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Nanotechnology and its Application in Dentistry- A Review

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ABSTRACT

Nanotechnology is one of the recent advances in the field of science. Nanotechnology is the manipulation of matter on the molecular and atomic levels. It has the potential to bring enormous changes into the fields of medicine and dentistry. Nanotechnology is believed to serve wide range of applications in the field of medicine and dentistry. Nanotechnology is used in the dental field as nano dentistry. While choosing the nanoparticle for the use in the field of nano dentistry its chemical, physical, along with the biological aspect of nanostructures are taken into account. The future holds in store an era of dentistry in which every procedure will be performed using equipments and devices based on nanotechnology. This article reviews the current status and the potential clinical applications of nanotechnology in dentistry.

1. Introduction

Nanotechnology is a highly multidisciplinary field of science, drawing from field such as applied physics, material science, interface and colloid science, device physics, supramolecular chemistry, chemical engineering and electrical engineering. It is the study of manipulating matter on an atomic and molecular scale.

The concept of nanotechnology first came into light in December 29, 1959 in a lecture on "there's plenty of room at the bottom "presented by physicist Richard Feynman at an American physical society meeting at Caltech. He described the idea of manipulating things on a very small scale by building them up one atom at a time.

Basic approaches used in nanotechnology

a. "**Bottom up"** approach- Materials and devices are built from molecular components which assemble themselves chemically by the principle of molecular recognition.

b. "**Top down**" approach- Nano objects are constructed from larger entities without atomic level control.

2. Bottom up Approach

1. Tooth Repair

Nanodental techniques for major tooth repair may evolve through several stages of technological development, first using genetic engineering, and tissue engineering and tissue regeneration and later involving the growth of whole new teeth in vitro and their installation. Ultimately, the nanorobotic manufacture and installation of a biologically autologous whole replacement therapy should become feasible within the time and economic constraints of a typical office visit, through the use of an affordable desktop manufacturing facility, which would fabricate the new tooth, in the dentist's office.

One aim of nanotechnology could be able to treat cavities at an early stage so it's not aggressive and non invasive and the patient does not need to keep coming back for treatment. Nanotechnology and modern dentistry concentrates on preventive techniques rather than restorative techniques.

Nano rods may also be used in restorative dentistry. They have structure similar to enamel specifically similar to the enamel rods (measuring 4-8 µm in diameter, enamel rods are tightly packed masses of hydroxyapatite crystals in an organized yet very complex pattern that make up the fundamental crystalline structure of enamel). Since they are similar to the enamel rods that make up the basic crystalline structure of the dental enamel, nano rods could contribute to a practical artificial creation of the naturally occurring structure.

2. Infection Control

After a treatment one cause of concern for dentist is infection, especially after a treatment such as extraction. Nanotechnology could aid in reducing the chances of infection after treatment. Nanorobots could contain antibiotics or disinfecting fluids within carriers such as buckyballs which can help to combat infection. They could be situated in vulnerable site and this would mean patients wouldn't have to put up with the pain of infection or the cost and time of another appointment sort it out.

3. Local anesthesia

Before a restoration, root canal treatment, crown or bridge preparation, extraction and many other dental procedures, an injection of anaesthetic is needed in the gum or palate to numb the area ready for treatment. Well known alternatives such as transcutaneous electronic nerves stimulation, cell modulation electronic targeted anaesthesia and other transmucosal intraosseous or topical techniques, are of limited clinical effectiveness.

To induce oral anaesthesia in the era of nanodentistry, dental professionals will install a colloidal suspension containing millions of active micrometer-sized dental nanorobot "particles" on the patient gingival. After contacting the surface of crown or mucosa the ambulating nanorobots reach the dentin by migrating into the gingival sulcus and passing

painlessly through the lamina propria or the 1-3 µm thick layer of loose tissue at the cemento-dentinal junction. On reaching the dentin, the nanorobots enter dentinal tubule holes that are 1 to 4 um in diameter & proceed toward the pulp, guided by a combination of chemical gradients, temperature differentials and even positional navigation, all under the control of the onboard nanocomputer, as directed by the dentist.

