International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 11ǁ November 2013 ǁ PP.01-05

Nanotechnology boon or bane for restorative dentistry; A review

Dr. Shweta Dwivedi[1], Dr. Chandra Dhar Dwivedi[2],
Dr. Akhilesh Chandra[3], Prof. Naresh Sharma[4]
[1]*(Conservative Dentistry and Endodontics, Faculty of Dental Sciences, I.M.S., BHU, Varanasi)*
[2,4]*(Oral & Maxillofacial Surgery, Faculty of Dental Sciences, I.M.S., BHU, Varanasi)*
[3]*(Oral Pathology, Faculty of Dental Sciences, I.M.S., BHU, Varanasi)*

ABSTRACT: Nanotechnology have potential to bring about significant benefits, such as improved health, better use of natural resources & imroved quality products. Nanomaterials, nanocomposites, nanoporous materials & nanomembranes will play a growing role in materials development for the dental industry.
As with all technologies, nanotechnology have potential to bring about significant benefits, such as improved health, better use of natural resources, and reduced environmental pollution. However, they also carries a significant potential for misuse and abuse on a scale and scope never seen before.

KEYWORDS: *Nanotechnology, nanodentistry, nanomaterials*

I. INTRODUCTION

Nanotechnology concept is the manipulation of matter on the molecular and atomic levels by using microscopic device entities to perform tasks, that are traditionally done by hand or with equipment. Tiny machines, known as nanoassemblers, could be controlled by computer to perform specialized jobs. Nanotechnology holds promise for advanced diagnostics, targeted drug delivery, and biosensors, but there are worries due to the unknown consequences to the environment and human health.

Nanodentistry

The nanodentistry involves the maintenance of oral health by the use of nanomaterials, biotechnology and dental nanorobotics.

II. NANOROBOTS

Nanorobots are microscopic in size, that would probably be necessary in very large numbers of them to work together to perform microscopic and macroscopic tasks".

Fabrication and machanism of action

Carbon is used due to its increased strength and chemical inertness. They are 0.5-3 µ in diameter and are constructed of parts with dimensions in the range of 1 to 100 nm. The external passive diamond coating provides a smooth, flawless coating to make reactionless for the body's immune system. The powering of nanorobots can be done by metabolizing local glucose, oxygen and externally supplied acoustic energy. They can be controlled on-board computers. A navigational network installed in the body, provide high positional accuracy to all passing nanorobots and keep track of the various devices in the body. Nanorobots are able to distinguish between different cell types by checking their surface antigens. Building nanorobots involves sensors, actuators, control, power, communications and interfacial signals across spatial scales and between organic / inorganic as well as biotic/abiotic systems.

Deactivation of nanorobots

When the task of the nanorobot is completed, they can be retrieved by allowing them to exfuse themselves via the usual human excretory channels. They can also be removed by active scavenger systems.

III. APPROACHES TO NANODENTISTRY[1]

a. Building up particles by combining atomic elements: i.e. bottom up approach
b. Using equipment to create mechanical nanoscale objects i.e. top down approach.

Nanodentistry as bottom-up approach

1. Local anaesthesia
2. Hypersensitivity cure
3. Nanorobotic dentifrice [dentifrobots]
4. Whole tooth replacement
5. Tooth renaturalization
6. Orthodontic treatment
7. **N**anodiagnosis
8. Treatment of oral cancer
9. Dental biomimetics
10. Endodontic regeneration
11. Nanoterminators

Nanodentistry as top-down approach

1. Nanocomposites
2. Nanolight curing glass ionomer
3. Pit & fissure sealants
4. Nanoencapsulation
5. Impression materials
6. Bone replacement materials
   Bone Targetting Nanocarriers
7. Nanoneedle
8. Other products

IV. APPLICATIONS OF NANOTECHNOLOGY IN RESTORATIVE DENTISTRY AND ENDODONTICS

Local anaesthesia[2]

One of the most common procedures in dentistry, is the injection of local anesthetia, which has itself several disadvantages i.e. patient discomfort, varying degrees of efficacy, requires manual skill and complications. With nanodentistry, a colloidal 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 guided by chemical gradient, temperature differentials all under control of dentist with help of onboard nanocomputer. Once installed in the pulp, the analgesic dental robots may be commanded by the dentist to shut down all the sensitivity in any particular tooth that requires the treatment.[3,4,5]

