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Nanotechnology in Periodontics: An Overview

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Abstract

Nanotechnology is a booming field during recent years in medicine and dentistry. Application of nanotechnology in Periodontics is referred to as nanoperiodontics. Nanoscale materials show superior quality and outcome than traditional materials used in almost all areas including diagnosis, prevention, treatment, drug delivery and in dental implant coatings. This article will overview the history, classification, synthesis, applications, toxicity and future of nanoperiodontics.

Keywords: *Nanotechnology, Nanoperiodontics, Category and Synthesis of Nanomaterials, Applications of Nano particles.*

Introduction

Nanotechnology is a flourishing field in Periodontics. Their contribution in Periodontics is increasing gradually due to expanding research. Nanomaterials exhibit size less than 100nm in atleast one dimension. Nanoperiodontics involves the analysis of matter at subatomic and microscopic level, which has progressed in the field of Periodontics. Nanoperiodontics will perpetuate periodontal health by relating nanomaterials and biotechnology, including tissue engineering and dental nanorobotics. Though it is at a preliminary stage, it has ample impact in clinical and commercially available substances. Moreover, it is shown to have assured role in periodontal health care in near future.

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History: The use of nanoparticles began as early as 9th century for creating glittering pots in Mesopotamia. It was Richard. P. Feyman a noble laureate who gave the concept of nanotechnology. In 1974, Norio Taniguchi devised the term 'nanotechnology', then Professor Kerie. E. Drexler used the term nanotechnology separately and also gave the first guidelines in the field of nanotechnology. Nanotechnology came into application after the discovery of scanning tunnelling microscope by noble prize winners Binnig and Rohrer in 1986. In the wake of book by Drexler, Peterson and Pergamil in 1991 highlighting the facts on nanorobots and assemblers, the term Nanomedicine was introduced by R.A. Freitus in 2000. To enhance the research in this field "National Nanotechnology Initiative" was developed in 2000 by Michael Roco. During 2005 and 2010, various innovations in the field of 3D robotics, networking and active nanoproducts production were done and from 2011, the generation of subatomic nanotechnology has been in use.

Category of Nanomaterials:

