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Review Article

Nanodentistry - "Unbounding The Future"

Munish Goel*, Neeraj Sharma, Sheenam Garg and Anish Garg

Department of Conservative Dentistry and Endodontics, Himachal Dental College and Hospital, India

***Corresponding Author:** Munish Goel, Department of Conservative Dentistry and Endodontics, Himachal Dental College, Sundernagar, Mandi, HP, India.

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Abstract

Nanotechnology, or nanoscience, refers to the research and development of an applied science at the atomic, molecular, or macromolecular levels i.e., molecular engineering & manufacturing [1]. In the long term, nanomedicine will allow instant pathogen identification and examination, in vivo individual cell surgery and improvement of natural physiological function. Nanotechnology holds a promise for advanced diagnostics, targeted drug delivery and biosensors [2]. The maintenance of comprehensive oral health care with the use of nanomaterials, biotechnology, and ultimately dental nanorobotics will be made possible by nanodentistry. Current research focuses on manufacturing of nanostructure, nanomotors and various means to assemble them together in larger structures. This article highlights the potential application of nanotechnology in dentistry and their impact on clinical dental practice.

Keywords: *Nanotechnology; Nanomedicine; Nanorobots and Nanodentistry*

Introduction

Mankind is now entering a new era of nanotechnology. It is an emerging field with a potential to revolutionize dentistry with advanced tools. It will not only be an aid to dental diagnosis but also transform dental therapeutic and cosmetic dentistry. The term "nanotechnology" was coined by Kerie E. Drexler [3]. Nanotechnology acts at a scale of one billionth of a meter which is one ten thousandth the width of a human hair involving individual atoms or molecules. It actually is engineering at the atomic or molecular scale [4]. It will provide tools for better understanding and prevention of oral diseases at molecular and cellular levels.

Perspectives of Nanotechnology

Larger to Smaller: A materials perspectives,
Simple to Complex: A molecular perspectives [5].

The maintenance of nearly perfect oral health can be made possible by nanodentistry through the use of nanomaterials, biotechnology, tissue engineering and nanorobotics. A nanorobot is an artificially fabricated object which is free to diffuse in the human body and there it interacts with specific cells at the molecular level. According to the pioneers of nanotechnology, nanorobots will be constructed in next 10 - 30 years [6]. In near future, the dentist will have the ability to influence oral health on a molecular and atomic level because of nanotechnology. Cavity free teeth, ageless teeth, augmented thinning of mandible with diamond, Nanorobotic therapy to tooth decay, periodontal disease, jaw cancer, root canals, implants… the possibilities are infinite. Where does this lead to… NANODENTAL CLINICS!!

The first observations and size measurements of nano-particles was made during the first decade of the 20th century. They are mostly associated with Richard Adolf Zsigmondy who made a detailed study of gold sols and other nanomaterials with sizes down to 10 nm and less. He published a book in 1914 [7]. He used ultra microscope that employs the dark field method for seeing particles with sizes much less than light wavelength. Zsigmondy was also the first who used nanometer explicitly for characterizing particle size. He determined it

as 1/1,000,000 of millimeter. He developed the first system classification based on particle size in the nanometer range [7,8].

Applications of Nanotechnology in Dentistry

Nanocomposites contain discrete nanoparticles that are homogeneously distributed in resins [9]. Microfill composites and core materials are manufactured using a "top-down" approach which cannot reduce the particle size below 100 nm whereas nanocomposites are synthesized using a "bottom-up" approach that starts at the molecular level and provides minuscule particles (1 nm = one billionth of a meter). When the particle size is less than a particular level (critical size), changes in particle properties can be observed. As the dimensions reach nanometre level, interactions at phase interfaces become largely improved which enhances the properties of the material. The nanofillers used can be of two types-

- Nanomeric type
- Nanocluster type.

Advantages

1. Excellent handling characteristics [10]
2. Superior physical properties like modulus of elasticity, flexural strength and translucency [8].
3. High polish retention [8].
4. 50% reduction in polymerization shrinkage.

Nanosolution produces unique and dispersible nanoparticles, which can be used in bonding agents. This ensures homogeneity and ensures that the adhesive is perfectly mixed every time [11]. The latest generation of bonding agents is self-etching [11]. The silica Nano filler contributes to higher bond strength performance while providing a stable, dispersed, filled adhesive that prevents particle settling, eliminating the need to be shaken prior to use [6].

Impression materials: Nano fillers are integrated in vinyl polysiloxanes, producing a unique addition of siloxane impression materials which have a better flow, improved hydrophilic properties and enhanced dental precision [12].