After oral procedures are completed, the dentist orders the nanorobots on the computer screen to restore all sensation, to relinquish control of nerve traffic and to egress from the tooth by similar pathways used for ingress.This analgesic technique is patient friendly as it reduces anxiety with quicker, more selective and controlled effects. This technique also avoids most of side effects and complications.[6,7]

Hypersensitivity cure[8]

Dental nanorobots could selectively and precisely occlude selected tubules in minutes, using native biological materials, offering patients a quick and permanent cure.[2,7,9]

Tooth renaturalization

Tooth renaturalization procedures may become a popular addition to the typical dental practice. This trend may begin with patients who desire to have their old dental amalgams excavated and their teeth remanufactured with native biological materials. Tooth durability and appearance may be improved by replacing upper enamel layers with covalently-bonded artificial materials such as sapphire or diamond which have 20-100 times the hardness and failure strength of natural enamel.

Dental biomimetics

The central theme of biomimetics[10,11] is the ways to mimic nature's already efficient use of nanotechnology which involves interaction between amelogenin and the formation and directional orientation of HA crystals to compose enamel.[12,13,14] The results may resemble processes that occur in actual enamel formation. A recent in vitro study by **Wang et al.** further elucidated mechanisms of HA crystal-growth process. It is hypothesis that the application of an appropriate formulation of colloidal nano-particle to a carious lesion may prevent further demineralization and may encourage remineralization. However, the treatment of larger visible cavities with nanomaterials is still at the research stage.

Whole tooth replacement

A team of Japanese researchers led by Professor Takashi Tsuji from Tokyo University of Sciences have constructed teeth out of mouse stem cells and successfully transplanted them into mice. The bioengineered teeth were fully functional, there was no trouble (with) biting and eating food after transplantation. But the technology to regulate tooth morphogenesis for whole tooth regeneration remains unexplored. However, with the understanding of nanoscale biological processes, autologous whole replacement tooth should become feasible within the time and economic constraints of a typical office visit, which would fabricate the new tooth in the dentist's office.

Endodontic regeneration

Teeth with degenerated and necrosed pulps are routinely saved by root canal therapy. However current treatment modalities of regenerative approaches will result in replacement of diseased or necrotic pulp with healthy pulp tissues to revitalize teeth. In a previous study, **Fioretti et al.** reported the first use of nanostructured and functionalized multilayered films containing α-MSH as a new active nanobiomaterial for endodontic regeneration.[15]

Nanoterminators

The question arises as what will happen if nanorobots free themselves from control (for example those intended for anesthesizing the dental pulp, pass through the blood stream arrive at one of the vital centres-respiratory centre at the medulla oblongata or conduction bundle in the heart and discontinue the current of nerve impulses), the consequences may be catastrophic. Nanorobots intended to widen or narrow the dentinal tubules may do the same in an unwanted place. To counteract the problem, researchers advocated the development of nanoterminators – killers of nanorobots, which will destroy the disobedient and crazy nanorobots. Scientists are yet to build a mechanism for self-destruction of nanorobots similar to apoptosis.

Nanocomposite

Evolution of direct RBC systems to the level of the nanofill composite has been recently reviewed by Puckett and colleagues.[16] The current clinical utility of nanotechnology's most tangible contribution to dentistry is the nanocomposites. Advantages are primarily in terms of smoothness, polishability and precision of shade characterization, plus flexural strength and microhardness similar to or more than conventional RBCs.[17,18,19,20]
Ormocer with nanoparticle fillers, are widely used in nanocomposite restorative systems. Moszner and colleagues found that modifying ormocers with organic moieties such as methacrylate-substituted $ZrO2$ or $SiO2$ organosol nanoparticles was to improve the mechanical properties and biocompatibility of RBCs.[21,22] Ormocers also claim decreased surface roughness.[23,24]

Nano light curing glass ionomer restorative:

By using bonded nanofillers and nanocluster fillers, manufacturers have begun to incorporate nanoscale structuring to produce "nanoionomers," in an effort to make their surface finish more closely approximate that of a hybrid composite and lesser wear.[25]

Pit & fissure sealants

The nanofissure sealant results in outstanding wear resistance and a reduced shrinkage, feasible sealing ability, hydrophilic material and easy to place. Due to high fluoride release, it may lead to remineralization.[22]

