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REVIEW ARTICLE

Nanotechnology: A Boon to Dentistry

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ABSTRACT

Nanotechnology influences almost every facet of everyday life from security to medicine. The concept of nanotechnology is not new. It all started with a macroscopic level and as the name suggests, turned gradually to microscopic, and hence even at the levels of a nanometer. The basic principles and ideas of nanotechnology got adapted and were even applied to the basic structure of matter, i.e., an atom. Nanotechnology has been used in various aspects of medicine earlier and later in various dental disciplines. The field of nanotechnology revolutionized dentistry with the potential to provide a comprehensive oral health care. It has been used in various diagnostic and treatment aspects pertaining to dentistry. This review focuses about the significance of nanotechnology in the field of dentistry.

Keywords: Dentifrobots, Nanocomposites, Nanodentistry, Nanorobots, Nanotechnology.

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INTRODUCTION

Nanotechnology or nanoscience refers to research and development of an applied science at the atomic or molecular level (i.e., molecular engineering, manufacturing). "Nano" is derived from the Greek word for "dwarf" and nanotechnology is the science of manipulating matter measured in the billionths of meters or nanometers, roughly the size of 2 or 3 atoms.

Recent years have witnessed an unprecedented growth in research in the area of nanoscience. There is increasing optimism that nanotechnology applied to medicine and dentistry will bring significant advancement in the diagnosis, treatment, and prevention of disease.[1]

Nanotechnology also known as molecular engineering is the production of functional materials and structures in the range of 0.1 to 100 nanometers by various physical or chemical methods.[2]

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NANOROBOTS

Nanorobots are robots prepared at the nanoscale. Nanorobots will allow us to construct such crystals molecule by molecule as incredibly fine-grained atomic structures, following a detailed blueprint.

Nanodentistry will make possible the new potential treatment opportunities in dentistry, which include, local anesthesia, dentition renaturalization, permanent hypersensitivity cure, complete orthodontic realignments during a single office visit, covalently bonded diamondized enamel, continuous oral health maintenance using mechanical dentifrobots,[1] and creation of artificial bone and teeth.[3]

HISTORY

The vision of nanotechnology was introduced in 1959 by late Nobel physicist Richard P Feynman. By the recent advances made in this field, his words have started forecasting its meaning, however, it was the Japanese scientist Norio Taniguchi of the Tokyo University of Science who first employed the term "nanotechnology" in 1974. The term "nanotechnology" was ultimately coined by Professor Kevie E Drexler in his 1986 book titled Engines of Creation: The Coming Era of Nanotechnology.[4]

Overview of Nanoparticles

The various nanoparticles[5] have special properties, such as chemical, optical, magnetic, and electro-optical properties which differ from those of either individual molecules or bulk spices. The improved relevant properties include enhanced toughness, stiffness, improved transparency, increased scratch, abrasion, solvent and heat resistance, and decreased gas permeability.[6]

APPLICATIONS IN DENTISTRY

Anesthesia

A suspension containing large numbers of active analgesic dental nanorobot "particles" migrate into the

gingival sulcus and then through the lamina propria and the dentinal tubules when placed. Once installed in the pulp, the robots may be commanded by the dentist to shutdown all sensitivity in any particular tooth that requires treatment.[7]

Tooth Repair

Chen et al used various aspects of nanotechnology to help tooth to remineralize, hence creating the hardest tissue in human body, i.e., dental enamel by using highly organised micro-architectural units of nanorod, such as calcium hydroxyapatite crystals arranged roughly parallel to each other which helped in the entire mineralization process making the tooth more resistant to any decay.[8]

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, which will be lethal to the target cell.[9]

Diagnosis of Oral Cancer

Oral cancer can be diagnosed with nanoelectromechanical systems (NEMS), cantilever array sensors and multiplexing modality.

Nanoneedles

Suture needles in the form of nanoneedles can be used for performing various dental procedures. Nanotweezers are also used, however, still under research to prove their efficacy in the field of dentistry.[10]

Implants

These implants use nanometer scale calcium phosphate to create a more complex topography on the implant surface, which has proven to expedite osseointegration by 150%, thereby decreasing the length of treatment by 1 or 3 months. Many nanoscale modifications have been done to improve the surface topography of dental implants.[11]

Salivary Diagnostics powered by Nanotechnology

Miniaturized saliva-based diagnostic technologies will enable the use of minute amounts of bodily fluids to yield critical patient information that reflects health and disease status and allow clinicians to achieve real time and simultaneous assessment of multiple diseases. The NEMS biosensors exhibit high levels of sensitivity and specificity for analyte detection, down to the single molecule level.[12]

Nano Glass Ionomer

"Nanoionomers," have been used and have proved their efficacy as compared to the conventional glass ionomer cements and composites. Research studies have proven the excellent results of these materials over the conventional materials.[13]