Dentifrices: Using nanosized hydroxyl apatite crystals, dentifrices are manufactured. These form a protective layer on tooth enamel and can help in the restoration of damaged areas [7]. These invisibly small dentifrobots [1-10 μ], crawling at 1-10 μ/sec, would be inexpensive, purely mechanical devices, that would safely deactivate themselves if swallowed and would be programmed with strict occlusal avoidance protocol [13].

Materials to Induce Bone Growth: Bone is made up of organic and inorganic components. Nanocrystals have nanopores with surface modified to adsorb protein. Calcium sulphate is used to fill small voids such as those found in post extraction sockets and periodontal bone defects and as an adjunct to the longer lasting bone graft material [7].

Hydroxyapatite nanoparticles used to treat bone defects [7] are:

- Ostim® (Osartis GmbH Germany) HA.
- VITOSS ® (OrthovitaInc, USA) HA+ TCP.
- NanOssTM (Angstrom Medica, USA) HA

Dental Implant: The reports of dental implantology date back to early 19th century and the concept of osseointegration were given by Branemark in 1952. The most common cause of failures of dental implants is insufficient bone formation around the biomaterial. Implants using nanotechnology can effectively expedite bone growth and increase predictability [15]. Bioactive approaches such as osseointegration involve the direct physiochemical bond formation and most commonly involve the use of titanium implants. Roughening the implant surface at the nanoscale level is important for the cellular response that occurs in the tissue [14]. It increases osteoblastic adhesion considerably.

The addition of nano - size deposits of hydroxyapatite and calcium phosphate creates a more complex implant surface for osteoblast to regenerate [15]. e.g. Osseotite Dental Implant. Titanium implants treated with a nanostructured calcium surface coat were inserted into rabbit tibias, and their effect on osteogenesis was investigated; the nanostructured calcium coat increased the responsiveness of the bone around the implant [16].

Nano needles: Suture needles incorporating nano-sized stainless steel crystals have been developed. e.g. Sandvik Bioline, RK 91™ Needles . Nanotweezers are also under development that will make cell-surgery possible in the near future [7].

Orthodontic wires: Excessive orthodontic forces have been known to be harmful leading to loss of vitality, resorption etc. Orthodontic nanorobots would allow tooth straightening, changes in horizontal and vertical position of tooth without pain. Sandirk Nanoflex is a new stainless steel, which allows ultra-high strength combined with good formability, corrosion resistance and a good surface finish [17].

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 to genes and drugs to human liver has been developed by Osaka University in Japan [7].

Other Products Manufactured by SWRI [7]

a. Protective clothing and filtration masks, using anti pathogenic nano-emulsions 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 which are easily flowable, moldable paste that conforms to and inter digitates with host bone. It supports growth of cartilage and bone cells.

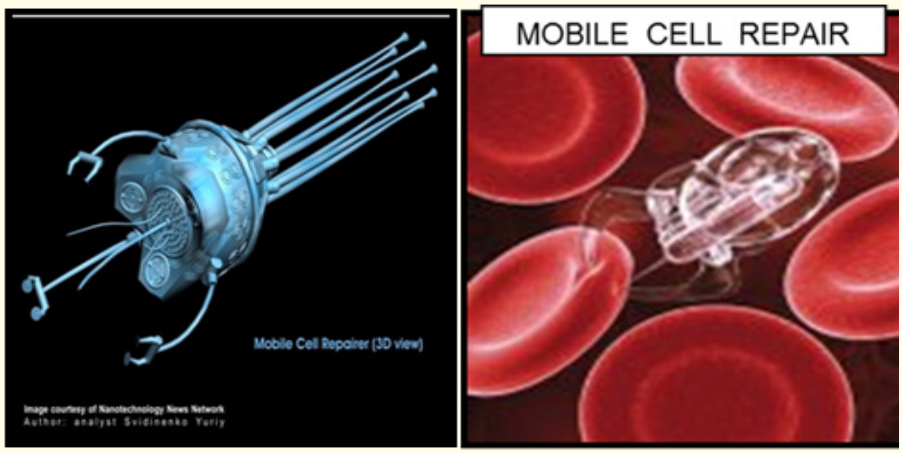
Future scope of nanodentistry

Anaesthesia

Imagine that you inject the anaesthetic solution and you can actually guide it through the gums and tooth pulp. Colloidal suspension carrying millions of active anaesthetic nanorobots is applied to the patients gingival which penetrates it & proceeds towards dental pulp painlessly through pathway directed by the dentists with the help of nanocomputer. When dentist select the icon the desired tooth numbs and the process is reversible. The nanorobot then egress out along the same way of ingress and are then aspirated. These all takes only 100 seconds [3]. The anaesthesia achieved is fast acting, reversible, reduces the complications associated with needle; making patient more comfortable and anxiety free.

