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Nanoparticles in dentistry "Miniature marvels that can move mountains": A Review article

Rohit Kumar Singh[1*], Deepak Nallaswamy[1], Shanmugam Rajeshkumar[2], Sheeja S Varghese[3], Abhishek Kumar Gupta[4]

[1]Department of Prosthodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Chennai - 600077, TN, India

[2] Nanobiomedicine Lab, Department of Anatomy, Saveetha Medical college and Hospital, Saveetha Institute of Medical and Technical Sciences, Chennai - 602105, TN, India

[3]Department of Periodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Chennai - 600077, TN, India

[4]Department of Prosthodontics, ESIC Dental College and Hospital, Dr KN Katju Marg, Rohini-110089, Delhi, India

***Corresponds to**

Dr Rohit Kumar Singh
PhD Scholar
Department of Prosthodontics,
Saveetha Dental College and Hospitals,
Saveetha Institute of Medical and Technical Sciences,
Chennai - 600077, TN, India
Email Id: rks.prosthodontics@gmail.com
Mo: 9742987218

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Abstract

Objectives: This article aims to review the application of nanotechnology in the field of dentistry, emphasizing the potential of nanoparticles to enhance the properties of dental materials. The focus is on how nanoparticles, particularly silver nanoparticles, can be used to improve the antimicrobial properties of dental products and how nanotechnology can overcome the limitations of current biomaterials.

Materials and Methods: A review of existing literature was conducted to explore the impact of nanotechnology on dental materials. The review included studies related to the incorporation of nanoparticles in dental biomaterials, such as tissue liners and restorative materials. Special emphasis was placed on analyzing the antimicrobial properties of nanoparticles, particularly silver, when used in dental applications. The review also highlights the natural phenomenon occurring at the nanoscale that can be harnessed for dental solutions.

Results: Nanotechnology, particularly the use of nanoparticles, has shown promising results in the dental field. The incorporation of silver nanoparticles in tissue liners has demonstrated significant antibacterial activity, making it an effective strategy against oral microorganisms. Nanoparticles are capable of enhancing the mechanical and physical properties of dental materials, making them more durable and resistant to environmental stresses. The unique properties of materials at the nanoscale offer opportunities to improve the performance and longevity of dental restoratives.

Conclusions: Nanotechnology in dentistry, or nanodentistry, holds great promise as an emerging field. The ability to manipulate materials at the nanoscale has led to the development of novel dental materials with superior properties, including enhanced antimicrobial activity. While much progress has been made, there remains significant potential for further advancements. Continued research is required to optimize the use of nanoparticles and fully realize their benefits in clinical dental practice.

Introduction:

Progressively, science is undergoing great evolutions that are leading humanity towards a new era of nanotechnology including dentistry that provides an insight to explore a coherent technology that is beneficial for the dental sciences. Nanodentistry helps in attaining good oral health while using Nanomaterials and various biotechnologies like nanorobots and tissue engineering etc. In dentistry, there are other treatment modalities where nanotechnology proves to be effective, and those include nanorobots, nanoneedles, nanorobotics dentrifices, bone replacement materials, nanocomposites, etc. In addition, nanotechnology has wider use in the field of medicine where its benefits in the development of drugs to the cells of cancer in the body which has proved to be safe and effective in treating cancer.

Definition and history: The word nanotechnology originates from a Greek word, 'nano' which means dwarf. Nano is a prefix that refers to one billionth of physical size. One nanometer (nm) refers to a unit of length that equals one billionth of a meter. [01]. Nanotechnology is a branch of technology that works on dimensions less than 100nm. It covers objects such as viruses at around 100nm size, down to glucose molecules at around 1nm. Hence, it is very much concerned with structures at the molecular and atomic scale. [02]. The concept of nanotechnology was introduced by Richard Feynman while presenting his conceptual theory "There's Plenty of Room at the Bottom" at the California Institute of Technology that was later published in "Engineering and Science". [06]. However, the actual term "nanotechnology" or "nanosciences" was described by Prof. Norio Taniguchi (Tokyo Science University) for the first time in 1974. [07]