Nanoadhesives: They are nanosolutions which produce unique and dispersible nanoparticles which prevent agglomerations.
Advantages:

- Higher dentine and enamel bond strength
- High stress absorption
- Longer shelf life
- Durable marginal seal
- No separate etching required
- Fluoride release

Nanoimpression materials

Nanofillers have been added to polyvinylsiloxane material to enhance his properties. These have better flow, fewer voids and enhanced detail precision.[26]

Bone replacement materials
Hydroxyapatite nanoparticles used to treat bone defects are
- ✓ Ostim® (Osartis GmbH, Germany) nano HA
- ✓ VITOSSO (Orthovita, Inc, USA) HA +TCP
- ✓ NanOSSTM (Angstrom Medica, USA) HA

These can be used in maxillofacial injuries requiring bone graft, cleft patient, endodontic surgeries and osseous defect in periodontal surgeries.

Others
a. Protective clothing and filtration masks, using antipathogenic nanoemulsions and nanoparticles
b. Medical accessories for instant healing
c. Biodegradable nanofibres - for haemostatic wound dressings with silk nanofibres

V. BIOCOMPATIBILITY OF NANOMATERIALS

Studies indicate that the biological consequences of nanomaterials are material and formulation specific. Most of the nanomaterials are compatible with biological systems and permissive for cell growth and differentiation. Despite efforts to improve their targeting efficiency, significant quantities of nanomaterials are cleared by the mononuclear phagocytic system before finding their targets, increasing the likelihood of unintended acute or chronic toxicity. Biological consequences include oxidative stress and inflammation, impaired pulmonary clearance, cardiac compromise, a skewed immune response, and development of pulmonary fibrosis and foreign body granulomas.

Also, nanorobots are may be pyrogenic or non-pyrogenic. The nonpyrogenic nanorobots used in vivo are bulk teflon, carbon powder and monocrystal sapphire whereas pyrogenic are alumina, silica and trace elements like copper and zinc. The pyrogenic nanorobots are controlled by invivo medical nanorobots. Each new nanomaterial must be assessed individually, and all material properties must be taken into account. To address such concerns, the Swedish Karolinska Institute conducted a study in which various nanoparticles were introduced to human lung epithelial cells. The results, released in 2008, showed that
- o Iron oxide nanoparticles caused little DNA damage and were non-toxic.
- o Zinc oxide nanoparticles were slightly worse.
- o Titanium dioxide caused only DNA damage;
- o Carbon nanotubes caused DNA damage at low levels.
- o Copper oxide was found to be the worst offender, and was the only nanomaterial identified by the researchers as a clear health risk.

Future trends
Dr. Franklin Tay, (endodontist in the MCG School of Dentistry) is trying to prevent the aging and degradation of resin-dentin bonding by feeding minerals back into the collagen network. He will investigate guided tissue remineralization, a new nanotechnology process of growing extremely small, mineral-rich crystals and guiding them into the demineralized gaps between collagen fibers. If Dr. Tay's concept of guided tissue remineralization works, he will create a delivery system to apply the crystals to the hybrid layer after the acid-etching process.

VI. CONCLUSION

As with all technologies, nanotechnology have potential to bring about significant benefits, such as improved health, better use of natural resources, and reduced environmental pollution. However, they also carries a significant potential for misuse and abuse on a scale and scope never seen before.

REFERENCES

[1] Rodgers, P. (2006). "Nanoelectronics: Single file". Nature Nanotechnology. doi:10.1038/nnano.2006.5
[2] Freitas R.A., Nanodent. Journal of American dental association, 2000, 131 (3) 1559-1566
[3] Estafan D.J. Invasive and non-invasive dental analgesia techniques // Gen Dent. – 1998. – Vol. 46, ¹6. –. 600-601.
[4] Herzog A. Of Genomics, Cyborgs and Nanotechnology: A Look into the Future of Medicine //Connecticut Medicine. – 2002. – Vol. 66, ¹1. – P. 53-54.
[5] Jhaver H.M. Nanotechnology: The future of dentistry // Journal Nanoscience and Nanotechnology. – 2005. – Vol. 5. – P. 15-17.
[6] Meechan J.G. Intra-oral topical anaesthetics: a review // Journal Dental. – 2000. – Vol. 28, ¹1. – P. 3-14.
[7] Whitesides G.M., Love J.C. The Art of Building Small // Scientific American. – 2001. – Vol. 285, ¹ 3. – P. 33-41.