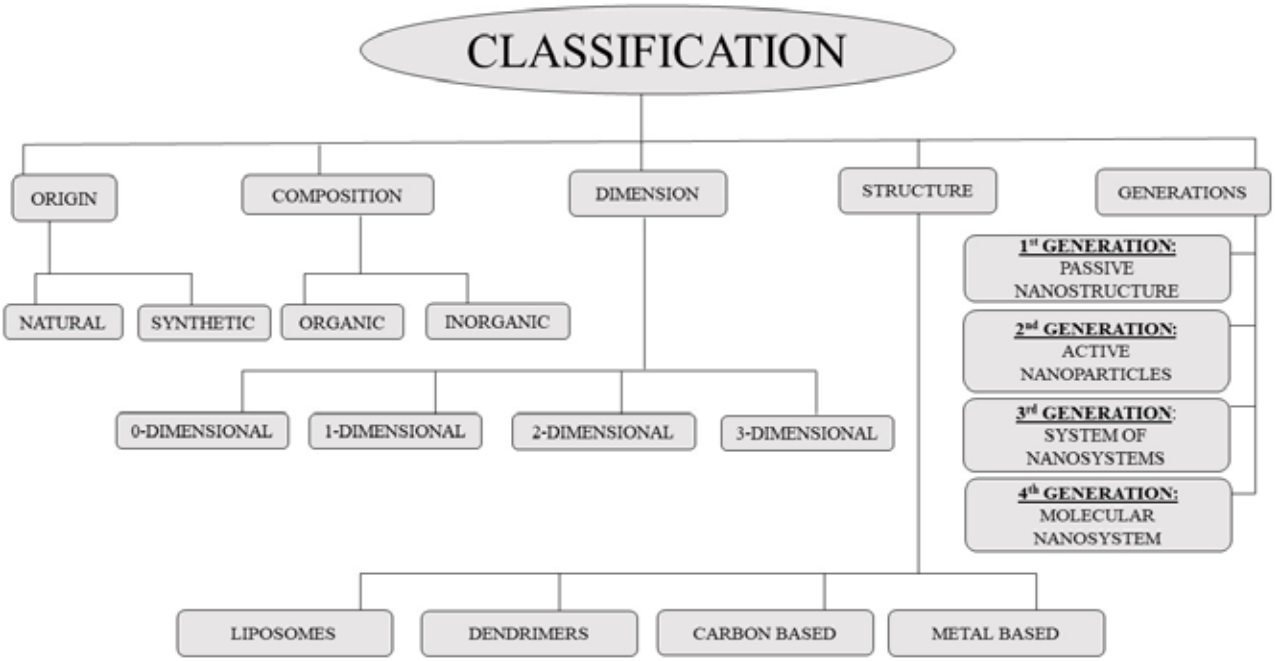

Figure 1: Category of nanoparticles

Properties of Nanomaterials: Properties of nanomaterials were first put forward by Michael Farady in 1857 during preparation of gold nanoparticles. Nanoparticles because of their surface area, dimensions and quantum effects exhibit enhanced rigidity,pelucidness, increased abrasion, stability,fire resistance and gas penetrability. Besides they also exhibit some unique features including ocular, electromagnetic characteristic different from one's owndiscrete molecule or bulk molecule.Another remarkable property of nanomaterials is their self-assembling capacity, i.e. they form copious arrangements in the absence of third party.

Synthesis of Nanomaterials: Top down approach involves devasting procedures in which the large materials are converted into smaller ones and these are further manipulated to form nanoparticles. Bottom up approach involves uniting atomic level substrate through ionization of energy from various sources based on which they are classified as shown in Figure 2. In green synthesis, the herboceutical products are used to synthesize nanoparticles, these nanoparticles are eco-friendly moreover the green synthesised nanoparticles are shown to exhibit enhanced properties. Biomimetic approach is the one in which microorganisms including fungus, bacteria or virus are used to manufacture nanoparticles; this method is in its initial stage and further research is needed to show its effectiveness.[1]

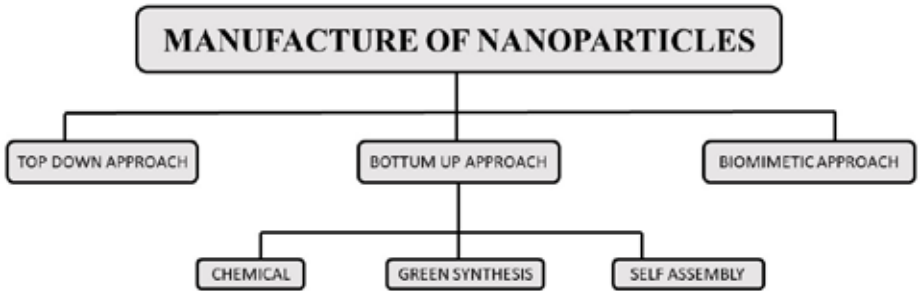

Figure 2: Manufacturing techniques

Applications of Nanoparticles in Periodontics: Nanoscale particle application in medicine and dentistry during the last decade has grown enormously. The applications of nanoscale particles in Periodontics can be broadly discussed under the topics namely prevention, detection and treatment.

Prevention: Antibacterial Agents: Nanoparticle derived antimicrobial agents are seen to have superior effect due to their large surface area. Various agents that can exhibit antimicrobial effects includes silica, silver, copper and zirconia. Commercially available nanotechnology-based disinfectant, Eco-True containing silver salts are employed for disinfecting instruments and surgical areas.

Personal Protective Equipment (PPE): PPE and masks incorporated with nanoparticles having antibacterial effect are shown to exhibit enhanced protection.

Surface Coatings: Nanomaterial coatings used in paints, medical instruments and other highly contagious surface can be employed to control the spread of COVID-19.

