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Nanotechnology in Periodontics: A Review

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ABSTRACT

The emerging science of nanotechnology, especially within the dental and medical fields, sparked a research interest in their potential applications and benefits in comparison to conventional materials used. Therefore, a better understanding of the science behind nanotechnology is essential to appreciate how these materials can be utilized in our daily practice. Nanotechnology is the research and development of materials, devices and systems exhibiting physical, chemical and biological properties that are different from those on a large scale. Nanotechnology offers a broad range of innovations and improvement in prevention, diagnostics, and treatment of oral diseases. Periodontal disease is one of the major dental illnesses that affect millions of people around the globe. It is estimated that 90% of the world population suffers from the disease. Recent nanotechnology advancement and innovations through Nano dentistry are increasingly providing a suitable solution for the treatment of many dental disorders including periodontal disease. This review aimed to provide an overview of the role of nanotechnology in periodontics and to evaluate its applicability in prevention and treatment of oral diseases and also to provide important recent updates on the various nanotechnology-based approaches for periodontal disease therapy. The present review will also help the reader understand Nano science, and its benefits and limitations by addressing its ethical, social, and health implications. Additionally, Nano-applications in dental diagnostics, role in periodontology will be addressed.

Key words: Nanotechnology, Nanoparticles, Nano spheres, Periodontal tissue engineering, Periodontal drug delivery

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INTRODUCTION

Nanotechnology is the art and science of material engineering on a scale of less than 100 nm. The first definition of "nanotechnology" was given by Norio Taniguchi (Tokyo Science University) in a 1974 paper. According to him, "nanotechnology" mainly consists of the processing of separation, consolidation, and deformation of materials by one atom or one molecule [1]. Nanomaterials are synthetic or natural materials with components <100 nm in at least one dimension, including clusters of atoms, grains <100 nm in size, fibers that are <100 nm diameter, films <100 nm in thickness, nanoholes, and composites that are a combination of these [2].

Nanomaterials due to their small size have a much-increased surface area per unit mass compared to bigger particles. All properties, including electrical, optical and magnetic ones, are altered. Many nanomaterials have been used as nanomedicines in the past few decades [3]. The concept of "nanomedicine" was given by Freitas in 1993 and was defined as observing, controlling, and treating the biological systems of the human body at the molecular level using nanostructures and nanodevices [3]. It revolutionized the medical and dental fields by improving mechanical and physical properties of materials, and helped introduce new diagnostic modalities and nano-delivery systems [4].

With the unstoppable trend of an increasing aging population in both the developing and developed countries, scientists in the field of regenerative medicine and tissue engineering are continually looking for new ways to apply the principles of cell transplantation, materials science, and bioengineering to construct biological substitutes that will restore and maintain normal function in diseased and injured tissues [5].

Periodontal disease is one of the major dental illnesses that affect millions of people around the globe. It is estimated that 90% of the world population suffers from the disease [6]. In addition, the development of more refined means of delivering medications at therapeutic levels to specific sites is an important clinical issue. Applications of such technology in dentistry, and periodontics in particular, are no exception as periodontal destruction can be found to increase in prevalence with increasing age [7]. This review aimed to provide an overview of the role of nanotechnology in periodontics and to evaluate its applicability in prevention and treatment of oral diseases and also to provide important recent updates on the various nanotechnology-based approaches for periodontal disease therapy.

Previously we have worked on plenty of topics in periodontology [8-20]. Now we are planning to review on the role of nanotechnology in periodontics.

NANOMATERIALS

Properties of Nanomaterials:

Nanomaterials are those materials whose components are less than 100 nm in minimum of at least one dimension, including clusters of atoms, grains as small as less than 100 nm in size, fibers which are as minute as less than 100 nm diameter and atlast films which are less than 100 nm in thickness, nanoholes, and composites that are also a constituent of these nanoparticles. The composition can be any combination of naturally occurring elements [21]. The improved relevant properties include enhanced toughness, stiffness, improved transparency, in- creased scratch, abrasion, solvent and heat resistance, and decreased gas permeability. In addition, nanoparticles have special properties which are different from other particles which include chemical, optical, magnetic, and electro-optical properties and which differ from those of either individual molecules or bulk species [22]. These significant properties of nanoparticles meet the intriguing demand to design multifunctional nanocomposite films, which cover properties of both inorganic and organic materials and exhibit immense prospects for developing light-emitting diodes, nonlinear optical devices, resistors, sensors, electrically conductive films, and gas separation membranes [23].

