The Vision into Advanced Dentistry - Nanotechnology: A Review

Dr. Prachi Khedkar, [1] Dr. Sonal Pamecha, [2] Dr. Manish Chadha, [3] Dr. Shrutika Khade, [4] Dr. Maulik Barmeda, [5] Dr. Matangi Thaker [6]

1. **Dr. Prachi Khedkar**
   Postgraduate Student, Department of Prosthodontics Crown & bridge and Implantology, Pacific Dental College and Hospital Udaipur, Rajasthan, India
2. **Dr. Sonal Pamecha**
   Professor, Department of Prosthodontics Crown & bridge and Implantology Pacific Dental College and hospital, Udaipur, Rajasthan, India
3. **Dr. Manish Chadha**
   Professor, Department of Prosthodontics Crown & bridge and Implantology Pacific Dental College and Hospital, Udaipur, Rajasthan, India
4. **Dr. Shrutika Khade**
   Postgraduate Student, Department of Prosthodontics Crown & bridge and Implantology Pacific Dental College and Hospital Udaipur, Rajasthan, India
5. **Dr. Matangi Thaker**
   Postgraduate Student, Department of Prosthodontics Crown & bridge and Implantology Pacific Dental College and Hospital Udaipur, Rajasthan, India
6. **Dr. Maulik Barmeda**
   Postgraduate Student, Department of Prosthodontics Crown & bridge and Implantology Pacific Dental College and Hospital Udaipur, Rajasthan, India

Abstract

Dentistry is presently undergoing a great revolution, emerging into the eon of nanotechnology. In recent years, Nanotechnology becomes an emerging interdisciplinary field in dentistry.

It has been recognized that the potential of many biomaterials used in dentistry has been significantly enhanced after their scales were reduced by nanotechnology, from micron-size into nanosize. With developments in material science and biotechnology, nanotechnology is specially anticipated to provide advances in dentistry and innovations in oral health-related diagnostic and therapeutic methods. This article reviews the current trends and the future perspective of nanotechnology in different branches of dentistry.

Keywords: nanodentistry, nanotechnology, nanomaterials

INTRODUCTION

One constant since the beginning of time is the "Change". These significant changes have transformed technology from solely macro to nano level. Today nanotechnology has a profound effect on the way we live, largely through modern technology and the use of scientific knowledge for practical purpose. Nanotechnology refers broadly to a field of engineering and technology whose unifying theme is that the control of matter on the molecular level. Nanotechnology has many applications in optical engineering, agriculture & food, metallurgy, defense security, textile, drug delivery, medical field, cosmetics.

Dentistry is also facing major revolution in the wake of this technology having already been targeted with nanomaterial and nanotechnology- NANODENTISTRY.

What is Nanotechnology?

"Nano" - from the Greek word "dwarf". It is the science of manipulating matter measured in the billionths of meters or nanometer, roughly the size of 2 or 3 atoms.[1] It is also known as molecular nanotechnology or molecular engineering. It refers to creating material & structures in the range of 0.1 to 100 nanometer by various physical or chemical methods.[2] In its original sense, it refers to the projected ability to make items using modern techniques and instrument to produce high performance products.

HISTORY

Nanotechnology - the term was coined by Prof. Kerie E. Drexlar researcher of nantechnology.[3] The conceptual underpinnings of nanotechnologies were first laid out in 1959 by the noble prize winning physicist Richard Feynman in his lecture, "There's plenty of room at the bottom". In his historic lecture, he concluded saying, "this is a development which I think cannot be avoided".[4]

Two Approaches in Nanodentistry

The fabrication method for the structures can be divided into 2 approaches: "bottom-up" and "top-down".

1) BOTTOM UP APPROACH [5]

The bottom – up approach begins by designing and synthesizing new nanostructure.

It includes - Local anesthesia, Major Tooth Repair, Hypersensitivity Cure, Nanorobotic Dentifrice (dentifrobots), Tooth repositioning, Local drug delivery, Nanodiagnostics, Therapeutic aid in oral diseases.

2) TOP DOWN APPROACH [6]

The top down techniques that are used to manufacture nanoscale structures are mostly extensions of methods already employed in small scale assembly at the micron scale.

It includes - Nano Light-Curing Glass Ionomer Restorative, Nano Impression Materials, Nano-Composite Denture Teeth, Nanosolutions, Nanoencapsulation, Prosthetic Implants, Nanoneedles, Bone replacement materials.