Oral Hygiene Maintenace: The mouthwash and dentifrices containing nanoparticles are shown to aid in oral hygiene maintenance. The mouthwash incorporated with nanorobots and selenium nanoparticles controls halitosis through the destruction of volatile sulphur compound producing bacteria. Dentifrices incorporated with nanorobots are employed to destroy the pathogenic flora while preserving around 500 oral commensals; but these are under study.

Detection: Nanotechnology based diagnostic kits exhibit increased efficacy compared to their original counterpart, besides they are easily portable and highly sensitive and specific.

Nanotubes: These are employed for detecting and locating altered disease-causing genes. Under this category comes the quantum dots that radiate bright light on stimuli and are used for cancer diagnosis.

Nanobelts: Are similar to nanotubes in their application except that they are cost effective and technique insensitive compared to nanotubes.

Lab on chip Method: These device merge numerous devices on single chip and they are employed in Periodontics for detection of IL-1ß, CRP, MMP-8 and TNF-α from whole saliva with minimum amount of sample.

Nanoplasmic Sensors: With the emergence of COVID-19 pandemic the need for rapid detection kits are increasing. This sensor rapidly detects live viruses using their corresponding antibodies.

Treatment:

Local Anaesthesia [LA]: Onboardnano computer-controlled micron sized dental nanorobots with colloidal suspension of functional analgesic molecules are employed. They are placed on gingiva and reach the dental pulp through gingival sulcus and dentin and they stay behind until the procedure is complete. Again, on command they reach the gingiva through the same way after restoring all sensations. They are painless and are said to have rapid onset of action in comparison to traditional LA.

Dentinal Hypersensitivity: Dental nanorobots occlude specific dentinal tubules instantly. Besides they also render durable results. Nanohydroxyapatite containing toothpastes are also shown to give promising results.[2]

Dental longevity and maquilage: They can be enhanced with the use of nano sapphire or diamond particle layers on upper enamel layer.

Host Immunomodulation Therapy: Cafferata et al stated the multitasking efficiency of nanocarriers for treating periodontal disease.[3] In this study, he highlighted the immunomodulatory effects of host modulating agents delivered through nanotechnology-based system. They were shown to decrease the level of proinflammatory and bone resorbing T-cell namely Th-1, Th-22 and Th-17. They also increase the differentiation of TH-2 and Treg cells.

Bone Grafts: Nanoscale based grafts are seen to have superior outcome, because of their small dimensions that mimic the natural bone particles. They can be successfully used for the treatment of intrabony defects[4], socket preservation[5] and sinus augmentation procedures[6].

Nanomembranes: KS Hong et al have used silk fibroin nanomembrane (*Nanoguide)* in guided bone regeneration and declared them to exhibit superior bone formation in comparison to biomesh.[7]

Nanoneedlees: Needles containing nanosized silver particles have been developed. They are usually painless and technique insensitive.

Nanotweezers: These are under development and will make cell surgery possible in mere future.

Tissue Engineering: Nonbiologic self-assembling system production by nanotechnology has made tissue engineering through nanoparticles possible. Polymer based scaffold for cell seeding, growth factor delivery and tissue engineering via the nanoparticles embedded in site of tissue damage can also be constructed.[8] Though tissue engineering through the use of nanoscale perspectives is spellbinding, their use in clinical scenarios still remains fictious.

Subgingival Irrigation: Hayakumo et al has described the use of ozone nanobubble water produced by nanobubble technology in subgingival irrigation. The results of their study demonstrated that it can be used as an adjunct to periodontal therapy because of their enhanced antibacterial activity.[9]

Laser and nanoparticles: Laser irradiation on nanotitaniumparticles coated surface are shown to increase collagen production. Using this principle, gingival depigmentation and other periodontal procedures can be carried out. Sadony and Abozaidillucidated that nanoparticles along with diode laser has the potential to decontaminate dentin surface.[10]

Chronic periodontitis: Kadam et al hypothesized that adjunctive use of silver nanoparticle gel with scaling and root planinghas superior effect in comparison to tetracycline gel in management of chronic periodontitis.[11] Nanoproresolving lipid mediators because of their increased ability to penetrate into periodontitis affected tissue may be an effective method to manage chronic periodontitis.

