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Review Article

Nanotechnology - An advanced dental innovation

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ABSTRACT

Researchers are interested in exploring the possible uses and advantages of nanotechnology compared to traditional materials, particularly in the domains of dentistry and medicine. The study and creation of materials, tools, systems with distinct biological, chemical, physical characteristics from those found in larger system is known as nanotechnology. Numerous advancements and improvement in oral disease prevention, diagnosis, and treatment are possible because of nanotechnology. Recent Nano - technology breakthrough developments in dentistry are progressively providing a viable therapeutic option for a wide range of dental problems. The purpose of this review was to provide an overview role of nanotechnology in dentistry, as well as to evaluate its application in the prevention and treatment of oral disorders, along with providing crucial new updates on the various nanotechnology – based techniques for dental disease management. The current review will also assist the reader in comprehending Nano science, as well as its benefits and drawbacks, by discussing its ethical, social, and health consequences. In addition, Nano -applications in dental diagnostics and their function in dentistry will be discussed.

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1. Introduction

Nanotechnology is the art and science of material engineering on a scale of less than 100 nm. Norio taniguchi of the Tokyo science university, for the first time defined the term nanotechnology in a paper published in 1974 on nanotechnology and concluded that it mainly consists of the processing of separation, consolidation and deformation of materials by one atom or one molecule.[1]

According to definition provided by national nanotechnology initiative, nanotechnology is the research and development of materials, devices and system exhibiting physical, chemical and biological properties that are different from those found on lager scale.[2]

Artificial or natural materials that have at least one dimension smaller than 100nm are known as nanomaterials. These materials can include atom clusters grains less than 100nm, fibres with a diameter smaller than 100 nm, for example nanoholes and composites made of a combination of these.

2. Generations (Table 1)

2.1. Properties

1. Nanomaterials perform better than conventional materials thanks to their notable surface effects, size effects, and quantum effects.
2. They are distinct from related materials, either as individual molecules or on a larger scale, in their unique chemical, optical, magnetic, and electro-optical properties.

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Table 1: There are four generations of nanotechnology introduced by Mike Roco of the U.S National Nanotechnology Initiative[3–5]

Genrations	Name	P products	Year
1^{st}	Passive nanostructures	(a) Dispersed and contact nanostructures (ex. Aerosols, colloids) (b) Products incorporating nanostructures (ex. Coatings, Nanoparticle reinforced composites nanostructured metals, Polymers, ceramics (Materials designed to perform one task)	2000
2^{nd}	Active nanostructures	(a) Bioactive health effects (ex. Targeted drugs, biodevices) (b) Physicochemical active (ex. 3D transistors, amplifiers, adaptive structures) (For multitasking eg. drug delivery devices and sensors)	2005
3^{rd}	Integrated Nano systems	Ex. Guided assembling,3D networking, robotics) Features nanosysems with thousands of interacting components	
4^{th}	Molecular Nanosystems	(Ex. Molecular devices by design atomic design, emerging functions)	2015- 2020

3. They possess the crucial ability to self – assemble.
4. Without outside assistance, they self-organize into structures or patterns.
5. Usually, the right conditions may be made to manipulate and facilitate this self-assembling capability
6. Self-assembly is primarily driven by electrostatic attractive interactions between positive and negative charges.

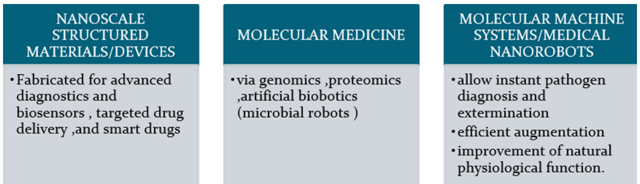

Figure 1:

3. Applications of Nanotechnology

3.1. Diagnostics

The concept of nano-biosensing was established with the aim of enhancing medical diagnostics. An analytical tool that combines a biological active component with a suitable physical transducer to produce a detectable signal proportional to the concentration of chemical species in any kind of sample is called biosensor. Nanobioreceptors will integrate nanotubes, and Nanodotes, nanowires into the sensing assembly of the nanobioreceptors were introduced in an effort to enhance the biorecognition process of the bioreceptor and overall bioreceptor and overall performance. One of the three approaches – top down, bottom up, or molecular self-assembly is used to generate nanoparticles. The biosensor can be converted into nanobiosensors by substituting nanosized particles for micro sized ones. This has the benefit of quickly detecting specific biological tissues at an ultra-low molecular level, for example, its great sensitivity is especially helpful in the diagnosis of cancer as nanobiosensors, as opposed to the traditional biosensors, can identify cancer cell chemicals at very early stages and in very low concentrations.[6,7]

According to Floriano et al.[8] salivary Nano- scale biosensors are beneficial in detecting acute myocardial infarctions, thereby assisting in identifying changes in patients.

