Nanotechnology : Rise of A New Era in Periodontology & Oral Implantology

Dr. Parul Gupta

PG, Department of Periodontics, Seema Dental College & Hospital, Rishikesh, Dehradun, Uttarakhand

Abstract

Periodontitis is one of the most common disease involving tooth and its supporting structures. Management of periodontitis is important for improvement of quality of life of the patient that ultimately has its 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 its horizons right from the diagnosis to the treatment and rehabilitation phase. The need for a synthetic implant to address multiple physical and biological factors imposes tremendous constraints on the choice of suitable materials. There is a strong belief that nanoscale materials will produce a new generation of implant materials with high efficiency, low cost, and high volume. The nanoscale in materials processing is truly a new frontier. Metallic dental implants have been successfully used for decades but they have serious shortcomings related to their osseointegration and the fact that their mechanical properties do not match those of bone. This paper reviews recent advances in the fabrication of novel coatings and nanopatterning of dental implants. The ultimate goal is to produce materials and therapies that will bring state-of-the-art technology to the bedside and improve quality of life and current standards of care.

Keywords: Periodontitis, Nanotechnology, Implants, Osseointegration, Nanopatterning.

How to cite this Article: Gupta P. Nanotechnology: Rise of A New Era in Periodontology & Oral Implantology.HTAJOCD.2019;11(4):56-57

Introduction

Nanotechnology can be defined as the science and engineering involved in design, synthesis characterization and application of materials and devices whose smallest functional organization in at least one dimension is on nanometer scale (one billionth of meter).[1]

Nanotechnology has been around since ancient times. The inspiration for the field of nanotechnology was provided by American Physicist and Nobel Laureate Dr. Richard Phillips Feynmaan in 1959. The term “Nanotechnology” was first coined by Norio Taniguchi in 1974.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.[2]

Nanotechnology (nanotech) is manipulation of matter on an atomic, molecular and supramolecular scale. The earliest, widespread description of nanotechnology referred to the particular technological goal of precisely manipulating atoms and molecules for fabrication of macroscale products, also now referred to as molecular nanotechnology.

In recent years, nanotechnology has found useful applications in various fields, such as preventive dentistry, disease diagnostics and monitoring at an early stage, drug development and targeting, the design of microbial resistant and biocompatible dental implants and clinical tools and devices for oral health care.[3]

Nanomaterials

According to the European Commission's recommendation, a “nanomaterial” is defined as “a natural, incidental or manufactured materialcontaining particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range of 1 to 100 nm”.[4]

Nanomaterials are classified as zero-dimensional, onedimensional, two-dimensional, and three-dimensional. Different types of nanoparticles are nanopores, nanotubes, quantum dots, nanoshells, dendrimers, liposomes, nanorods, fullerenes (bucky-balls), nanospheres, nanowires, nanobelts, nanorings, nanocap, and many more.[5]

Different approaches for the synthesis of nanoparticles are top-down approach, bottom-up approach and functional approach. 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. Examples of bottom-up approach is local anesthesia, tooth regeneration, hypersensitivity cure, nanodiagnostics, oral tissurebiomimetics 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.[6]

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]Self-assembly is a significant feature of nanostructured materials where an autonomousorganization of components into patterns or structures without human intervention occurs. Self – assembly has been classified into static and dynamic processes based on whether the system dissipates energy. The most universal driving forces for establishing self-assembly are electrostatic attractive interactions between positive and negative charges.

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.[8]Nanoscale-structured materials, biotechnology, genetic engineering, and complex molecular machine systems help in preserving and improving human health.[9]

Nanotechnology in periodontics:Recently, scientists produced and characterized triclosanloaded nanoparticles by the emulsification–diffusion process, 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.[10] 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.[11]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.[12]

Nanotechnology & Dental Implants

Nanotopography can determine various cellular processes like cell orientation, alignment, differentiation, migration and proliferation by regulating cell behavior. These

surfaces hasten the recovery process thus enhancing the process of osseointegration. Nano topographic modifications are described as surfacenano roughness produced by adding nano features to the implant surface.

Dalby et al. concluded that nanoscale topography controls osteoblastic differentiation and cell adhesion. Oh et al. illustrated that nanoscale technology can alter oral implant surface at an atomic level and may influence the chemical composition of these implant surfaces.

TYPE	IMPLANT MATERIAL
Metal–based implant	Titanium Titanium alloys Tantalum Gold alloys Stainless steel Cobalt chromium alloy
Ceramics-based implant	Bioglass ß- Tricalcium phosphate Zirconia (ZrO_2) Zirconia (ZrO_2)-toughened-alumina (Al_2O_3) Alumina (Al_2O_3) Hydroxyapatite (HA)
Polymer-based implant	Polymethylmethacrylate(PMMA) Polytetrafluoroethylene(PTFE) Polyethylene(PE) Polysulfone(PSF) Polyurethane(PU) Polyether ether ketone(PEEK)

Classification of dental implants based on the materials used for fabrication

Types of materials	Body responses	Nanostructured materials
Bioinert	Fibrous capsule is formed surrounding the biomaterial	Nanostructured stainless steel Nanostructured Co-Cr alloy Nanostructured zirconia Nanostructured alumina
Bioactive	Osseointegration is induced by the bioactive material. Ionic changes and biomaterial resorption occur on the surface of bioactive materials	Nanostructured titanium Nanostructured niobium Nanostructured tantalum Nanostructured hydroxyapatite Nanostructured calcium phosphate Nanostructured bioactive glass

Types of nanostructured materials based on their interactions with the body

Classification of Nanostructured Dental Implants:

Nanostructured dental implants can be classified into several categories based on (i) the form, shape and type of prosthesis connection of the implant;(ii) the nature of materials used for fabrication; (iii) the biological responses they are intended to elicit upon implantation.[13,14]

Nanofabrication Techniques for Dental Implants.