Biofilm management: Biofilms incorporate wide array of microorganisms that results in increased antimicrobial resistance and pathogenicity. Till today, effective technique for biofilm management has not been devised. Nanoscale materials including zinc oxide, titanium dioxide, copper oxide, carbon nanotubes, chitosan, gold and quaternary ammonium compounds are shown to exhibit antibiofilm activity through the disruption of bacterial cell membrane by generating reactive oxygen species.[12]

Nanoantibiotics: These are the antibiotics that are delivered through nanocarriers with specialized antibiotic coating on their surface. They manifest broad spectrum of activity and decrease the probability of secondary infections. Gold nanoparticles are described to have increased adhesiveness to antibiotics. Besides nanoscale particles and antibiotics demonstrate positive interactions.[13]

Wound Healing: Improved wound healing with the use of nanomaterials has been reported in many studies. Polymer and lipid-based materials revealed excellent antimicrobial and antiinflammatory property with enhanced wound healing capacity. Carbon based particles showed good wound healing and angiogenesis, besides the metal-based nanoparticles showed scarless healing.[14]

Local Drug Delivery: Drug delivery using nanotechnology has been formulated as they have increased biocompatibility, targeted release, decreased antimicrobial resistance, long duration of action and less toxicity. Various drug delivery agents include liposomes[15], micelles[16], dentrimers[17], polymers[18], nanorattels[19], nanowires[20] and niosomes[21]. Nanoencapsulation technique is a recent technique developed by SWRI for delivering antibiotics and vaccines. Besides nanocomposite hydrogel-based delivery system through the use of triclosan, chitosan and biodegradable nanoparticles are also productive delivery vehicle.[22]

Nanoscale particles in dental implantology: Chemical and mechanical modifications dental implants are said to have better osseointegration. Various nanoscale mechanical modifications include creation of nanoareas like nanogrooves, nanopillars and etc.[23] Chemical coatings include coating with nanoparticles of diamond[24], hydroxyapatite[25], graphene, titanium oxide and metalloceramic based nanomatters[26]. Nanohydroxyapatite coated implants are commercially available as Nono Tite BIOMET 3i and have around 50% of nanohydoxyapatite.

Self assembling implants: C.X. Li et al investigated the effectiveness of nano structured self-assembling dental implants in type-II diabetes patients and stated that they exhibited decreased marginal bone loss and better osseointegration than the conventional dental implants used.[27]

Periimplantitis: Clot stability can be increased by using nanohydroxyapatite on citric acid conditioned surface. Elangovan et al in their study demonstrated enhanced fibroblast proliferation with the use of platelet derived growth factor-BB delivered using calcium phosphate nanoparticle.[28]

Toxicity of Nanoscale Particles: Increased surface area although seems to be beneficial they can cause increased toxicity by enhancing the duration of action, aquaphobic drug solubility and also their ability to cross blood brain barrier. Because of their small size, the host immune system reaction to the nanoparticle cannot be detected. Other drawbacks include difficultyin concomitant bulk synthesis, haemolytic activity towards host cell, cost ineffective, social and ethical challenges. Biocompatibility of traditional nanoparticles is unsure, since the nanoparticles in gas exhausts from vehicles and industries are shown to elevate respiratory and cardiovascular morbidity & mortality and to overcome these green nanoparticles were introduced; but still, they are synthesized in crude form and is also difficult to find which among the component is active constituent.

Future of Nanoperiodontics: Method for synthesizing high calibrated nanoparticles in bulk will be developed in near future. Most of the nanoparticles-based studies in Periodontics are in-vitro, the productive outcome of in-vivo studies is to be demonstrated. Materials with enhanced antibacterial effect, self-repairing property and compatible drug carriers are to be developed. The self-assembling antimicrobial peptides are under study and may be used for the treatment of periodontal diseases. Numerous untreatable diseases may be treated using nanotechnology. Nanotechnology based diagnosis and treatment of COVID-19 pandemic is the present focus of research and will be made possible in near future.