3.2. Nanomedicine

Human health can be preserved and improved through the use of complex molecular machine systems, genetic engineering, biotechnology, and nanoscale structured materials. Chemotherapeutic chemicals can be accurately delivered to target cells using nanorobots, which can be used in chemotherapy to treat cancer.[9–11] This would be a smarter and more effective approach that would spare normal cells from adverse effects.

In 2000, R.A Freitas[12] coined the term ‘pharmacytes’ to describe drug delivery nanorobots. Medical nanorobots are thought to enhance immune system performance through pathogen, viral and other hazardous microorganism detection and deactivation.

3.3. Local anesthesia

In the field of nanodentistry, anesthetic is administered to the patient by injecting a colloidal suspension that contains millions of active analgesic micron-sized dental robots on the patient’s gingiva causing anesthesia.[13]

3.4. 3D Printed tissue enginering scaffolds

Tissue engineering is defined as an interdisciplinary field which basically aims to combine life sciences and engineering to create therapies that regenerate functional tissue. Research has demonstrated that building scaffolds from biologically active materials can aid in regeneration by permitting cell-scaffold interactions or the release of the substances that aid in regeneration. Previously, tissue engineering efforts primarily used materials as inert scaffolding structures. A possible method for creating scaffolds for tissue engineering that is both structurally and compensation ally complicated is three-dimensional (3D) printing. These scaffolds can be further enhanced in their capacity to promote regeneration and interact with cells by functionalizing them using methods pioneered in nanotechnology research. The creation of 3D printed scaffolds can make use of nanoscale textures, nanotechnological elements, and micro scale/nanoscale printing.[14]

3.5. Nanotechnology for hypersenstivity management

One of the most prevalent dental problems brought on the exposed tooth roots is hypersensitivity. It can because by changes in pressure transmitted hydrodynamically to the pulp. This is based on the fact that hypersensitive teeth have eight times higher surface density of dentinal tubules and that is why the tubular diameters are twice as large as nonsensitive teeth. By adding nanorobots to dentinal tubules, patient's hypersensitivity problem is permanently resolved as the sensitive tubules in question become more occluded. These dentinal tubules are where gold nanoparticles are more frequently used. Furthermore, by desensitizing reducing the number of microtubules in mineralizing agents, and inhibiting microtubules, reconstructive dental nanorobots can also selectively manage hypersensitivity.[15]

Compared to their nonosensitive counterparts, natural hypersensitive teeth have much larger dentinal tubule surface densities and diameters. Using natural biological materials, reconstructive dental nanorobots could quickly and permanently heal patients of dentin hypersensitivity by precisely and selectively occluding the dentinal tubules

3.6. Nanomaterials for oral hygiene maintenance

Mouthwash is being made with nanorobots in order to more readily detect and eliminate the harmful bacteria, leaving healthy oral flora to thrive in the oral ecosystem. Additionally, it would detect plaque, tartar, and food particles and pull them off the teeth so they could be cleaned, leaving the oral cavity clear and free of food particles and plaque. To distribute periodontal drug locally, hollow sphere, core-shell structures, nanotubes, and nanocomposite can be employed.

3.7. Nanomaterials for the treatment of wound healing and bone defects

Bone is a naturally occurring composite with a nanoconstructive made of inorganic (hydroxyapatite crystals) and organic (compound) reinforcement. Nanotechnology is used to heal bone defects with nano-bone graft materials, particularly helpful in the repairing. A nano bone graft ought to have the same characteristics as contemporary bone grafts. He best way to correct infrabony flaws is the take advantage of their larger surface area to mass ratio. The development of nanoneedles and nanotweezers will also enable cell surgery in the near future.[16] Azeltine et al[17] claimed that nanomaterials facilitate and quickens the healing process of wounds.

3.8. Nanomedicine in periodontal drug delivery

Nanomaterials are interesting because, when the size of the constituent particles of a material decrease, the material's characteristics—such as it's optical, electrical, and physical qualities—change. New applications of nanoparticles have been proven or suggested in fields as diverse as microelectronics, coatings and paints, and biotechnology.[18] With new qualities come new prospects for scientific and commercial development. The creation of nano pharmaceuticals, nanosensors, nanoswitches, and nanodelivery systems has resulted from these uses. Each of these is extremely important, in the area of targeted or localized drug delivery.

In an attempt to develop a novel delivery mechanism suitable for the treatment of periodontal disease, Pinon-Segundo et al[19] recently generated and analyzed triclosan-loaded nanoparticles using the emulsification-diffusion technique. Poly (D, L-lactide-co glycolide), poly (D, L-lactide), and cellulose acetate phthalate were used to create the nanoparticles. Vinyl alcohol, or poly, was employed as a stabilizer. To assess the impact of the medication on the characteristics of nanoparticles, batches containing varying concentrations of triclosan were created. According to release kinetics, when the medication is released, the depletion zone advances toward the center of the apparatus.

This behavior implies that the diffusion is controlling factor of the release.