Once installed in the pulp and having established control over nerve impulse traffic, the analgesic dental nanorobots may be commanded by the dentist to shut down all sensitivity in any tooth that requires treatment. After the oral procedures are completed the dentist order the nanorobots to restore all sensation, to relinquish control of nerve traffic to egress from the tooth via similar pathways used for ingress; following this they are aspirated. Nanorobotic analgesics offer greater patient comfort and reduced anxiety, no needles, greater selectivity, and controllability of the analgesic effect, fact and completely reversible action and avoidance of most side effects and complications.

4. Dentin Hypersensitivity

The cause of dentin hypersensitivity is change in pressure transmitted hydrodynamically to the pulp. It's been found that the teeth which are hypersensitive have dentinal tubules with surface number densities that are eight times higher and the diameters of tubules are twice than those of non sensitive teeth. Dental nanorobots, using native biological materials, could selectively and precisely occlude the desired tubules providing fast and permanent cure.

5. Renaturalization of Tooth

Dentition renaturalization may become a perfect treatment method for aesthetic dentistry. For the patients who desire to have their old amalgam restorations enclave, the tooth is re-restored with native biological materials. So that it becomes indistinguishable from the original teeth.

6. Orthodontic Nanorobots

Orthodontic nanorobots could directly manipulate periodontal tissues, including gingiva, periodontal ligament, cementum and alveolar bone, allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours. This is in contrast to current molar uprighting techniques, which require weeks or months to complete.

7. Durability and Esthetics

Durability and appearance of tooth can be enhanced/improved by replacing upper enamel layers with pure sapphire and diamond are which can be made fracture resistant as nanostructured composite material that possible includes embedded carbon nanotubes.

8. Nanorobotic Dentifrice

Nanorobotic dentifrice delivered by mouthwash or toothpaste could patrol all supragingival and subgingival surfaces atleast once a day metabolizing trapped organic matter into harmless and odourless vapours and performing continuous calculus debridement.

These dentifrobots would be inexpensive, purely mechanical devices that would safely deactivate themselves if swallowed and would be programmed with strict occlusal avoidance protocol.

9. 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 ultraviolet light, they can give rise to reactive oxygen, species and thus will be lethal to the target cells.

10. 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

a. Diagnosis of diabetes mellitus and cancer b. Detection of bacteria, fungi and viruses.

11. Treatment of oral Cancer

- Nanomaterials for brachytherapy.
- Drug delivery across the blood-brain barrier/ more effective treatment of brain tumors, Alzheimer's, Parkinson's in development.
- Nanovectors for genetherapy- non viral gene delivery system.

3. Nanodentistry as top down approach

1. Nanocomposites

A Nanocomposite is a multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nm, or structures having nano-scale repeat distances between the different phases that make up the material. In mechanical; electrical; thermal, optical; electrochemical; catalytic properties of the Nanocomposites will differ markedly from that of the component materials size limits for these effects have been proposed <5 nm for catalytic activity, <20 nm for making a hard magnetic material soft, <50 nm for refractive index changes and <100 nm for achieving superparamagnetism, mechanical strengthening or restricting matrix dislocation movement.

Advantages

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

2. Nanosolutions

Nanosolutions produce unique and dispersible nanoparticles, which can be used in bonding agents. This ensures homogeneity and ensures that the adhesive is perfectly mixed every time.

3. Impression materials

Nanofillers are integrated in vinyl polysiloxane producing a unique addition of siloxane impression materials. The material has better flow, improved hydrophilic properties and enhanced detail precision.

4. Nanoencapsulation

Nanoencapsulation is the coating of various substances within another material at sizes on the nano scale. Application:

- Targeted drug delivery system that releases the only when the drug has arrived at the site in the body where it is required.
- Timed release drug delivery where the Nanoencapsulation material slowly allows the drug to be released into the body such as nasal delivery of insulin. The coating material can be customized to determine the rate of delivery.
- Embedded fragrances for branded perfumed clothing.
- Food additions and food enhancements such as omega-3 fatty acid addition to bread that do not alter taste.
- Increasing shelf life and stability of products like vitamins.