NANOMEDICINE

Nanomedicine helps in prevention, diagnosis, and treatment of various diseases. Nanorobots can be applied in chemotherapy to treat cancer and to precisely deliver exact amounts of chemotherapeutic agents directly to the target cells. This would be a more efficient and brilliant mechanism, which reduces the side effects and so the normal cells would be spared. Drug delivery nanorobots were called ''Pharmacytes'' by R.A.Freitas in 2000. Medical nanorobots are believed to improve the immune system functioning by detecting and deactivating the harmful microorganisms like bacteria, viruses, and other pathogens [24]. Nanoscale-structured materials, biotechnology, genetic engineering, and complex molecular machine systems help in preserving and improving human health [25].

IMPLICATIONS OF NANOTECHNOLOGY

Ethical implications

After the thorough research and development phase of any particular dental or medical nanoproduct, it undergoes various testing which includes the extensive preclinical in vitro testing to investigate the mechanical, toxicological, and immunological potential of that particular product. Many agencies such as the U.S Environmental Protection Agency and the National Institute of Occupational Safety and Health have introduced guidelines for investigating the risks of nanomaterial [26]. The traditional ethical decision making steps followed by the ethical committee, mainly utilitarianism, is unable to keep up with the rapid development and uncertain future of nano-technological developments and products. For that reason, a more in-depth understanding of the science is required, including risk/ benefit analysis and ethical considerations throughout the development process [27]. This led to the proposal of the anticipatory ethics and governance concept, developed to identify and address ethical and societal implications through ethical analysis models when the technology is in its introductory stage to be then easily modified and guided towards an ethically acceptable outcome.

NANOTECHNOLOGY IN DENTISTRY

Dental diagnostics

In an attempt to improve upon medical diagnostics, the concept of nano-biosensing was introduced. A biosensor is described as"an analytical device which incorporates a biologically active element into it with an appropriate physical transducer to generate a measurable signal which is proportional to the concentration of chemical species in any type of sample". In order to improve the biorecognition process of the bioreceptor and overall bioreceptor performance, nanobio receptors were introduced with incorporated nanotubes, nanowires, and nano-dots into the sensing assembly of the nano bioreceptors. Nanoparticles are created by either following the top down, bottom up, or molecular self-assembly approach [28]. Replacing micro sized particles with nanosized ones transforms the biosensor into a nanobiosensor, with the advantage of rapidly identifying targeted biological tissues at an ultra-low molecular level [29]. Its high sensitivity is particularly useful in cases of cancer diagnosis for example, as nanobiosensors in comparison to conventional biosensors are able to detect cancer cell molecules at very early stages and in very low concentrations [30].

NANOTECHNOLOGY IN PERIODONTICS

Nanomaterials for periodontal drug delivery

Nanomaterials are of interest from a fundamental point of view because the properties of a material (e.g. physical properties, electronic properties, optical properties) change when the size of the particles that make up the material becomes nanoscopic. With new properties, come new opportunities for technological and commercial development, and applications of nanoparticles have been demonstrated or proposed in areas as diverse as microelectronics, coatings and paints, and biotechnology [31]. From these applications has come the development of nano-pharmaceuticals, nanosensors, nanoswitches, and nanodelivery systems. Each of these has considerable significance in the field of local, or targeted, drug delivery.

Recently, Pinon-Segundo et al. [29] produced and characterized triclosan-loaded nanoparticles by the emulsification–diffusion process, in an attempt to obtain a novel delivery system adequate for the treatment of periodontal disease. The nanoparticles were prepared using poly (D,L-lactide-co glycolide), poly (D,L-lactide) and cellulose acetate phthalate. Poly (vinyl alcohol) was used as a stabilizer. Batches were prepared with different amounts of triclosan in order to evaluate the influence of the drug on nano- particle properties. Release kinetics indicates that the depletion zone moves to the center of the device as the drug is released. This behavior suggests that the diffusion is the controlling factor of the release.

Nanomaterials including hollow spheres, core-shell structure, nano- tubes and nanocomposite have been widely explored for controlled drug release [32]. It is conceivable that all of these materials could be developed for periodontal drug delivery devices in the future. Drugs can be incorporated into nanospheres composed of a biodegradable polymer, and this allows for timed release of the drug as the nanospheres degrade. A good example of how this technology might be developed is the recent development of ArestinÒ in which tetracycline is incorporated into micro- spheres for drug delivery by local means to a periodontal pocket [33].