[8] Nagpal Archna, Kaur Jasjeet, Sharma Suchita, Bansal Arti, Sachdev Priyanka; Nanotechnology – the era of molecular dentistry; Indian Journal of Dental Science; December 2011; 3(5)
[9] Freitas R.A. Jr. Exploratory design in medical nanotechnology: A mechanical artificial red cell // Artificial Cells Blood Substitute Immobile Biotechnology. – 1998. –Vol. 26. – P. 30-32.
[10] Mashaghi, S.; Jadidi, T.; Koenderink, G.; Mashaghi, A. Lipid Nanotechnology. Int. J. Mol. Sci. 2013, 14, 4242-4282.[1]
[11] C.Michael Hogan eds. S.Draggan and C.Cleveland 2010. Virus. Encyclopedia of Earth. National Council for Science and the Environment.
[12] Fan Y, Sun Z, Wang R, Abbott C, Moradian-Oldak J. Enamel inspired nanocomposite fabrication through amelogenin supramolecular assembly. Biomaterials. 2007;28(19):3034–3042.
[13] Brookes SJ, Lyngstadaas SP, Robinson C, Shore RC, Kirkham J. Intracellular nanosphere subunit assembly as revealed by amelogenin molecular cross-linking studies. Eur J Oral Sci. 2006;114 Suppl 1: 280–284; discussion 285–286, 382.
[14] Du C, Falini G, Fermani S, Abbott C, Moradian-Oldak J. Supramolecular assembly of amelogenin nanospheres into birefringent microribbons. Science. 2005;307(5714):1450–1454.
[15] Fioretti F, et al.; Nanostructured assemblies for dental application. ACS Nano. 2010 Jun 22;4(6):3277-87
[16] Ernst CP, Brandenbusch M, Meyer G, Canbek K, Gottschalk F, Willershausen B. Two-year clinical performance of a nanofiller vs a fine-particle hybrid resin composite. Clin Oral Investig. 2006; 10(2):119–125.
[17] Chan KS, Lee YD, Nicolella DP, Furman BR, Wellinghoff S, Rawls HR. Improving fracture toughness of dental nanocomposites by interface engineering and micromechanics. Eng Fract Mech. 2007; 74(12):1857–1871.
[18] Xu HH, Weir MD, Sun L. Nanocomposites with Ca and PO4 release: effects of reinforcement, dicalcium phosphate particle size and silanization. Dent Mater. 2007;23(12):1482–1491.
[19] Karabela MM, Sideridou ID. Effect of the structure of silane coupling agent on sorption characteristics of solvents by dental resinnanocomposites. Dent Mater. 2008;24(12):1631–1639.
[20] Tanimoto Y, Kitagawa T, Aida M, Nishiyama N. Experimental and computational approach for evaluating the mechanical characteristics of dental composite resins with various filler sizes. Acta Biomater. 2006; 2(6):633–639.
[21] Moszner N, Gianasmidis A, Klapdohr S, Fischer UK, Rheinberger V. Sol-gel materials 2. Light-curing dental composites based on ormocers of cross-linking alkoxysilane methacrylates and further nanocomponents. Dent Mater. 2008;24(6):851–856.
[22] Voco. 2008 [cited 2008 26 Nov]; Available from: http://voco.com/ index_en.html.
[23] Baseren M. Surface roughness of nanofill and nanohybrid composite resin and ormocer-based tooth-colored restorative materials after several finishing and polishing procedures. J Biomater Appl. 2004;19(2):121–134.
[24] "Nanotechnology Consumer Products". nnin.org. 2010 [last update]. Retrieved November 23, 2011
[25] Oxman JD, Falsafi A, Mitra S, Ton TT, Madsen VJ, Bui HT. Improved polish, wear-resistance and esthetics of a nanoiomer restorative material [abstract]. London, UK: Pan European Federation of the International Association for Dental Research; 2008.
[26] Kumar S.R., Vijaylaxmi R; Nanotechnology in dentistry, Indian Journal of Dental Research 2006; 17 ;62-69