Nanotechnologies are increasingly used for surface modifications of dental implants. There are several techniques to modify the bulk and surface properties of dental implants to create varied surface roughness from the micro to nanoscale. These methods can be divided into three groups: (i) surface etching and patterning techniques, (ii) surface functionalization techniques, and (iii) surface coating techniques which can be undertaken by various chemical and physical techniques.[15]Principal function of these techniques is to modify the implant surface characteristics such as increasing bone formation to improve periimplantosteogenesis, improvement of corrosion and wear resistance and removal of surface contaminants.

1. Physical FabricationTechniques

- Machining
- Grit blasting
- Laser treatment
- Sputtering deposition (SD)
- Plasma spraying (PS)
- Ion- beam assisted deposition(IBAD)

2. Chemical Fabrication Techniques

- Chemical method is the most commonly used method to modify titanium surface at nanoscale. According to Bagno and Di Bello surface roughness, composition and surface wettability are altered by chemical surface modification of titanium.[16]
- Acid etching
- Alkali treatment
- Anodization or Anodic Oxidization
- Micro-arch oxidation (MAO)
- Wet chemical deposition "sol-gel"
- Chemical vapor deposition[17]
- Self-assembled monolayers (SAMs)

Conclusion & Future Prospects

Recent developments in nanomaterials and nanotechnology have provided a promising insight into the commercial applications of nanomaterials in the management of periodontal diseases. To achieve great results in the field of periodonticsmore researches on the development of nanomaterials and nanodevices are required.

Inadequate bone formation around implants and osseointegration, exacerbated by microbial infection, is the most likely reason for implant failure. With recent progress in surface engineering at the nanoscale, we can now better control the complex biological events such as the adsorption of proteins, blood clot formation, migration, adhesion, and differentiation of cells. A major problem with current dental implants is the achievement of mechanical properties similar to bone tissue. There are still no available optimized implant surface modification methods and protocols for clinical application.

Nanotechnology has brought new insight into the production of the second generation of implants, and through the manipulation and engineering of bone implants to mimic the natural topography, nanomaterials processing is truly a new frontier.

Nanotechnology can fabricate a new generation of implant materials with high efficiency, low cost and high surface area to volume to ratio. Scientists are still looking to produce an implant similar to the structure of the tooth, which can provide the best biological response in terms of structure, surface chemistry and function. There is the need for more research into the interaction of cells with implant surfaces, as well the influence of different chemical compositions and nanopatterns in the interactions of biological molecules and cells with implant surface, and the stimulation of osseointegration and bone formation.

References

1. Siegel RW, Fougere GE. Mechanical properties of Nanophase metals. Nanostruc Mater 1995; 6: 205-16.
2. Deyhle H, Hieber S, Muller B. In: Bhusan B, Winbigler HD, eds. In: Encyclopedia of Nanotechnol. Berlin, Heidelberg: Springer-Verlag; 2012:1514–1518.
3. I.S. Yeo, Open Biomed. Eng. J., 2014, 8: 114–119.
4. J. Jeevanandam, A. Barhoum, Y. S. Chan, A. Dufresne and M. K. Danquah, Beilstein J. Nanotechnol, 2018, 9: 1050–1074.
5. Rao KVP, Kumar JS. Nanotechnology in dentistry. Kerala Dent J. 2013; 36:56–59.
6. Sivaramakrishnan SM, Neelakanthan P. Nanotechnology in dentistry – what does the future hold in store. Dentistry. 2014; 4:1–3.
7. Patil M, Mehta DS, Guvva S. Future impact of nanotechnology on medicine and dentistry. J Indian Soc Periodontol. 2008; 12(2): 34-40.
8. Sujatha V, Suresh M, Mahalaxmi S. Nanorobotics – a futuristic approach. SRM Univ J Dent Sci. 2010; 1:86–90.
9. Freitas RA. Nanodentistry. J Am Dent Assoc. 2000; 131: 1559–1565.
10. Pinon-Segundo E, Ganem-Quintanar A, Alonso-Perez V, Quintanar-Guerrero D. Preparation and characterization of triclosan nanoparticles for periodontal treatment. Int J Pharm 2005: 294: 217–232.
11. Paquette DW, Hanlon A, Lessem J, Williams RC. Clinical relevance of adjunctive minocycline microspheres in patients with chronic periodontitis: secondary analysis of a phase 3 trial. J Periodontol 2004: 75: 531–536.
12. Jhaveri HM, Balaji PR.Nanotechnology.The future of dentistry a review. Jr I Prosthetic 2005; 5:15-17.
13. R. B. Osman and M. V. Swain, Materials, 2015, 8, 932–958.
14. F. Rupp, L. Liang, J. Geis-Gerstorfer, L. Scheideler and F. Hüttig, Dent. Mater; 2018, 34(1), 40–57.
15. A. M. Ballo, O. Omar, W. Xia and A. Palmquist, in Implant Dentistry-A Rapidly Evolving Practice, InTech; 2011.
16. T. J. Webster and J. U. Ejiofor, Biomaterials, 2004, 25; 4731–4739.
17. P. Pachauri, L. R. Bathala and R. Sangur, J. Adv. Prosthodont: 2014, 6; 498–504.