APPLICATIONS IN DENTISTRY

A. Nanotechnology in Implant[7]

One of the major tests of Implantology is to achieve and maintain Osseointegration. Implant surfaces can be modified at nanoscale with the aim of improving the implant surface for better Osseo integration-

' NANO SURFACE MODIFICATION'. It include-

1. Anodization - Voltage and galvanic current are used to create the oxide layer on the implant surface.
2. Acid etching- This process uses strong acids which are effective in creating a thin grid of Nano pits on a titanium surface.
3. Plasma Spray- The process starts by using vacuum to remove all the contaminants, kinetic energy than guides the charged metallic ions or plasma to the surface.
4. Grid blasting- A porous layer is prepared on the implant surface by collision of microscopic particles.

B. Nanotechnology in Oral surgery

1. Nano Needles
   Modification in suture needle has also been developed. Suture needles are incorporated with nano-sized chrome steel crystals.
2. Surgical Nanorobotics. [8]
   Nano robots are programmed devices to perform specific biological task after they are injected into the body. These surgical nanorobot, are programmed by a dentist, could act as a semi-autonomous on site inside the body. These devices will perform various functions like trying to find pathology and so diagnosing and correcting lesions by nanomanipulation.
3. Local nanoanaesthesia: [9]
   Pain management stands for a part of major therapeutical goal. The utilization of nanotechnology via liposomal formulation has recorded high successfully end in pain control & quick patient recovery. Additionally, controlled release of an anaesthetic drug is alleged to prevent overdosing, reduced side effects, especially cardiotoxicity, neurotoxicity and tissue lesions.
4. Vibrotactile devices (VibraJact, DentalVibe)
   It uses the concept of gate control theory, that is simultaneous activation of nerve fibers via vibrations.
5. Computer controlled local anaesthesia system (CCLAD) (WandTM/ CompuDentTM system)-

It controls the flow rate of local anaesthetic solution through light weight hand piece and foot control.

6. Jet injection technology
   It uses mechanical force developing sufficient pressure to push LA via small orifice. It creates a skinny column of fluid which might penetrate soft tissues without needle.
7. Safety dental syringes
   By covering the needle with a sheath after it is off from patient's tissue, it reduces the risk of accidental needle prick injury Eg.Ultra Safety Plus XL syringe, UltraSafe Syringe.
8. Nano-encapsulation:
   This include controlled drug delivery, which comprises of hollow spheres, core–shell & nanotubes. E.g., arestin and minocycline are incorporated into microspheres for drug delivery by local means into the periodontal pocket.
9. Surface modified silicone nanowires -
   It delivers bio-molecule in mammalian cells without modifying its chemical structures hence allowing assessment of phenotypic sequences DNA, RNA, peptides, proteins and tiny molecules.
10. Trans-dermal drug delivery system - [10]
    It comprises of drug delivery system which, bypasses the primary metabolism and goes into systemic circulation with more targeted effect thus leading to least toxicity.
11. Bone replacement materials: [11]
    Bone is consist of organic compounds which is reinforced with inorganic compounds. This bone replacement material include,the nanocrystallites which shows a loose microstructure, with nanopores situated between the crystallites. From this process, a rough surface area is formed on the boundary layer between the biomaterial and cell, which is incredibly important for fast cell growth.
    Advantage of this material include- osteoinduction, fully synthetic, can't be sintered, highly porous.

C. **Nanotechnology in Orthodontics**:[12]

Nano - robots have major role in orthodontic. These nano-robots could directly manipulate the periodontal tissues which allows rapid tooth straightening, rotating and vertical repositioning within minutes to hours. With nanotechnology orthodontic realignments can be completed in a single office visit.

Application of Nanotechnology in Orthodontics-

- Orthodontic bands
- Orthodontic power chains
- Orthodontic elastomeric ligatures
- Orthodontic miniscrews
- Coated orthodontic archwires
- Control of oral biofilm

D. Nanotechnology in Prosthodontic

Impression materials [18]

Impression materials are used to copy the teeth and surrounding oral structures by creating a dental impression poured with dental plaster to fabricate a dental cast.Impression materials are available now with nanomaterials. Nanofillers in Poly Vinyl Siloxane (PVS) have shown good flow, improved hydrophilic properties and superior detail precision, hence fewer voids at margin and better model pouring. (Trade name: Nanotech Elite H-D)

IN FIXED PROSTHODONTICS

Nanoceramics: [13, 14]

'Nanoceramic' are the ceramics, which have superior mechanical properties, like strength and hardness. The hardness and strength of the many nanoceramics has increased four to five times higher over those of the available materials.