Conclusion

This is the era of nanotechnology since there is a gradual increase in research and applications of nanotechnology in numerous fields. This review has described in detail the history, classification, manufacture and application in Periodontics of nanoscale particles. Although the field of nanoperiodontics is fascinating, data on long term in-vivo effect of nanoscale particles are essential for clinical application.

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Conflict of Interest: Nil

References

1. Heuer AH, Fink DJ, Laraia VJ, Arias JL, Calvert PD, Kendall K, Messing GL, Blackwell J, Rieke PC, Thompson DH. Innovative materials processing strategies: a biomimetic approach. Science. 1992 Feb 28;255(5048):1098-105.
2. Yu J, Yang H, Li K, Lei J, Zhou L, Huang C. A novel application of nanohydroxyapatite/ mesoporous silica biocomposite on treating dentin hypersensitivity: An in vitro study. Journal of dentistry. 2016 Jul 1;50:21-9.
3. Monasterio G, Alvarez C, Vernal R, Cafferata EA, Covarrubias C, Maureira M, Gonzalez FE, Diaz KT. Multifunctional nanocarriers for the treatment of periodontitis: Immunomodulatory, antimicrobial, and regenerative strategies.
4. Jain R, Kaur H, Jain S, Kapoor D, Nanda T, Jain M. Comparison of nano-sized hydroxyapatite and β-tricalcium phosphate in the treatment of human periodontal intrabony defects. Journal of clinical and diagnostic research: JCDR. 2014 Oct;8(10):ZC74.
5. Mazor Z, Horowitz R, Chesnoiu-Matei I, Mamidwar S. Guided Bone Regeneration Using Nanocrystalline Calcium Sulfate Bone Graft in an Extraction Socket: A Case Report. Clinical Advances in Periodontics. 2014 Feb;4(1):49-55.
6. Mazor Z, Mamidwar S. Effect of Nanocrystalline Calcium Sulfate Bone Graft in a Bilateral Sinus-Augmentation Procedure: A Case Report. Clinical Advances in Periodontics. 2015 Feb;5(1):76-81.
7. Hong KS, Chung CH, Yim SB. A comparative study for guided bone regeneration of silk fibroin nanomembrane (NanoGide-S (TM)). The Journal of the Korean Academy of Periodontology. 2008 Sep 1;38(3):475-82.
8. Peng L, Cheng X, Zhuo R, Lan J, Wang Y, Shi B, Li S. Novel gene-activated matrix with embedded chitosan/plasmid DNA nanoparticles encoding PDGF for periodontal tissue engineering. Journal of Biomedical Materials Research Part A: An Official Journal of The Society for Biomaterials, The Japanese Society for Biomaterials, and The Australian Society for Biomaterials and the Korean

Society for Biomaterials. 2009 Aug;90(2):564-76.