Major tooth repair

Tooth structure loss is treated by various filling materials. These days we use nanofilled composites resembling as close as tooth structure. LET'S DREAM MORE... How about replacing the damaged tooth with natural tooth developed in vitro and placed in tooth socket using nanorobots. This may be the dream of today but may be reality of tomorrow [18]. Both mineral and cellular components would be regenerated and this will be made possible by nanodentistry along with tissue engineering.



Tooth renaturalization

Tooth renaturalization procedures may become a popular addition to the typical dental practice, providing perfect methods for esthetic dentistry. This trend may begin with patients who desire to have their old dental amalgams excavated and their teeth remanufactured with native biological materials [19].

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 compared to nanostructured composites which possibly include embedded carbon nanotubes [20].

Plaque control

Plaque is a bacterial biofilm and the main etiological agent for most dental and periodontal diseases is "bacteria". Daily plaque control measures can help prevent these diseases. Mouthwash or toothpaste could be used to deliver nano robotic dentrifices and could patrol all the supra and subgingival surfaces metabolizing trapped organic foods into harmless, odourless vapours thereby preventing colonization of microbes and eventually halitosis. They move throughout the supragingival and subgingival surfaces keeping them clean. In case they are swallowed, they are programmed to be deactivated.

Dentirobots could identify and destroy pathogenic bacteria residing in the plaque and elsewhere, while allowing the 500 or so species of harmless oral micro flora to be maintained in a healthy ecosystem. With this kind of daily dental care available from an early age, conventional tooth decay and gingival disease will disappear [7].

Orthodontic treatment

Orthodontic nanorobotic remodeling of periodontal tissues would allow painless tooth repositioning in unbelievable time span of few hour. So you walk in for an orthodontic treatment, watch television, listen to music and enjoy while your teeth are getting aligned and walk out with a perfect smile [4].

Dentin hypersensitivity

Dentin hypersensitivity occurs when the dentine tubules become exposed and opened. The fluid flow along these open tubules caused by mechanical, chemical or thermal stimuli can result in an uncomfortable pain response. The primary approach to treat dentin hypersensitivity is the occlusion of dentinal tubules. Presently we are using restorative procedures and hypersensitivity toothpaste for this. It's quite likely that with nanorobots, a precise and selective occlusion of dentinal tubules by active biomolecules would be possible, thus granting quick and permanent cure.

Diagnosis of oral cancer

With alarming number of cases of oral cancers, the early diagnosis of oral cancer is becoming essential but yet it is a great challenge for the dentists. However with the evolution of nanoprobes the diagnosis can be done by sensing large number of biomolecules and converting the biochemical signals into electric one thus speeding up early diagnosis of cancers [3].

Local drug delivery system

With nanotechnology it would be possible to deliver drugs in the specific tissues thus nullifying the adverse side effect on other tissues. Drugs can be incorporated into nanospheres composed of a biodegradable polymer, and this allows for timed release of the drug as the nanospheres degrade and also for site-specific drug delivery. E.g. ARESTIN which is minocycline hydrochloride incorporated in form of microspheres having specificity for the periodontal pockets [3].

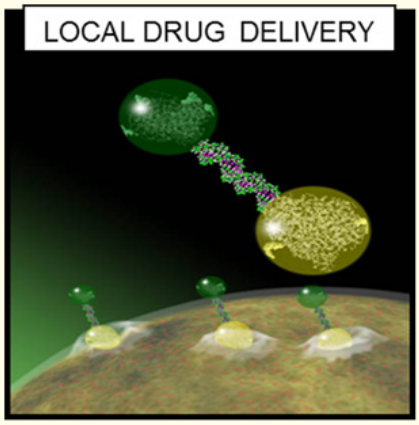


Photo sensitizers and carriers

Quantum dots can be used as photo sensitizers and carriers. They can destroy the target cell by binding 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 [3].

Conclusion

Preventive intervention is the new trend of oral health in the modern era and nanodentistry would give a new dimension to it. This science might sound like a fiction now, but Nanodentistry holds a strong potential. It opens up new ways for vast and abundant research work. Nanotechnology will change dentistry, health care and human life more profoundly than other developments. But there are larger social issues of public acceptance, ethics, regulation and human safety that must be addressed before molecular nanotechnology can enter the modern medical armamentarium.

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