5. Other products manufactured by SWRI (South West Research Institute).

1. Protective clothing and filtration marks, using antipathogenic nanoemulsions and Nanoparticles.
2. Medical appendages for instantaneous healing.
   Biodegradable nanofibers delivery platform for haemostasis.
   Wound dressings with silk nanofibers in development.
   Nanocrystalline silver particles with anti-microbial properties on wound dressing.

3. Bone Targeting Nanocarriers

Calcium phosphate based biomaterial has been developed.

This bone biomaterial is an easily, flowable, mouldable paste that conforms to & interdigites with host bone. It supports growth of cartilage & bone cell.

6. Nanoneedles

Suture needles encorporating nanosized stainless steel crystals have been developed. Nanotweezers are also under development which will make cell surgery possible in the near future.

4. Ethics of Nanotechnology

There are many ethical issues surrounding nanotechnology, some are not specific to medicine whereas others are. Nanotechnology gives us more "god like" powers which many people believe is wrong as we are not his equal. It is unnatural for us to recreate molecules from such fundamental principles. Another concern regarding nanotechnology is on health of a person. Nano particles have a large surface area: volume ratio. The greater the specific surface area the more chance it could lead to increased rates of absorption through the lungs, skin or digestive tract, this could cause unwanted effects on the lungs and the other organs in the body, as non degradable nanoparticles could accumulate.

The next thing to be considered is potential interaction with natural biological processes in the body. This is primarily down to their large surface area, nano particles, upon exposure to tissue and fluids will straight away absorbed onto their surface some of the macromolecules they encounter.

1. Challenges faced by nanotechnology
2. Precise positioning and assembly of molecular scale part.
3. Economical nanorobot mass production technique.
4. Biocompatibility
5. Simultaneous co-ordination of activities of large members of independent micron scale robots.
6. Social issues of public acceptance ethics, regulation and human safety.

5. Nanotechnology and Society

Since society is the consumer, funding party, and policy and decision maker, the public's attitude towards nanotechnology plays a fundamental role in its success and failure, in other words society is the judge and jury. This is driven by ethics, morals, and values that have recently became more accepting of the new sparking technologies as the perceived benefits outweigh the perceived risks (10). However, although nanotechnology is currently integrated in fields that directly affect the public such as in energy supply, health care and diagnostics, telecommunications, and pollution control, this has created fear as these advancements might cost the public thousands of jobs to accommodate for a more machinery reliant system (11).

In an effort to address social concerns, various initiatives were put in place to bridge the gap between society and nanoscience. The National Nanotechnology Initiative report claims that advancement in technology will require a new generation of trained workers with advanced set of operational and managerial skills (12). In 2003, Technologist Ray Kurzweil claimed that: ''Portable manufacturing systems will be able to produce virtually any physical product from information for pennies a pound, thereby providing for our physical needs at almost no cost" (13). This calls for an immediate engagement with the public to address concerns and spread awareness on current and future applications of nanotechnology to gain and maintain public support.

6. Conclusion

It would be difficult to reject the idea of nanotechnology as it has already infiltrated so many areas of society. However

there should be regulation and guidelines in the development of nanotechnology so that it does not become out of control. It should also be taken in account different religious and the medical ethics.

It is believed that the use of nanotechnology could be very valuable in the field of dentistry and result in a number of new minimally invasive procedures with shorter recovery period for the patient, less time required for the treatment, few external scars and less painful procedures.

However there are certain issues and problems regarding the use of nanotechnology since it is very recent discovery. As the long term effects of nanotechnology are unknown, therefore problems caused by nanotechnology might not show for many years.

When it comes to the use of nanotechnology, we should not totally rely on nanotechnology as it could become out of hand but merely use of it along side our current treatment methods, to improve and enhance the dental experience.

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