Nanomaterials for oral hygiene maintenance

Nanorobots are being incorporated in mouthwash so that they can easily identify and destroy the pathogenic bacteria that can cause gingivitis and periodontitis thus leaving behind harmless oral flora to flourish in the oral ecosystem. It would also identify food debris, tartar and plaque and would lift them from the teeth to be rinsed away thus making oral cavity clean and plaque and food debris free. Hollow spheres, core–shell structure, nanotubes, and nanocomposite can be used as periodontal drug-delivery systems in the near future [34].

Continuous debridement of supra and sub gingival calculus is supposed to be done by nanorobots incorporated in dentifrices in near future. They will also provide a continuous barrier to halitosis by removing the bacteria responsible for production of volatile compounds leading to halitosis [35].

Nanomaterials for periodontal tissue engineering

Currently, tissue engineering concepts for periodontal regeneration are focused on the utilisation of synthetic scaffolds for cell delivery purposes [36]. Although the usage of such synthetics scaffold systems offers promise, it is very likely that the next generation of materials will rely mainly on nanotechnology and its potential to produce nonbiologic self-assembling systems required for tissue engineering purposes. The clinical utility of these nano-constructed self-assembling materials is their capacity to be developed into nanodomains or nanophases, leading to unique nanobuilding blocks with inbuilt nanocontrol and nanodelivery capabilities. For tissue engineering purposes the potential of nano- technology is limited only by our imagination. Our present capacity to create polymer scaffolds for cell seeding, growth factor delivery and tissue engineering purposes is well recognized In the future these processes may well be manipulated via nanodevices implanted to sites of tissue damage [37].

Nanomaterials in treating dentin hypersensitivity in case of recession

Natural hypersensitive teeth have much higher surface density of dentinal tubules and diameter in comparison to their nonsensitive counterparts. Reconstructive dental nanorobots, using native biological materials, could selectively and precisely occlude the dentinal tubules within minutes, offering patients a quick and permanent cure from dentin hypersensitivity [38].

Nanomaterials in Implants

In dental implants, one of the commonest reasons for failure is insufficient bone formation around the implant. For sufficient bone formation, surface of implants need to be modified, which may include nanoscale topography and/or coatings for better and faster osseointegration of implants [39]. The development of nanostructured implants which will combine the inertness with a mechanical response to the dental implant alloy.

Nanomaterials in treating bone defects and wound healing

Bone is a natural nanostructured composite composed of organic compounds reinforced with inorganic components (hydroxyapatite crystals). Nanotechnology is very useful in bone defect repair as it can be utilized to treat bone defects with nano-bone graft materials. Nano bone graft should possess the qualities of bone grafts being used today. Their higher surface area to mass ratio can be used in the most advantageous manner for treating intrabony defects. Nanoneedles and nanotweezers are also being developed that will make cell surgery a possibility in the near future [40]. According to Azeltine, et al. Nanomaterials promote and accelerate the process of wound healing [41].

CHALLENGES FACED IN NANODENTISTRY

Although we have numerous ideas and dreams for nanodentistry, actually most of them in reality are not possible till the date due to various challenges such as engineering challenges, biological challenges and social challenges. It is really challenging to position and assemble the nano molecular scale part precisely. Biological compatible molecules which are environmentally friendly, economically and ethically acceptable still are a distant site in the field of nanodentistry.

CONCLUSION

Nanotechnology is a promising technology that is playing an increasingly important role in the diagnostics, prognostics, prediction, and management of various treatments. Although the achievement of the goal of complete and proper regeneration of the periodontal tissues which includes the cementum, periodontal ligament and bone for various periodontal management may not be feasible for many years, recent developments and achievements in nanomaterials and nanotechnology have provided a promising hand into the commercial applications of nanomaterials in the diagnosis and management of periodontal diseases. Although many studies have been published concerning nanocomposite and nanoporous materials, it will become of increasing importance to specifically develop nanomaterials for the management of periodontal diseases. It is envisaged that this trend will be further improved in the future as more and more nanotechnologies are commercially explored.

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AUTHOR CONTRIBUTION

First author Vaishali.S contributed acquisition of literature collection, drafting the article and revising it critically for important intellectual content Second author Nashra Kareem contributed to conception, formatting, manuscript preparation, supervision and guidance.

CONFLICT OF INTEREST

None.

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