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NANOTECHNOLOGY IN PERIODONTICS: CURRENT CONCEPTS & CHALLENGES FACED IN ITS APPLICATION

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ABSTRACT

Nanotechnology is the study of small things. It is the research and development of materials, devices, and systems exhibiting physical, chemical, and biological properties that are different from those found on a larger scale. Thus nanotechnology can be best understood as a broad collection of technologies from diverse fields such as physics, materials science, engineering, chemistry, biochemistry, medicine, and optics each of which may have different characteristics and applications. Therefore, the purpose of this review is not only to cover the development of nanotechnology in all areas and its impact on periodontal diseases but also it focuses on the development of nano materials and their potential to be used in managing periodontal diseases, including diagnosis and treatment.

KEYWORDS: Nanotechnology, Physics, Material science, Periodontal disease.

INTRODUCTION

Nanotechnology is the engineering of molecularly precise structures. The term "nanotechnology" was coined by Professor Kerrie E. Drexler, a lecturer and researcher of nanotechnology. The prefix ''nano'' means 10^{-9} or one billionth of a unit. The Nano scale is approximately 1000 times smaller than a micro scale, which is approximately 1/80000 the diameter of a human hair. These small scientific scales were first revolutionized by Richard Feynman at his famous speech at the Annual Meeting of the American Physical Society in 1959 entitled: ''There is plenty of room at the Bottom''. He proposed that machines and tools that make smaller machine tools could in turn be used to make even smaller machines and

tools, right down to molecular levels.[1] He suggested that such Nano machines, Nano robots, and Nano devices could ultimately be used to develop a wide range of atomically precise microscopic instrumentation and manufacturing tools. In his historical lecture in 1959, he concluded by saying, "This is a development, which I think cannot be avoided".[2]

Nanotechnologies consist of three mutually overlapping and progressively more powerful molecular technologies

1. Nano scale structured materials and devices that can be fabricated for advanced diagnosis and biosensors, targeted drug delivery and smart drugs.
2. Molecular medicine via genomics, proteomics, artificial biobotics (microbial robots).
3. Molecular machine systems and medical nanorobots allow instant pathogen diagnosis and extermination and efficient augmentation and improvement of natural physiological function.[3]

Periodontitis being the most common disease involving tooth and its supporting structures also has impact on overall health of an individual. Management of periodontitis is hence important for improvement of quality of life of the patient.

Role of Nanotechnology in Periodontics

Local anaesthesia: Most dental procedures involve administration of local anaesthesia and several patients defer their dental treatment for the fear of injections. Truly painless methods of administration of local anaesthesia may be achievable by the application of nanotechnology. Hypothetically, a colloidal suspension containing millions of active analgesic micron-size dental robots will be instilled on the patient's gingiva. After contacting the surface of the crown or mucosa, the ambulating Nano robots would reach the pulp via the gingival sulcus, lamina propria and dentinal tubules guided by chemical gradients and temperature differentials under the control of the dentist with the help of Nano computer. [4, 5] Once installed in the pulp, these robots may shut down all sensitivity in any particular tooth that requires treatment. After the procedures are completed, these nanorobots may be manipulated to restore all sensation and relinquish control of nerve traffic and regress from the tooth by similar means used for ingress.

Dentinal hypersensitivity: Natural hypersensitive teeth have eight times higher surface density of dentinal tubules and diameter twice as large as non-sensitive teeth. Dental nanorobots could selectively occlude these tubules within minutes and thus offers patients a

quick and permanent cure.[5] These nanorobots reach the dentinal tubules and proceeds toward the pulp, guided by chemical gradients, temperature differentials, all under the control of Nano computer. They can reach the pulp in approximately 100 seconds thereby offering a rapid relief of sensitivity.[6,7,8]

Drug delivery: Periodontal therapy requires local delivery of drugs for more predictable results of treatment. Drug delivery systems based on triclosan incorporated nanoparticles have been developed. Pinon-segundo et al.[9] have produced triclosan-loaded nanoparticles by the process of emulsification-diffusion, in an attempt to obtain a novel delivery system for the treatment of periodontal disease. Tetracycline based microspheres are also being evaluated for placement in periodontal pockets.

Nano materials - Bone Growth

Bone is a natural nanostructured composite composed of organic materials like collagen reinforced with inorganic ions in the form of hydroxyapatite crystals. This natural nanostructure uses the nanotechnology to emulate for dental applications. As the particle size decreases, the surface area becomes larger in volume. Nano bone uses this basic principle of nanostructure.[10] Nowadays alloplastic bone grafts are being developed with nanoscale particles. Nano-HAP (n-HAP) bone grafts, which are available in crystalline, chitosan-associated and titanium-reinforced forms is one such type of bone graft. These n-HAP composite bone graft scaffolds are highly biocompatible, have superior mechanical properties, and induce better cellular responses compared to 'plain' chitosan scaffolds. [11]

Nanotechnology in Dental Implants

Nanotechnology can be used in the surface modifications of dental implants since surfaces properties such as roughness and chemistry play a determinant role in achieving and maintaining their long-term stability in bone tissue. Deficient formation of bone around the biomaterial immediately after the implantation is the most common reason for failure of dental implant. The coating of nano particles over the dental implants, improves the adhesion and integration of surrounding tissues. [12] Biologically active drugs such as antibiotics or growth factors can be incorporated in the implants Eg: Nanotite™ Nano-Coated Implant. Recently three nano-structured implant coatings are developed:

1. Nanostructured diamond: They have ultrahigh hardness, improved toughness over conventional microcrystalline diamond, low friction, and good adhesion to titanium alloys.[13]

2. Nanostructured processing applied to hydroxyapatite coatings: This is used to achieve the desired mechanical characteristics and enhanced surface reactivity and has been found to increase osteoblast adhesion, proliferation, and mineralization.[13]
3. Nanostructured metalloceramic coatings: These provide continuous variation from a Nano crystalline metallic bond at the interface to the hard ceramic bond on the surface.[13]

Laser Plasma Application in Periodontics

Use of nano-sized Titanium particle emulsion on human skin followed by laser irradiation, leads to the disintegration of the particles along with other results like: Shock waves, Micro abrasion of hard tissues, Stimulus to produce collagen. Clinical applications of this laser plasma application in periodontics are periodontal therapy, melanin removal and soft tissue incision (without anesthesia).[14]

Challenges faced by Nanodentistry

1. Engineering challenges

- Feasibility of mass production technique
- Precise positioning and assembly of molecular scale part
- Manipulating and coordinating activities of large numbers of independent micro scale robots simultaneously

2. Biological challenges

- Developing bio friendly nanomaterial
- Ensuring compatibility with all intricate of human body

3. Social challenges

- Ethics
- Public acceptance
- Regulation and human safety

CONCLUSION

As with all technologies, nanotechnology carries a significant potential for misuse and abuse on a scale and scope never seen before. Nano devices cannot be seen, yet possess powerful capabilities. They have the potential to bring about significant benefits, such as improved health, better use of natural resources, and reduced environmental pollution. Applications of nanotechnologies in dentistry are especially promising, and such areas as disease diagnosis,

drug delivery targeted at specific sites in the body, and molecular imaging are being intensively investigated. Nanodentistry will give a new vision to comprehensive oral health care, as trends of oral health have been changing to more preventive intervention than a curative and restorative procedure. Nanotechnology will change dentistry, health care and human life more profoundly than other developments. However, at the same time, there will be increased social issues of public acceptance, ethics, regulation, and human safety that must be addressed before molecular nanotechnology can enter the modern medical and dental armamentarium.

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