Coating Agents

These light-cured agents contain nanosized fillers and are used as a final coating over composite restorations, glass ionomer restorations, jacket crowns, veneers, and provisionals.[14]

Hypersensitivity Cure

Nanorobots could selectively and precisely occlude selected tubules in minutes, offering patients a quick and permanent cure as compared to the other methods of desensitization. This analgesic technique is patient friendly as it reduces anxiety, needle phobia, and most importantly, quick and has completely reversible action.[15,16]

Nanotechnology Microscope

Nanotechnology is emerging to underpin a new generation of deep probe detectors; a new area of the electromagnetic spectrum is becoming available for probing the human body and revealing hidden matter. This is known as Terahertz radiation, the area is in between light and radio waves in the spectrum. It can be used to see tumors within the skin and more importantly to spot cavities in teeth.[17]

Nanoparticles as Antimicrobial Agents

Nanoparticulates exhibit higher antibacterial activity as a result of their polycationic or polyanionic in nature with higher surface area and charge density, resulting in a greater degree of interaction with the bacterial cell. It has been used as a carrier for the delivery of drugs and gene *in vivo* to treat various systemic diseases and have low levels of cytotoxicity. These have been shown to provide a significant improvement in the root canal disinfection by effectively eliminating the residual adherent and nonadherent bacteria as well as increasing the diffusion of antibacterial components from the root canal sealers.[18]

Nanotechnologybased Root-end Sealant

Nanomaterial enhanced retrofill polymers provide better bond strength and adaptability to the tooth structure and have really proved their worth in comparison to the other root end sealants.[19]

Nanotechnology: Role in Dental Biofilms

Nanotechnology helps in understanding of the role of interspecies interaction in the development of biofilm and used to study the dynamics of demineralization/remineralization process in dental caries by using tools, such as atomic force microscopy which detect bacteria induced demineralization at an ultrasensitive level. Another nanotechnology application used so far is $^{16}O/^{18}O$ reverse proteolytic labelling to determine the effect of biofilm culture on the cell envelope proteome of oral pathogen, Porphyromonas gingivalis which is linked to chronic periodontitis.[20] It is effective against *Escherichia Coli, Streptococcus Pneumoniae, Staphylococcus Aureus* and *Aspergillus Niger*.[21]

Oral Hygiene and Halitosis

Since bacterial putrefaction is the central process of oral malodor, these nanorobots will work to stop this process by destroying the bacteria residing in the plaque and elsewhere in the tooth and gingival surfaces.

Stronger Resin-based Composite

Nanoscale silica-based fibers have also been produced that produce a resin-based composite nearly twice as strong as the conventional resin-based composite materials.

Impression Materials

Impression materials can also be used by incorporating various nanofillers for example in polyvinyl siloxanes impression materials, producing a unique additional silicone elastomeric impression material that have better flow and precision properties.

Orthodontic Treatment

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

Surgical Nanorobotics

A surgical nanorobot, programmed or guided by a dentist, could act as a semi-autonomous on-site surgeon inside the human body. Such a device could perform various functions, such as searching for pathology and then diagnosing and correcting lesions by nanomanipulation, coordinated by onboard computer while maintaining contact with the supervising surgeon via coded ultra sound signals.

Renaturalization Procedures

Dental renaturalization may begin with the patients who desire to have their dental amalgam restorations excavated and their teeth remanufactured with the native biological materials that will become indistinguishable from the original teeth.

BONE REPLACEMENT MATERIALS

Nano-hydroxyapatite is more biodegradable and highly biocompatible as compared to micro-hydroxyapatite. These materials can be incorporated in various aspects of dental practice particularly dental implants thereby aiding in osseointegration because of increased osteoblastic differentiation.

Periodontal Tissue Engineering

Tissue engineering concepts for periodontal regeneration are focused on the utilization of synthetic scaffolds for cell delivery purposes. Non-biologic self-assembling nanosystems will automatically undergo prespecified assemblies much in line with known biologic systems associated with cells and tissues.

Nanomaterials for Periodontal Drug Delivery

Various drug delivery systems have been used, however, involving more of the nanoparticles to these systems helped to achieve better results as compared to the conventional systems.

Limitations and Risks

There are certain limits to what nanotechnology can accomplish:

- Reducing the size of structures to a nanolevel results in distinctly different physical properties and these have not been largely evaluated till date.
- Currently procedures of nanotechnology are costly but this might not be an issue once they are manufactured on a large scale.

CONCLUSION

Keeping in view, the various applications of nanotechnology in the field of dentistry apart from being in medicine, there has been tremendous research in the field of nanotechnology in the past few decades. Nanotechnology has definitely proved to be a boon for dental fraternity, however, more research is required to prove its efficacy. Considering the various advantages and limitations of nanodentistry, it can be rightly said that it is the "Future of Dentistry."[22]

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