron scale. By further miniaturization, the nanodimension is entered [8]. 'Bottom-up' fabrication methods for manufacture are the methods used for producing nanoscale structures [4],[5],[6],[7],[8],[9].

The various nanostructures are [6]

1. Nanopores
2. Nanotubes
3. Quantumdots
4. Nanoshells
5. Dendrimers

Nanodentistry
[10]

Nanodentistry will make possible the maintenance of near-perfect oral health through the use of nanornaterials, biotechnology including tissue engineering and nanorobotics. Oral health and disease trends may change the focus on specific diagnostic and treatment modalities.

Nanodentistry as bottom-up approach [7]

1. Local anaesthesia

In the era of nanodentistry a colliodal suspension containing millions of active analgesic micron-size dental robots will be instilled on the patient's gingiva. After contacting the surface of crown or mucosa, the ambulating nanorobots reach the pulp via the gingival sulcus, lamina propria and dentinal tubules.

Once installed in the pulp, the analgesic dental robots may be commanded by the dentist to shut down all sensitivity in any particular tooth that requires treatment. After oral procedures are completed, the dentist orders the nanorobots to restore all sensation, to relinquish control of nerve traffic and to egress from the tooth by similar pathways used for ingress.

2. Hypersensitivity cure

Dentin hypersensitivity may be caused by changes in pressure transmitted hydrodynamically to the pulp. This is based on the fact that hypersensitive teeth have 8 times higher surface density of dentinal tubules and tubules with diameters twice as large than nonsensitive teeth. Dental nanorobots could selectively and precisely occlude selected tubules in minutes, using native biological materials, offering patients a quick and permanent cure.

3. Nanorobotic dentifrice [dentifrobots]

Subocclusal dwelling nanorobotic dentifrice delivered by mouthwash or toothpaste could patrol all supragingival and subgingival surfaces atleast once a day, metabolising trapped organic matter into harmless and odorless vapors and performing continuous calculus debridement.

These invisibly small dentifrobots [1-10 micon], crawling at 1-10 microns/sec, would be inexpensive, purely mechanical devices, that would safely desactivate themselves if swallowed and would be programmed with strict occlusal avoidance protocol.

4. Dental durability and cosmetics

Tooth durability and appearance may be improved by replacing upper enamel layers with pure sapphire and diamond which can be made more fracture resistant as nanostructured composites, possibly including embedded carbon nanotubes.

5. Orthodontic treatment

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

6. Photosensitizers and carriers

Quantum dots can be used as photosensitizers and carriers. They can bind to the antibody present on the surface of the target cell and when stimulated by UV light, they can give rise to reactive oxygen species and thus will be lethal to the target cell.

7. Diagnosis of oral cancer

NANO ELECTROMECHANICAL SYSTEMS(NEMS)

Convert (bio) chemical to electrical signal

CANTILEVER ARRAY SENSORS

Ultrasensitive mass detection technology:

Picogram (10-12)-bacterium

Femtogram (10-15)-virus

Attogram (10-18)-DNA

MULTIPLEXING MODALITY

Sensing large numbers of different biomolecules simultaneously in real time

APPLICATIONS

- Diagnosis of diabetes mellitus and cancer
- Detection ofbacteria, fimgi and viruses

8. Treatment of oral cancer

NANOMATERIALS FOR BRACHYTHERAPY

BrachySilTM (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

NANOVECTORSFORGENE THERAPY

Non-viral gene delivery systems

Nanodentistry as top-down approach [11]

1. Nanocomposites

Nanoproducts Corporation has successfully manufactured nonagglomerated discrete nanoparticles that are homogeneously distributed in resins or coatings to produce nanocomposites. The nanofiller used includes an aluminosilicate powder having a mean particle size of 80 ran and a 1:4 M ratio of alumina to silica and a refractive index of 1.508.

Advantages

- Superior hardness
- Superior flexural strength, modulus of elasticity and translucency
- 50% reduction in filling shrinkage
- Excellent handling properties

Trade name: Filtek O Supreme Universal Restorative P Lire Nano O

2. 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.

Trade name: Adper O Single Bond Plus Adhesive Single Bond

3. 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.

Trade name: Nanotech Elite H-D

4. Nanoencapsulation

SWRI [South West Research Institute] has developed targeted release systems that encompass nanocapsules including novel vaccines, antibiotics and drug delivery with reduced side effects.

