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NANOTECHNOLOGY : RISE OF A NEW ERA IN PERIODONTICS

Review Article

[1]Vivek Kumar Sharma, [2]Himanshu Trivedi, [3]Afshan Bey, [4]N. D. Gupta
[1]Associate Professor, Periodontics & Community Dentistry, Deptt. of Periodontics & Public Health Dentistry, Dr. Z. A. Dental College, AMU, Aligarh
[2]. Post Graduate student, Dept. of Periodontics & Public Health Dentistry, Dr Z. A. Dental College, A.M.U., Aligarh, 202001, UP, India
[3,4] Professor, Dept. of Periodontics & Public Health Dentistry, Dr Z. A. Dental College, A.M.U., Aligarh, 202001, UP, India

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Abstract: Periodontitis is one of the most common disease involving tooth and it's supporting structures. Management of periodontitis is important for improvement of quality of life of the patient that ultimately has it's impact on overall health of an individual. With upsurge of various treatment methodologies for treatment of periodontitis nanotechnology has evolved as a promising mode of treatment. Nanotechnology is an emerging field in the field of medicine and dentistry extending it's horizons right from the diagnosis to the treatment and rehabilitation phase.

INTRODUCTION:

From the definition by the National Nanotechnology Initiative, nanotechnology exploits specific phenomena and direct manipulation of materials on the nanoscale (28). Nanotechnology is not just the study of small things; it is the research and development of materials, devices, and systems exhibiting properties that are unique and different from those found on a larger scale. Thus nanotechnology can be best described as a broad amalgamation of technologies from diverse fields such materials science, engineering, chemistry, biochemistry, medicine, and physics, each of which may have different characteristics and applications. Nanomaterials are materials with components less than 100 nm in at least one dimension, including clusters of atoms, molecules less than 100 nm in size, fibers and films that are less than 100 nm diameter, nanoholes, and composites that are a combination of these.

History of nanotech

As early as 1867, James Clerk Maxwell proposed a revolutionary concept of nanotechnology. The term nanotechnology was given by Prof. Kerie E. Drexler. In the early 20th century, Richard Zsigmondy brought about the concept of nanomaterials.[1] In 1959, Richard P. Feynman, the Nobel Laureate said that his friend, Albert R. Hibbshad suggested an interesting possibility for extremely small machines.[2] R.A. Freitas Jr., in the year 2000, coined the term "nanodentistry". He developed visions using nanorobots for orthodontics, dentition regeneration, nanomaterials, and robots in dentifrices–dentifrobots. Although most of his ideas were and remain science fiction, these ideas are gradually being realized into practice. Today many applications of nanoscale technology are known and used in the field of dentistry.[3]

Nanomaterials:

Nanomaterials are classified as zero-dimensional, one-dimensional, two-dimensional, and three-dimensional.9 Different types of nanoparticles are nanopores, nanotubes, quantum dots, nanoshells, dendrimers, liposomes, nanorods, fullerenes (bucky-balls), nanospheres, nanowires, nanobelts, nanorings, nanocap, and many more.[4] Different approaches for the synthesis of nanoparticles are top-down approach, bottom-up approach and functional approach.5 In top-down approach, particles are manufactured in the conventional manner and made smaller in size by grinding or milling. Examples of top-down approach are nanocomposites, nanoencapsulation, nanoneedles, nano based bone replacement cement, nano impression materials, nano coatings on implants. While in the bottom-up approach, nanoparticles are synthesized by direct molecular synthesis and bonding, i.e., they are synthesized from molecular level and assembled to form larger units.6 Examples of bottom-up approach is local anesthesia, tooth regeneration, hypersensitivity cure, nanodiagnostics, oral tissure biomimetics etc. The functional approach, on the other hand, does not give importance to the method of production of a nanoparticle; rather, it emphasizes on production of nanoparticle with a specific use.[5]

Properties of nanomaterials:

Nanomaterials exhibit much better mechanical properties such as enhanced toughness, stiffness, improved transparency, increased scratch, abrasion, solvent and heat resistance, and decreased gas permeability compared to traditional materials.[7] Nanoparticles have a greater surface area per unit mass than compared with larger particles.[8] Self-assembly is a significant feature of nanostructured materials. Here, an autonomous organization of components into patterns or structures without human intervention occurs.[9]

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 amount of chemotherapeutic agents directly to the target cells. This would be a more efficient mechanism, with much reduced side effects as normal cells would be spared. Drug delivery nanorobots were called "Pharmacytes" by R.A. Freitas in year 2000. Medical nanorobots improves the immune system by detecting and deactivating the harmful bacteria, viruses, and other pathogens.[10] Nanoscale-structured materials, biotechnology, genetic engineering, and complex molecular machine systems help in preserving and improving human health.[11]

Nanotechnology in periodontics:

Recently, scientists produced and characterized triclosan-loaded nanoparticles by the emulsification–diffusion process12, in an attempt to obtain a novel delivery system adequate for the treatment of periodontal disease. These triclosan nanoparticles behave as a homogeneous polymer matrix-type delivery system, with the drug (triclosan) molecularly dispersed.. Timed release of drugs may occur from biodegradable nanospheres. A good example is Arestin in which tetracycline is incorporated into microspheres for drug delivery by local means to a periodontal pocket.13 Nanorobots are being incorporated in mouthwash so that they can identify and destroy pathogenic bacteria leaving behind harmless oral flora to flourish in the oral ecosystem. It would also identify food particles, tartar and plaque lift them from the teeth to be rinsed away. Hollow spheres, core–shell structure, nanotubules, and nanocomposite can be used as periodontal drug-delivery system in near future.

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.14 Nanotechnology has got the potential to produce nonbiologic self-assembling systems for tissue engineering purposes.15 Self-assembling systems are those which undergo prespecified assemblies automatically much in line with known biologic systems related to cells and tissues. Researchers are working to create polymer scaffolds for cell seeding, growth factor delivery and tissue engineering via nanodevices implanted to sites of tissue damage. 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 dentinal tubules within minutes, offering patients a quick and permanent cure.[11]

In dental implants, one of the commonest reasons of 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.[16] The development of nanostructured implants which will combine the inertness with a mechanical response to the dental implant alloy. Bone is a natural nanostructured composite composed of organic compounds reinforced with inorganic components(hydroxyapatite crystals). Nanotechnology can also be used 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 most advantageous manner for treating infrabony defects. Nanoneedles and nanotweezers are also being developed that will make cell surgery a possibility in the near future.[17] According to Dr. Friedman, nanomaterials promotes ant accelerates the process of wound healing. In mice, burn wounds were treated with curcumin nanoparticles and accelerated wound healing was observed.[18]

Problems faced by nanodentistry:

Although we have numerous ideas and dreams for nanodentistry, but in reality most of them are not possible till the date because of 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 environmental friendly, economic and ethically acceptable still are a distant site in the field of nanodentistry.

Conclusion:

Although the achievement of the goal of complete regeneration of the periodontal tissues for periodontal management may not be possible for many years, recent developments in nanomaterials and nanotechnology have provided a promising insight into the commercial applications of nanomaterials in the management of periodontal diseases. More researches on the development of nanomaterials and nanodevices are required to achieve great results in the field of periodontics. The foundation has been laid and It is envisaged that this trend will be further improved in the future as more and more nanomaterials and devices are commercially explored.

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CORRESPONDING AUTHOR:
Dr. Vivek Kumar Sharma
Associate Professor
Periodontics & Community Dentistry
Deptt. of Periodontics & Public Health Dentistry,
Dr. Z.A. Dental College, AMU, Aligarh
Email : yeahlifehai@yahoo.com