9. Hayakumo S, Arakawa S, Mano Y, Izumi Y. Clinical and microbiological effects of ozone nano-bubble water irrigation as an adjunct to mechanical subgingival debridement in periodontitis patients in a randomized controlled trial. Clinical oral investigations. 2013 Mar 1;17(2):379-88.
10. Sadony DM, Abozaid HE. Antibacterial effect of metallic nanoparticles on Streptococcus mutans bacterial strain with or without diode laser (970 nm). Bulletin of the National Research Centre. 2020 Dec 1;44(1):2.
11. Kadam P, Mahale S, Sonar P, Chaudhari D, Shimpi S, Kathurwar A. Efficacy of silver nanoparticles in chronic periodontitis patients: a clinico-microbiological study. Iberoamerican Journal of Medicine. 2020 Apr 13;2(3):142-7.
12. Chaudhary S, Jyoti A, Shrivastava V, Tomar RS. Role of Nanoparticles as Antibiofilm Agents: A Comprehensive Review. Current Trends in Biotechnology & Pharmacy. 2020 Jan 1;14(1).
13. Vazquez-Muñoz R, Meza-Villezcas A, Fournier PG, Soria-Castro E, Juarez-Moreno K, Gallego-Hernández AL, Bogdanchikova N, Vazquez-Duhalt R, Huerta-Saquero A. Enhancement of antibiotics antimicrobial activity due to the silver nanoparticles impact on the cell membrane. PloS one. 2019 Nov 8;14(11):e0224904.
14. Swarna Meenakshi S, Sankari M. Nanoparticles in wound healing-a review. Indian J Public Heal Res Dev. 2020;11(6):831-835. https://www.embase.com/search/results? subaction=viewrecord&id=L2004762037&from=export.
15. Gregoriadis G, Swain CP, Wills EJ, Tavill AS. Drug-carrier potential of liposomes in cancer chemotherapy. The Lancet. 1974 Jun 29;303(7870):1313-6.
16. Nasongkla N, Bey E, Ren J, Ai H, Khemtong C, Guthi JS, Chin SF, Sherry AD, Boothman DA, Gao J. Multifunctional polymeric micelles as cancer-targeted, MRI-ultrasensitive drug delivery systems. Nano letters. 2006 Nov 8;6(11):2427-30.
17. Majoros IJ, Myc A, Thomas T, Mehta CB, Baker JR. PAMAM dendrimer-based multifunctional conjugate for cancer therapy: synthesis, characterization, and functionality. Biomacromolecules. 2006 Feb 13;7(2):572-9.
18. Pinon-Segundo E, Ganem-Quintanar A, Alonso-Pérez V, Quintanar-Guerrero D. Preparation and characterization of triclosan nanoparticles for periodontal treatment. International journal of pharmaceutics. 2005 Apr 27;294(1-2):217-32.
19. Li L, Guan Y, Liu H, Hao N, Liu T, Meng X, Fu C, Li Y, Qu Q, Zhang Y, Ji S. Silica nanorattle–doxorubicin-anchored mesenchymal stem cells for tumor-tropic therapy. ACS nano. 2011 Sep 27;5(9):7462-70.
20. Djalali R, Chen YF, Matsui H. Au nanowire fabrication from sequenced histidine-rich peptide. Journal of the American Chemical Society. 2002 Nov 20;124(46):13660-1.
21. Pradeepkumar Y, Panishankar KH, Saraswathi PK, Saravanan AV. Current research in Nano periodontics. SRM Journal of Research in Dental Sciences. 2012 Jan 1;3(1):46.
22. Jayakaran TG, Arjunkumar R. Nanocomposite hydrogels as local drug delivery in periodontics. Journal of Pharmaceutical Sciences and Research. 2013 Dec 1;5(12):277.
23. Tomsia AP, Launey ME, Lee JS, Mankani MH, Wegst UG, Saiz E. Nanotechnology approaches for better dental implants. The International journal of oral & maxillofacial implants. 2011;26(Suppl):25.
24. Paul W, Sharma CP. Nanoceramic matrices: biomedical applications. Am J Biochem Biotechnol. 2006;2(2):41-8.
25. Cheng Z, Guo C, Dong W, He FM, Zhao SF, Yang GL. Effect of thin nano-hydroxyapatite coating on implant osseointegration in ovariectomized rats. Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology. 2012 Mar 1;113(3):e48-53.
26. Catledge SA, Fries MD, Vohra YK, Lacefield WR, Lemons JE, Woodard S, Venugopalanc R. Nanostructured ceramics for biomedical implants. Journal of Nanoscience and Nanotechnology. 2002 Jul 1;2(3-4):293-312.
27. Li CX, Wang F, Jin ZL. A four-year prospective study of self-assembling nano-modified dental implants in patients with type 2 diabetes mellitus. Journal of Dental Sciences. 2020 May 20.
28. Elangovan S, Jain S, Tsai PC, Margolis HC, Amiji M. Nano-sized calcium phosphate particles for periodontal gene therapy. Journal of periodontology. 2013 Jan;84(1):117-25.