At present, targeted delivery of genes and drugs to human liver has 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 indispensable for liver-specific entry by the virus in humans. Future specialized nanoparticles could be engineered to target oral tissues, including cells derived from the periodontium [Yamada *et al* , 2003]

5. Other products manufactured by SWRI

a. Protective clothing and filtration masks, using antipathogenic nanoemulsions and nanoparticles

b. 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^{TM}, UK]

c. Bone targeting nanocarriers

Calcium phosphate-based biomaterial has been developed. This bone biomaterial is an easily flowable, moldable paste that conforms to and interdigitates with host bone. It supports growth of cartilage and bone cells.

6. Nanoneedles

Suture needles incorporating nano-sized stainless steel crystals have been developed.

Trade name: Sandvik Bioline, RK 91^{TM} needles [AB Sandvik, Sweden].

Nanotweezers are also under development which will make cell-surgery possible in the near future.

7. Bone replacement materials

Hydroxyapatite nanoparticles used to treat bone defects are

- Ostim® (Osartis GmbH, Germany) HA
- VITOSSO (Orthovita, Inc, USA) HA +TCP
- NanOSS™ (Angstrom Medica, USA) HA

How safe are these nanorobots? [12]

The nonpyrogenicnanorobots used in vivo are bulk teflon, carbon powder and monocrystal sapphire. Pyrogenic nanorobots are alumina, silica and trace elements like copper and zinc.

If inherent nanodevice surface pyrogenicity cannot be avoided, the pyrognic pathway is controlled by invivo medical nanorobots.

Nanorobots may release inhibitors, antagonists or dowmegulators for the pyrognic pathway in a targeted fashion to selectively absorb the endogenous pyrogens, chemically modify them, then release them back into the body in a harmless inactivated form.

Challenges faced by nanodentistry [13]

- Precise positioning and assembly of molecular scale part
- Economical nanorobot mass production technique
- Biocompatibility
- Simultaneous coordination of activities of large numbers of independent micron-scale robots.
- Social issues of public acceptance, ethics, regulation and human safety

Problems for research in nanotechnology in India[13]

- Painfully slow strategic decisions
- Sub-optimal funding
- Lack of engagement ofprivateenterprises
- Problem of retention of trained manpower

Future top

Nanotechnology is foreseen to change health care in a fundamental way:

- Novel methods for disease diagnosis and prevention
- Therapeutic selection tailored to the patient's profile
- Drug delivery and gene therapy

Conclusion

It sounds like science fiction, but to treat the merest trace of an oral disease, we dentists will ask the patients to rinse with a solution containing millions of microscopic machines called "nanoassemblers". These minute workers, receiving signals from a computer controlled by the dentist, will swami to the areas of patient's mouth and eliminate the disease and bacteria causing the disease.

References

1. Kaehler T, Nanotechnology: Basic Concepts and Definitions, Clinical Chemistry, 40[9]: 1797-1799,1994.
2. Gordijn B: Medizinische Utopien. Elite ethische Betrachtung, G6ttingen, Vandenhoeck and Ruprecht,169-180,2004.
3. FeynmanR:There's Plenty ofRoom attheBottom, In: Gilbert HD (Ed.), Miniaturization, New York: Reinhold,282-296,1961.
4. Drexler KE: Nanosystems. Molecular Machinery, Manufacturing and Computation, New York: John Wiley and Sons, 990-998,1992.
5. Bachmann G: Innovationsschub aus dem Nanokosmos, Technologieanalyse. Dbsseldorf: VDI-Technologiezentrum,233-245,1998.
6. Freitas RA Jr: Nanomedicine, Volume I: Basic Capabilities, Georgetown, TX: Landes Bioscience,345-350,1999.
7. Whitesides GM and Love JC: The Art of Building Small, Scientific American, 285[3]: 33-41, 2001.
8. Ashley S: Nanobot Construction Crews, Scientific American, 285[3]: 76-77,2001.
9. Herzog A: Of Genomics, Cyborgs and Nanotechnology: A Look into the Future of Medicine, Connecticut Medicine, 66[1]: 53-54, 2002.
10. Freitas RA Jr: Nanodentistry, Journal of the American Dental Association, 131(11):1559-1565,2000.
11. Jhaver HM and Balaji: Nanotechnology: The future of dentistry, 5:15-17, 2005.
12. Joy B: Why the Future doesn't need us. 804-810, 2000, http://www.wired.com/wired/archive/8.04/ j oy.html
13. Rudra Pratap: Engaging Private Enterprise in Nanotech Research in India: ICS, Trieste, February, 675-680, 2005.

Correspondence Address:
Vijayalakshmi R
Department of Periodontics, Meenakshi Ammal Dental College and Hospital, Alapakkam Main Road, Maduravoyal, Chennai 600 095
India
sr_vijayalakshmi@rediffmail.com