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Review Article

Nanotechnology in dentistry: A review

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ABSTRACT

Our quest to create new technology and the ever-increasing demand for advances in diagnosis and treatment modalities has led to the advent of nanotechnology. Nanotechnology employs structures measured in the billionth of a meter or nanometer. This technology has exceptional capability of groundbreaking results in the field of medicine. When nanotechnology is applied to dentistry, it is known as nanodentistry. This article summarizes the applications of nanotechnology in dentistry.

Keywords: Nanotechnology, nanodentistry, nanorobots, nanocomposites

Introduction

Nanotechnology deals with the manipulation of materials at the nanoscale.[1,2] The term 'Nano' originates from a Greek word meaning "dwarf." The concept of nanotechnology was introduced in 1959 by Richard Feynman, a Nobel Prize winning physicist in a lecture titled, "There's plenty of room at the bottom." He concluded, "this is a development which I think cannot be avoided."[3] Nanotechnology utilizes individual atoms and molecules to construct functional structures. The term "nanotechnology" was coined by Prof. Kerie. E. Drexler who emphasized on the technological importance of nanoscale phenomena. Any synthetic material does not have the ability to react to external stimuli like natural tissues. Following are the possible ways of creating such materials which can mimic the natural ones:

- Material synthesis: Producing similar materials with regard to morphology and properties as that of natural dental tissues.
- Tissue engineering: Using regenerative medicine and tissue engineering concepts for replacing the lost dental tissues by regeneration.
- Biomimetic approaches: It deals with the replacement of lost dental tissues by producing biomaterials resembling closely to the original tissues.

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All these approaches are feasible only with the intervention of nanotechnology. The dental hard tissues such as enamel, dentin, and cementum are composed of nanoscale structural units.

The fabrication methods of these structures can be grouped into two approaches.[4,5]

a. Top-down approach:[6] This approach utilizes larger particles to make nanoscale structures in precise patterns.
b. Bottom-up approach:[7] This approach employs smaller components to create compound structures.

The current research is aimed at producing an array of various nanoscale structures.

Nanostructures used in dentistry.

Following are the various nanostructures which can be used in dentistry:

- Nanofibers – Nanofibers silicate crystals have been studied for their potential in reinforcing dental composites. They can significantly improve the physical properties of composites when added in appropriate proportion.
- Dendrimers – These are macromolecules produced by a series of branches around an inner core. Combinations of specific polymers to improve the efficacy of restorative applications have been reported.[9]
- Nanopores – Titanium surfaces with nanopores of 30nm have been shown to promote early osteoblastic differentiation and consequently, rapid osseointegration of titanium implants.[10]
- Nanoshells – These are miniature beads coated with gold. By manipulating the thickness of the layers making up the nanoshells, these beads can be designed to absorb near-infrared light, creating an intense heat, which is lethal to cancer cells.[11]

- Nanotubes – Titanium oxide nanotubes have been used *in vitro* to accelerate the kinetics of hydroxyapatite formation. This can serve as a coating of the implant to accelerate bone growth.
- Nanorods – They can serve as an artificial approximation of enamel rods.[12] They exhibit self-assembly properties.
- Nanoparticles – Among nanoscale units, they are the most extensively used particles in dentistry. They range in diameters of 0.1–100 nm.

