Nanotechnology : A new era in dentistry.

Mujoo S*, Khan F*, Thakur D**, Jain S*, Deeplaxmi R*
*Department of Oral Medicine & Radiology, Rungta College of Dental Sciences & Research, Bhilai
**Department of Oral &Maxillofacial Surgery, Rungta College of Dental Sciences & Research, Bhilai

ARTICLE INFO

Keywords:
Nano dentistry, Nano Medicine,
Nano technology, Oral cancer

Corresponding Author:
Dr.Sheetal Mujoo
P.G student,
Department of Oral medicine & Radiology,
Rungta College of Dental Sciences & Research
Kohka-Kurud Road, Kurud, Bhilai, Chhattisgarh
Contact: +919419181657
Email: sheetalmujoo@yahoo.co.uk

ABSTRACT

Nanotechnology is an area of science devoted to the manipulation of atoms and molecules leading to the construction of structures in the nanometer scale size range.
Biological process of living organisms occur basically at nanometer scale, elementary biological units like DNA, proteins or cell membranes are of this dimension. Nano-scale devices can easily enter most cells and blood vessels, thus they have a great potential for application in detection, diagnosis, monitoring and therapeutics.
Nano technology has a big role to play in screening and imaging of oral cancer. Nano scale devices operate on principles of selectively capturing cells or target proteins, thus aid in screening tests. Imaging of biomarkers produced by cancer cells can be achieved by imaging probes which are carried to target area by nano devices. Nano electrical mechanical system (NEMS) biosensors demonstrate the presence of RNA in saliva as well as its clinical translational potential for oral cancer detection. Nano robots can also be used to deliver chemotherapeutic drug at the cancer site. Safety studies are needed for use in vivo case.

Introduction

The word Nano has been derived from Greek word nannos meaning "dwarf." According to National Nanotechnolgy Initiative, 2000 [1], nanotechnology is defined as "Understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel application".The concept of nanonology was visualised in 1959 by physicist, Richard P. Fenyman [2] but his idea remained undisussed until mid 80's and later in 1986 Eric Drexler published "Engines of Creation" which popularized potential of molecular nanotechnology. Nanotechnology have a potential to provide benefits in numerous areas such as synthesis of new material with advanced properties, production technology, electronics, ecology, energy conservation, nanobiosystems, medical appliances etc. A nanoparticle is a billionth of a meter, or about 1/80,000 of the diameter of a human hair. As they are so small in size,nanoparticles can easily interact with biomolecules present on the surface of and inside the cells and can revolutionize cancer diagnosis and treatment.[3] The types of nanoparticles are quantum dots, carbon nanotubes paramagnetic nanoparticels,liposomes, gold nanoparticles. The subtype of gold nanoparticles are nanosphere, nanorods, nanocages, nano shells.[4] The Properties of material changes very drastically by just manipulating the way atoms or molecules are arranged and the discovery of atomic force microscope made it possible to identify each and every atom individually which made possible the use of nanotechnology in medicine and dentistry.[5]

There are three approaches in nanotechnolgy [6]
1. Bottom Up: it is the method for producing nanoscale structure directly from the particles
2. Top Down: Then, nanoscale structures are produced by further miniaturization of micron size particles
3. Functional Approach: And the components of a desired functional structure are developed.

Nanomedicine

Drug delivery: Liposomes and polymer-based nanoparticles are the widely used nanoparticles as drug-delivery system. 5fluorouracil, doxorubicin, paclitaxl are some of the anti cancer drugs used. Biodegradable nanoparticles based vaccines are used for oral vaccination. VivaGel microbicide intended to be applied to prevent the spread of HIV and other sexually transmitted diseases (STDs), a combination of drug and dendrimer-based drug-delivery system which is proven to be effective in preventing the transmission of STDs.[7]

A type of long-acting insulin, Basulin, is developed as a product of nanoparticulate system.

As Diagnostic biomarkers: Nanoparticles help in increasing the concentration, amplification and protection of a biomarker from degradation. For example, streptavidin-coated fluorescent polystyrene nanospheres are applied in single color flow cytometry to detect the epidermal growth factor receptor (EGFR) on A431 cells (human epidermoid carcinoma cells) and the sensitivity of fluorescent nanospheres is 25 times more than that of the conjugate streptavidin-fluorescein.[7]

Microbivore: These are nanorobotic phagocytes of each measuring 2-3 microns. They act 1000 times faster than normal phagocytes and will be the ultimate defense against biological weapons or biological warfare agents as well as against any influenza pandemic or other potential pathogens.[6]