Nano-Glass ceramics have good translucency, excellent corrosion resistance, higher hardness and low modulus of elasticity when produced with sol-gel method. Carbon nanotubes (CNTs) have exceptional mechanical and electronic properties, result of their reinforcement. Lava Ultimate Resin Nano Ceramic blocks are innovative new CAD/CAM materials with superior esthetic results, durability and fracture resistance.

Nano resin based materials [15,16,17]

Organic fillers are incorporated in nanomers to boost the desirable rheological properties of nano resin based materials. These materials are available as titanium dioxide, aluminum oxide and silica oxide are employed in small amounts (1%–5%) to improve powder flow of the material.

Examples

- TIO2 Reinforced Resin Based Composite
- Ormocers (Organically Modified Ceramics)

- Nanocomposites With Alumina Nanoparticles
- Calcium Phosphate and Calcium Fluoride Nanoparticles Based Composites

IN REMOVABLE PROSTHODONTICS

Nano Composite Teeth [19]

Nanocomposite denture teeth are made of Polymethyl methacrylate (PMMA) and distributed nanofillers.

Advantages

- It has excellent polishing ability and stain-resistant
- It increases aesthetics & surface structure
- It alsoenhances wear resistance and surface hardness.

Nanoadhesives [22]

By adding nano- particles, the properties are improved without increasing the viscosity of the adhesive. The silica nano filler technology also contributes to higher bond strength performance.

Tissue Conditioners And Soft Liners [23,24]

Addition of silver nano-particles in these materials have displayed antimicrobial properties against S.mutans and S.aureus. Solutions of chlorhexidine mixed with sodium triphosphate (TP), trimetaphosphate (TMP) o r Hexametaphosphate (HMP) were investigated for antifungal property on silicone soft liners and obturators and Chlorhexidine-HMP coating has been proved to be the foremost effective antifungal agent thus enhancing the lifetime of the prosthesis.

Nanoparticles In Polymethyl Methacrylate Resin. [20, 21]

PMMA resin are commonly used as a denture base material and in making orthodontic appliances. However because of the surface porosities they have been prone to plaque accumulation, thus increasing the cariogenic oral flora. Nanoparticles are added to polymethyl methacrylate as antimicrobial agents to improve the viscoelastic property of resins. Similarly incorporation of nanoparticles like silver, platinum, titanium and iron have shown increase in flexural strength, antimicrobial properties, surface hydrophobicity, viscoelasticity, decrease in porosity.

MAXILLO-FACIAL PROSTHESIS [25,26]

Among all the different materials, silicone is the most popularly used for the fabrication of maxillofacial prostheses. Titanium dioxide, Zinc oxide and Cerium dioxide nano particles are added as opacifiers for silicone elastomers. Titanium dioxide and Cerium dioxide nano particles have exhibited the least colour instability. Addition of surface treated Silicone dioxide nano particles in 3% concentration have improved the mechanical properties like the tear strength.

E. Nanotechnology in Periodontics:

1. Dentinal Hypersensitivity:[27]
   Dental nanorobots occlude specific dentinal tubules instantly. These nanorobots enter dentinal tubular holes and proceed toward the pulp.When the dentist presses the icon for the desired tooth on the hand held controlled display monitor, it is immediately anesthetized. Besides this, Nanohydroxyapatite containing toothpastes are also shown to give promising results.
2. Oral Hygiene Maintenace:[27]
   The mouthwash and dentifrices containing nanoparticles are shown improvement 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.
3. Lab on chip Method: [27]
   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.
4. Nanomaterials for periodontal drug delivery:[28]
   An effective and satisfactory drug delivery system for the treatment of periodontal diseases has been developed by producing nanoparticles impregnated with triclosan. They have increased biocompatibility, targeted release, decreased antimicrobial resistance, long duration of action and less toxicity. Various drug delivery agents include liposomes, micelles, dentrimer, polymers, nanorattels, nanowires and niosomes. Nanoencapsulation technique is a recent technique developed by SWRI for delivering antibiotics and vaccines.
5. Nanomembranes: [29]

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.