Applications in dentistry

- Dental nanorobots: They have the capability to move through the teeth and surrounding tissues. A pre-programmed computer can control their movement and function.[3] They can be employed to achieve the desired function and can be deactivated when required.
- Dentinal hypersensitivity: Using the available biological materials, the dental robots can occlude the exposed dentinal tubules offering a quick relief from hypersensitivity.[13]
- Nano-orthodontics: Orthodontic nanorobots can achieve rotation and vertical repositioning of tooth within minutes to hours as compared to current orthodontic techniques.
- Nanorobotic dentifrice: Nanorobotic dentifrice delivered by mouthwashes or toothpaste can check tooth surfaces for trapped organic matter and clean it off by metabolizing it.[14]
- Local anesthesia: A colloidal suspension of millions of active analgesic dental robots can be delivered in the oral cavity. They reach the pulp through dentinal tubules and lamina propria. After reaching the pulp, the dentist commands these robots to shut all sensitivity in the required tooth, and after completion of the procedure, the normal sensation can be restored.
- Diagnosis and treatment of oral cancer: Nanotubes can detect the affected genes and their precise location which can be useful in diagnosis of oral cancer. Nanomaterial for brachytherapy BrachySil TM (Sivida, Australia) delivers 32P which is useful in the treatment of cancer.
- Nanocomposites: Nanoparticles evenly distributed in composite resins have been successfully used.[8] The nanofiller used in composites exhibit superior physical properties leading to the excellent clinical outcome.[5]
- Nano solutions: Nano solutions produce dispersible nanoparticles, which in turn can be used in bonding agents. This ensures uniformity in the bonding agent and ensures that the adhesive is perfectly mixed every time.
- Nanoneedles: For the purpose of suturing, needles incorporated with nano-sized stainless steel crystals have been developed.
- Impression material: Nanofillers are incorporated into vinyl polysiloxanes which provide better flow and detailed precision. It is marketed as Nanotech Elite HD$^+$.[15]
- Nanocomposite artificial teeth: Inorganic nanofillers are evenly dispersed in artificial teeth. This helps to achieve a smoother surface of teeth which makes the teeth more durable in the long run.[16,17]
- Nanotechnology in prevention of dental caries: Silver, zinc oxide, and gold nanoparticles incorporated into toothpastes can significantly lower the antimicrobial action of *Streptococcus mutans* which causes dental caries.[18]
- Digital dental imaging: To obtain high-quality images and to lower the radiation dose, nanophosphor scintillators can be used in digital dental imaging techniques.[19]
- Prosthetic implants: Nanotechnology would help in developing implant surfaces with definite topography and chemical composition leading to predictable tissue integration.[20]
- Major tooth repair: Nanotechnology can utilize genetic engineering, tissue engineering and tissue regeneration initially, followed by growing new tooth *in vitro* and their installation.
- Periodontal drug delivery: Nanoparticles impregnated with triclosan can be used for periodontal drug delivery. Application of triclosan particles into the test area alleviated inflammation.[21] This gives a clue that targeted drug delivery with nanomaterials is possible for other treatments as well. The best example of the future use of this technology is a procedure called Arestin, in which microspheres containing tetracycline are placed into periodontal pockets, and tetracycline is administered locally.

Challenges

Although nanotechnology sounds very promising in the field of dentistry, it still faces significant challenges in realizing its potential. Following are the issues which should be addressed before considering it as a major hope for the future.

- It is essential to regulate and standardize the characterization, safety and environmental impact of nanomaterials.[22] At present, these nanoparticles are not subject to any special regulation regarding their production, handling, and labeling.
- Nanomaterials released in the environment can be further modified by temperature, pH which can alter the soil, water and prove harmful to flora and fauna. Once they enter the body, they can cross the blood-brain barrier also. As long-term effects of nanotechnology are unknown, potential hazards might not show for many years.
- The fabrication and delivery of nanoparticles are an expensive procedure which has sub-optimal funding currently.
- The biocompatibility of nanomaterials is yet to be established.
- Social issues of public acceptance, ethics, and human safety have to be further contemplated upon.

Conclusion

Although the effect of nanotechnology on dentistry is limited at present, rapidly progressing investigations and research will ensure that nanotechnology is going to be the next big thing. It will have a far-reaching effect on oral health and developments which seem unrealistic today will help to achieve a near to perfect oral health in future. As with all emerging technologies, a successful future for nanotechnology in dentistry will only be achieved through exchange of ideas and research findings.

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