Respirocytes: This nanorobot would deliver 236 times more oxygen to body tissues per unit volume than natural red cells.An injection of respirocytes administered by emergency medical personnel would allow the patient's brain and other vital organs to be perfused with oxygen for several hours.[6]

Nanorobotic surgeon: A surgical nanorobot, programed or guided by a human surgeon, could act as a semiautonomous, on site surgeon, inside the human body, when introduced into the body through vascular system or cavities. Axotomy of roundworm neurons was performed by femtosecond laser surgery after which the axons are functionally regenerated. Femtolaser acts like a pair of nanoscissors by vaporizing tissue locally while leaving adjacent tissue unharmed.[6]

Nanosensors: Ion channel switching (ICS) technology allows its biosensor to potentially detect a variety of disease-causing agents. Multiple tests can be performed on a single disposable chip. The hand held reader helps to determine prognosis after reading the results of the tests. This technology has potential application in diagnosis, bacterial detection.[6]

NanoDentistry

1. ***Local anesthetics:*** To induce local anesthesia in the era of nanodentistry, a colloidal suspension containing millions of active analgesic micron-size dental robots will be installed on the patients gingiva. After contacting the surface of crown or oral mucosa, the ambulated nanorobots reach the pulp via gingival sulcus, lamina propria and dentinal tubules. Once installed in the pulp, the analgesic dental robots will establish control over nerve impulse traffic which inturn will be controlled by the dentist on board. When the dentist presses the icon for the desired tooth on the hand held controller display, the selected tooth will numb immediately. After the surgical procedures are complete, the dentist orders the nanorobots to restore all sensations, to regress from the tooth by similar pathway used for ingress.[8]

2. ***Dentine Tubules Blocking:*** Dentine hypersensitivity is an acute pain condition that typically occurs when the surface of the root becomes exposed. When the gingiva has receded and cementum removed, the dentine tubules become exposed and opened and then fluid flow along these open tubules caused by mechanical, chemical or thermal stimuli can result in an uncomfortable pain response in the nerve fibers. Atomic Force Microscope (AFM) has proven to be a useful tool for the study of dentine surfaces and collagenous tissues that indicates its potential in understanding oral disease processes. Alternate modes of AFM also prove to be useful in studying dental surfaces, such as piezoresponse force microscopy (PFM) to differentiate between organic and mineral components on dental tissues with nanoscale resolution. Further research utilizing AFM's ability to simultaneously collect qualitative and quantitative analysis of dentine and collagen at the nanoscale should therefore prove essential in providing important insights on the effectiveness of oral treatments for periodontal disease prevention, disease progression, and development in collagen dependant materials such as bone, cartilage, tendons, skin, collagen-based materials in tissue engineering and biomedical device coating.[8,9]

3. ***Dentrifice:*** They are nanosized hydroxy apatite crystals and form a protective coat on tooth enamel and restore the surfaces of damaged teeth. Dentrifice like Microbrite has microhydrin which consists of molecular cages, 1-5 nanometers in diameter and degrade the organic food.[8]

4. ***Photosensitizers and Carriers***: Quantum dots can be used as photosensitizer and carriers.They can bind to the antibody present on the surface of the target cell and when stimulated by UV light can give rise to reactive oxygen species which will be lethal to the target cells.[10]

5. ***Orthodontic wires:*** Sandrik Nanoflex is a new stainless steel which allows the ultra-high strength with good deformability, corrosion resistance and a good surface finish.[11]

6. ***Bone Replacement materials:*** Hydroxyapatite nanoparticles used to treat bone defects. Trade name Ostim HA, VITTOSSO.[12]

7. ***Nanocomposites:*** Composite with nanofillers are available, Trade name: Filtek supreme universal restorative pure nano.[12]

8. ***Nano impression materials:*** Nano impression materials are available in which nanofillers are integrated in the polyvinyl siloxane producing a unique addition siloxane-impression material.[12]

9. ***Oral Fluid Diagnostic Biomarker:*** Saliva is inexpensive, non invasive and easy -to-use diagnostic medium containing proteomic and genomic markers for molecular disease identification. Exosomes are secreted by salivary gland epithelium and released into the salivary fluid via exocytosis. Malignancy and other diseases cause elevated exosome secretion and tumor antigen enrichment of exosomes associated with cancer cell. Detection tools like NEMS/MEMS(nano.-electrical -mechanical system)biosensors can be used for rapid detection.[10]

10. ***Role of gold nanoparticles in Cancer diagnosis and treatment:*** Worldwide oral cancer is the eleventh most common cancer. Often, oral cancer is preceded by the presence of clinically identifiable premalignant changes [13] and oral physicians can play a crucial role by identifying these changes for reducing the incidence and mortaility of cancer. Nano particles for oral cancer diagnosis are more accurate and less invasive to the body. Many cancer cells have a

protein, epidermal growth factor receptor (EGFR), distributed on the outside of their membranes,non cancer cells have much less of this protein. By attaching gold nanoparticles to an antibody for EGFR, researchers have been able to bind the nanoparticles to the cancer cells. Once bound, the cancer cells manifest different light scattering and absorption spectra than benign cells.[2] Pathologist can thereafter use these results to identify malignant cells in biopsy sample.