For controlled drug release, nanomaterials that include hollow spheres, core-shell structures, nanotubes, and nanocomposite have been thoroughly investigated. All of these materials could potentially be developed in the future for periodontal medication delivery systems.[20,21] Drugs can be added to biodegradable polymer nanospheres, enabling the medicine to be released gradually as the nanospheres break down. The recent invention of ArestinÒ in which tetracycline is integrated into micro-spheres for local drug administration to a periodontal pocket, is an excellent illustration of how this technology may be developed.[22]

3.9. Diagnosis of oral cancer (Figure 2)

3.9.1. Nanoscale cantilever

These are flexible beams that resemble a line of diving boards and can be designed to bind to molecules linked to cancer.

3.9.2. Nanopores

One strand of DNA at a time can flow through these microscopic pores. They will improve the effectiveness of DNA sequencing.

3.10. Quantum dots

Nanomaterial's termed quantum dots emit a brilliant glow when exposed to UV light. They can be covered in a substance that causes the dots to adhere only to the target molecule for tracking. Quantum dots actually highlight malignancies by attaching themselves to proteins specific to cancer cells.

3.11. Nanotubes

These are carbon rods, roughly half the diameter of DNA molecule, that can identify changed genes and potentially assist researchers in determining the precise location of those alterations.[21,23]

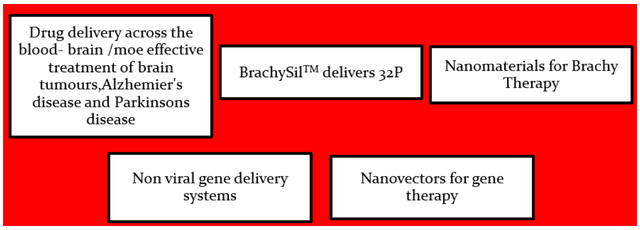

Figure 2: Treatment of oral cancer[24]

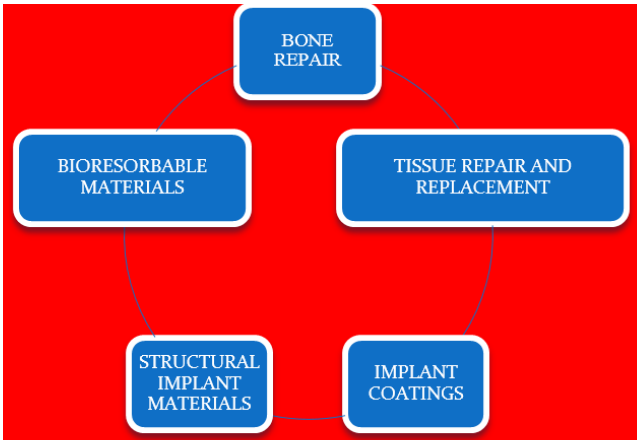

Figure 3: Implantable materials

4. Implications of Nanotechnology

4.1. Ethical implications

Any specific dental or medical nanoproduct that has undergone considerable research and development is put through a battery of tests, including a preclinical in vitro testing phase that looks into the product's mechanical, toxicological, and immunological potential. Guidelines for examining the dangers of nanomaterials have been introduced by numerous agencies, including the National Institute of Occupational Safety and Health and the U.S. Environmental Protection Agency**.** The ethical committee uses standardized ethical decision-making processes, primarily utilitarianism, which is out of step with the swift advancement and unpredictable nature of nanotechnology-related goods and advances. Because of this, a deeper comprehension of the science is needed, along with risk/benefit analysis and ethical concerns at every stage of development.

This resulted in the notion of anticipatory ethics and governance being proposed. It was created to use ethical analysis models to detect and solve ethical and societal issues when the technology is still in its early stages of development.

Figure 4: Limitations in the field[25,26]

5. Challenges Faced in Nanodentistry

Even while we have a lot of hopes and ideas for nanotechnology, the majority of them are currently unattainable because of a variety of issues, including social, biological, and engineering difficulties. Accurately positioning and assembling the nano molecular scale component is quite difficult.

In the field of nanotechnology, biologically compatible compounds that are economically, ecologically and morally acceptable are still a way off.

6. Future Perspective and Conclusion

This article has illustrated how advancements in Nano-dental science have improved teeth's quality, appearance, wear ability, resistance, sensitivity, and hyperactivity. It is anticipated that nanotechnology will deeper and develop further and find other uses in the scientific study of health. This prediction is supported by the possible advantages and cost effectiveness; the advantages for the public, workplace, socio environment; and risks related to Nano – dental research. While attempting to address its shortcomings, researchers have been developing deeper and deeper into the field of Nano-dental science throughout time. Future study should focus on overcoming the constraints placed on the nanodental sector and modifying the sociocultural and economic agenda to fit within the boundaries of therapeutic applications of nanodentistry.

In the near future, it is expected that conventional treatment procedures will be replaced by nanodentistry. Scientists must continue to be committed to Nano-research at this time, handle any obstacles, perform safety evaluation, and create marketing acceptance and promotional plans.

7. Source of Finding

None.

8. Conflict of Interest

None.

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