6. Subgingival Irrigation: [30]
   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.
7. Laser and nanoparticles: [31]
   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]
8. Bone Grafts: [32]
   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, socket preservation and sinus augmentation procedures. Biologically, inspired rosette nanotubes and nanocrystalline hydroapatite hydrogel nanocomposites can be used as improved bone substitutes.

E. Nanotechnology in Conservative dentistry:

1. Nanocomposites: [15]
   Nanotechnology has made possible the creation of nano-dimensional filler particles, which are added either singly or as nanoclusters into composite resins. These composites produce a smooth surface after the polishing process are also superior in esthetic features. These fillers in nano- composites have higher translucence as they're smaller than the wavelength of light, which creates more esthetic restorations.
2. Tooth Repair [33]
   Nanorobotic manufacture and installation of a biologically autologous whole replacement tooth that includes both mineral and cellular components (ie, complete dentition replacement therapy) should become feasible within the time and economic constraints of a typical office visit through the employment of a reasonable desktop manufacturing facility.
3. Cavity Preparation : [34]
   Nano robots may be used for cavity preparation and restoration of teeth. Multiple nano robots working on the teeth in unison, invisible to the naked eye. As the cavity preparation is restricted to the demineralised enamel and dentin, thus providing maximum conservation of sound tooth structure.
4. Nanofilled glass ionomer cement: [35]
   Nano glass ionomers are designed to meet the various requirements, same as other materials used in the mouth. Nanotechnology was used in the development to provide some value added features not typically associated with glass ionomer restorative materials. By using bonded nanofillers and nanocluster fillers, along with FAS glass newer type of GIC was formulated using nanotechnology along with its fluoride releasing property. This product meets a wide range of clinical indications ranging from Class I, II, V and core buildup. Nano GIC is an ideal restorative material for everyday dentistry. Advantages of this material are: superb polish, excellent esthetics, higher wear resistance, It is faster, easier to mix and dispense.
5. Nanozone: [36]
   Nano technology based ozone therapy. It provides strongly oxidizing ozone. When given in adequate doses allows removal of 99.9% of bacteria which are responsible for the development of dental caries.

F. Nanotechnology in Oral medicine and radiology: [37,38]

Nanodiagnostics: Nano diagnostics is the use of nano devices for the first disease identification. In in-vitro diagnostics, nano medicine could increase the efficiency and reliability of the diagnostics using human fluids saliva or tissues samples by using selective nano devices, ready to work multiple analyses at sub cellular scale. In in- vivo diagnostics, nano medicine could develop devices able to work inside body to spot the early presence of a disease, to identify and quantify toxic molecules, tumor cells.

Diagnosis and Imaging: Scientists have successfully produced microchips that are coated with human molecules. The chip is designed to emit an electrical impulse signal when the molecules detect signs of a disease. Special sensor nanobots can be inserted into the blood under the skin where they check blood contents and warn of any possible diseases. They can also be used to monitor the sugar level in the blood. Advantages of using such nanobots are that they are very cheap to produce and easily portable.

Diagnosis and Management of Oral Cancer: Nanoscale cantilevers These are flexible beams resembling a row of diving boards that can be engineered to bind to molecules associated with cancer are-

a. Nanopores These are tiny holes that allow DNA to pass through one strand at a time. They will make DNA sequencing more efficient.

b. Nanotubes These are carbon rods about half the diameter of a molecule of DNA that not only can detect the presence of altered genes but also may help researchers pinpoint the exact location of those changes.

c. Quantum dots are nanomaterials that glow very brightly when illuminated by ultraviolet light. They can be coated with a material that makes the dots attach specifically to the molecule to be tracked. Quantum dots bind themselves to proteins unique to cancer cells, literally bringing tumors to light.

d. Dendrimers These are highly branched macromolecules with a controlled three-dimensional architecture. The branched structure makes it possible to attach other molecules like drugs and contrast agents to the cancer cell surface.

e. Nanoshells These are miniscule beads coated with gold. By manipulating the thickness of the layers making up the nanoshells, scientists can design these beads to absorb near-infrared light, creating an intense heat that is lethal to cancer cells. Nanoshells have a core of silica and a metallic outer layer.