11. ***Cancer therapy:*** Gold and nanotechnology based treatment potentially provide localized targeted therapies with an aim to enhance efficacy, reduce side effects and improve patient's quality of life.

Gold nanoparticles-based cancer therapy uses photothermal therapy for the destruction of cancer cells or tumor tissue. When irradiated with focused laser pulses of suitable wavelength, targeted gold nanospheres, nanorods, nanoshells, nanocages can kill bacteria. It was estimated that 70-800 C was achieved through light absorption by the gold nanoparticles and upto 150 antibodies can conjugated to a nanoshell.[11] "Nanodumbles" target cancer cells,have been designed to to function like "guided missile" in the targeted destruction.This approach could reduce side effects associated with anti-cancer drugs and has the potential to be adapted for different types of cancer.

Shouheng et al suggested "stuck gold and iron oxide nanoparticles" together to make a dumbell-shaped drug delivery vessel. On the gold side, they anchored Cisplastin-a powerful anti cancer agent & to the iron oxide they attached a targeting molecule called Herceptin- is an antibody that recognizes molecule unique to breast cancer cells allowing the complex to occur. After the drug enters into the cellular system, it can be hydrolysed becoming smaller species which then attack nuclear regions and interact with DNA. Kanzius RF therapy where the microscopic nanoparticles "cooks" tumor inside the body with harmless radiowaves. When the gold nanoparticles are inside the malignancy, a blast from a radio-frequency generator causes them to heat and cook the cancer cells.

Advantages of Nanotechnolgy

Simple, less invasive, nontoxic, increased contrast, early diagnosis of oral cancer, localized targeted therapies , enhance efficacy and reduce side effects with better quality of life for patient.[8]

Problems for Research in India

Low strategic decisions, sub-optimal funding, lack of problem of retention of trained manpower, lack of engagement of private enterprises.[8]

Challenges for Nanodentistry

Precise positioning and molecular scale for nano structures are required, biocompatibility of nanomaterial. To have a control over the simultaneous coordination of large no. of micro scale robots. Physiochemical changes of nanoparticles after coming in contact with biological media

Conclusion

Once Nanomechanics are available, programmable and controllable gives an opportunity for Oral Physician to diagnose malignant disease at an earliest. Also, it is a newer treatment modality to be executed .Hence, it may reduce the morbidity and mortality of Head and Neck Cancer.

References

1. Alhoff F. The Comin Era of Nanomedicine. American Journal of Bioethics 2009;9(10):3-1 .
2. Nagalaxmi V. Small Wonders Paving a Great Future-Nanotechnology. Annals and essence of Dentistry 2012;4(1):99-10.
3. Reddy P. Role of Gold Nanoparticles in Early Detection of Oral Cancer. J Indi Acad of Oral Med and Radiol 2010;22(1):30-3.
4. Fruites RA. Nanomedicine,Basic Capabilitise. Londes Bioscience 1999;1:345-54.
5. Satyanarana T. Nanotechnolg.The Future J Interdisciplinary Dent 2011;1(2):93-100.
6. Rybachunk AV. Nanotechnology and Nanoparticles in dentistry. Pharmacol Pharm 2009:1:18-21.
7. Grossman T. Latest Advances in anti ageing mesdicine.Keio J Med 2005;54:85-94.
8. Kumar S. Nanotechnolgy in dentistry. Ind J Dent Res 2006;17(2):62-5.
9. Nagpal A, Kaur J, Sharma S. Nanotechnology-the era of molecular Dentistry. Ind J Dent Sci 005 3(5);80-2.
10. Wong D. Salivary diagnostics powered by nanotechnologies, proteomics and genomics. JADA 2006; 137;313-21.
11. Cai W. Application of gold nanopartilcles in cancer technology Nanotechnolgy. Sci Application 2008:1:17-32.
12. Freitas RA Jr. Nanodentistry. J Am Dent Assoc 2000:131:1559-66.
13. Murdoch C, Reeves KJ, Hearnden V, Colley H, Massignani M, Canton I. Internalization and biodistributionof polymersomes into oral squamous cell carcinoma cellsin vitro and in vivo. Nanomedicine (London, England). 2010;5: 1025-1036

Source of Support: Nil. **Conflict of Interest:** None