Nanotechnology in cancer pain: Nanotechnology has exhibited a remarkable progress over the past 20 years in the management of pain in cancer patients. Recent applications at the nanoscale level include novel drug-delivery systems, such implantable drugdelivery devices, transdermal or transmucosal patches, and micro-needles. Oral transmucosal fentanyl citrate (OTFC; Actiq®, Cephalon, UK) is the first medication developed specifically for the treatment of breakthrough pain and provides its active ingredient, fentanyl, in a unique oral transmucosal delivery system, utilizing microfabrication technology, offering personal pain control for cancer patients.

Digital Dental Imaging: In digital radiographies obtained by nanophosphor scintillators, the radiation dose is diminished and high quality images obtained.

G. Nanotechnology in Tissue Engineering: [39]

Potential applications of tissue engineering and stem cell research in dentistry include the treatment of orofacial fractures, bone augmentation, cartilage regeneration of the temperomandibular joint, pulp repair, periodontal ligament regeneration, and implant osseointegration.

F. Nanotechnology in Pandemic Situation [40]

Rhinocerebral Mucormycosis is a potentially life-threatening disease, which affects mainly immunocompromised patients. Treatment options include reversing immunosuppression, surgery and systemic and local administration of anti-fungal medication. Amphotericin B is the primary agent employed, but its use is often limited by frequent side effects. Complexing Amphotericin B with lipid structures avoids most of the negative side effects, most importantly the dose-limiting nephrotoxicity.

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.

CONCLUSION

Nanotechnology will change dentistry, healthcare, and human life more profoundly than many developments of the past. As with all technologies, nanotechnology carries a major potential for misuse and abuse on a scale and scope never seen before. However, they also have potential to achieve significant benefits, like improved health, better use of natural resources, and reduced environmental pollution. These truly are the time of miracle and wonder. Nanodentistry still faces many significant challenges in realizing its tremendous potential.

BIBLIOGRAPHY

1. Kaehler T. Nanotechnology: basic concepts and definitions. Clin Chem. 1994 Sep;40(9):1797-9.
2. Mitra S, Dong Wu, Holmes B. An application of nanotechnology in advanced dental materials. J Am Dent Assoc 2003,1382-1390.
3. Reifman EM. Nanotechnology's impact on dentistry in Los Angeles, California in 2020 A. D.; expert from award winning book Nanotechnology: Speculations on a Culture of Abundance; 1996.
4. Feyman R. There is Plenty of Room at the Bottom: Miniaturization. New York: Reinhold; 1961:282–296. 5. Herzog A. Of genomics, cyborgs and nanotechnology: a look into the future of medicine. Conn Med. 2002;66:53-4.
5. Ashley S. Nanobot construction crews. Sci Am. 2001;285:84-5.
6. Bressan E, Sbricoli L, Guazzo R, Tocco I, Roman M, et al. (2013) Nanostructured Surfaces of Dental implants. Int J MolSci 14:1918- 1931.
7. Editorial. Nanotechnology, nanomedicine and nanosurgery. International Journal of Surgery 2005: 1-4.
8. Moradkhani MR, Karimi A, Negahdari B. Nanotechnology application to local anaesthesia (LA). Artif Cells Nanomed Biotechnol. 2018 Mar;46(2):355-360.
9. Prausnitz MR, Mitragotri S, Langer R. Current status and future potential of transdermal drug delivery. Nature reviews Drug discovery. 2004 Feb;3(2):115-24.
10. Saravana K, Vijaylakshmi R. Nanotechnology in Dentistry ; Ind J Dent Res 2006 ; 17(2); 62-65.
11. De Stefani A, Bruno G, Preo G, Gracco A. Application of Nanotechnology in Orthodontic Materials: A State-of-the-Art Review. Dent J (Basel). 2020;8(4):126.
12. Chen C, Trinidade FZ, de Jager N, Kleverlaan CJ, Feilzer AJ.The fracture resistance of a CAD/CAM Resin Nano ceramic (RNC) and a CAD ceramic at different thickness. Dent Mater 2014; 30(9);954-962.
13. Wei Wang, Susan Liao, Ming Liu, Qian Hhaoang Yating Fu.Recent Applications of Nanomaterials in Prosthodontics. J Nanomater 2015, article ID 408643, 11 pgs. http://dx.doi.org/10.1155/2015/408643.
14. CRA Foundation Newsletter Clinicians' guide to Dental products and techniques, understanding current resin basedc composites relative to filler. 2007;31(10):1-2.
15. Li L, Pan H, Tao J, Xu X, Mao C, Gu X,Tang R. Repair of enamel by using hydroxyapatite nanoparticles as the building blocks. J Mater Chem 2008;18(34):4079-84.
16. Malathi S, Sujatha V, Mahalaxmi S. Nanotechnology- an asset to Dentistry!!!. Int J Comm Dent 2014;5(1):27-31
17. Jhaveri HM, Balaji PR. Nanotechnology: the future of Dentistry. J Ind Prosthodont Soc 2005;5:15-17.
18. Chandki R, Kala M, Kumar KN, Brigit B, Banthia P, Banthia R. Nanodentistry – Exploring the beauty of the miniature. J Clin Exp Dent 2012;4(2)119-124.
19. Price CA. A history of dental polymers. Aust Prosthodont J 1994;8:47-54.
20. Acosta- Torres LS, Lopez- Marin LM, Nunez- Anita RE, Hernandez-Padron G, Castano VM. Biocompatible metal oxide nanoparticles: Nanotechnology improvement of conventional prosthetic acrylic resins J Nanomater 2011.
21. Silikas N, Masouras K, Satterthwaite J, Watts DC. Effects of nanofills in adhesives and aesthetic properties of dental resin composites Int J Nano Biomater 2007;1(2): 116-27.
22. Ki-Young Nam. In vitro antimicrobial effect of the tissue conditioner containing silver nanoparticles. J Adv Prosthodont 2011;3:20-24.
23. Garner SJ, Nobbs AH, McNally LM, Barbour ME. An antifungal coating for dental silicones composed of chlorhexidine nanoparticles. J Dent 2015;43(3):362-72.
24. Han Y, Zhao Y, Xie C, Powers JM, Kiatamnuay S. Colour stability of pigmented maxillofacial silicone elastomer; Effects of nano-oxides as opacifiers. J Dent 2010;38(2): 100-5.
25. Sara M Zayed, Ahmad M A, amal E Fahmy. Effect ofsurface treated silicon dioxide nanoparticles on some mechanical properties of maxillofacial silicone elastomer. Int J Biomater 2014
26. 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.
27. Jayakaran TG, Arjunkumar R. Nanocomposite hydrogels as local drug delivery in periodontics. Journal of Pharmaceutical Sciences and Research. 2013 Dec 1;5(12):277.
28. 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.
29. Hayakumo S, Arakawa S, Mano Y, Izumi Y. Clinical and microbiological effects of ozone nanobubble 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.
30. 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.
31. Thomas B, Mathew CA, Muthuvignesh J. Nanotechnology—Applications in Prosthodontics: A Literature Review. J Orofac Res 2014;4(2):103-110
32. Kanaparthy R, Kanaparthy A. The changing face of dentistry: nanotechnology. Int J Nanomedicine. 2011;6:2799-2804.
33. Biji Balan, Sreejesh Narayanan. NANO ROBOTICS - ITS TIME FOR CHANGE, IJOCR Jul - Sep 2014; Volume 2 Issue 5.
34. Najeeb S, Khurshid Z, Zafar MS, et al. Modifications in Glass Ionomer Cements: Nano-Sized Fillers and Bioactive Nanoceramics. Int J Mol Sci. 2016;17(7):1134.
35. Nanotech Endo and Nanozon at IDS 2013 in Cologne.
36. Patil M, Mehta DS, Guvva S. Future impact of nanotechnology on medicine and dentistry. J Indian Soc Periodontol. 2008;12(2):34-40.
37. Jackson, T., Patani, B. and Ekpa, D. (2017) Nanotechnology in Diagnosis: A Review. Advances in Nanoparticles, **6**, 93-102.
38. Shi J, Votruba AR, Farokhzad OC, Langer R. Nanotechnology in drug delivery and tissue engineering: from discovery to applications. Nano Lett. 2010;10(9):3223-3230.
39. Handzel O, Landau Z, Halperin D. Liposomal amphotericin B treatment for rhinocerebral mucormycosis: how much is enough? Rhinology. 2003 Sep;41(3):184-6.
40. Anusavice, K. J., Phillips, R. W., Shen, C., & Rawls, H. R. (2013). Phillips' science of dental materials.