This branch of science has attracted the attention of researchers owing to its broad range of applications in medicine and engineering. Unique characteristics of the nanoscale may not only have profound effect on the physical properties such as tensile strength, fracture resistance, surface hydrophobicity, but also affect the biological properties like biocompatibility and cytotoxicity. The physical, chemical, mechanical, and biological properties of materials at an individual molecular level may differ compared to their bulk properties at the nanoscale. [08] Considering the role of nanotechnology in enhancing the properties of the materials, it could be applied in dentistry and medicine.[03]. According to a review study conducted by Zarchi et al., utilizing smart nanocarriers along with external stimuli could remarkably improve drug potency and significantly reduce possible adverse side effects.[04]

According to Kachoei et al., the coating of some Nanomaterials on the orthodontic wires could decrease the friction force between the brackets and wires, thereby facilitating the treatment procedure compared to conventional materials.[05]

Nanostructures used in dentistry include nanorods, nanospheres, nanotubes, nanofibers, Dendrimers, and dendritic copolymers.[06]. Nanotechnology can also help in the reduction of post operative pain after the usage of endodontic sealer and endoactivator because of the increased drug delivery mechanism of the nanoparticles.[07]. The cone beam technique is used in evaluating the remaining dentin thickness of the canal after cleaning and shaping process.[08]

General properties of Nanomaterials:

The properties of Nanomaterials may vary based on multiple factors such as the material type and morphological structure. These materials are expected to exhibit novel and significantly better physical, chemical and biological properties. Few expected properties of Nanomaterials are listed below:

- At nanoscale, greater the surface area greater is the surface functionalities
- High surface area facilitates better mechanical interlocking of nanoparticles to the polymer matrix. [09]
- Inorganic ceramic nanoparticles are brittle and hard and can reinforce to provide superior mechanical properties. [10]
- The areas of stress concentration are reduced, resulting in improved resistance to the crack propagation and higher fatigue strength. [11]
- Optical properties and surface finish are improved while using nano sized fillers. [12]
- The biodegradability and biodegradation rates can be better controlled compared to conventional composite materials. [13]
- They can present antimicrobial, antiviral, and antifungal properties and as a consequence, can prevent biofilm formation when nanoparticles loaded with an antimicrobial agent are incorporated in resin composites. [17]

Approaches to Nanodentistry

Primarily, the fabrication techniques for the production of various nanoscale structures can be categorized into two approaches.

- **Bottom-up approaches:**
  Bottom-up approach means to aggregate smaller nano-sized particles to form complex assemblies with improved functional properties. This aims for designing custom made nano-sized particles which demonstrate the ability of self-assembling or self-organizing into complex high order macro scale particles or structures.
  Nanodentistry as bottom-up approach: [04]
- Local anaesthesia
- Hypersensitivity cure
- Nanorobotics dentrifice
- Dental cosmetics
- Orthodontic treatment
- Photosensitizers and carriers
- Diagnosis and treatment of oral cancer

- **Top-down approaches:**
  In simpler terms, top-down approach means to create smaller nano-sized particles from complex structures with improved functional properties. As size of the particle in a system decreases, there is an increase in surface area resulting in pronounced increase in physical phenomenon or properties due statistical as well as quantum mechanical effects.
  Nanodentistry as top-down approach: [05]
    - Nanocomposites
    - Nanosolutions
    - Impression materials
    - Nanoencapsulation
    - Nanoneedles
    - Bone graft materials

Nanoparticles used in dentistry:

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1. Carbon based nano-materials

A. Carbon nanotubes:

carbontube nanoparticles possess unique chemical, mechanical properties, thermal and electrical properties. [09]Carbon nanotubes (CNTs) have unique electrical property as well as mechanical property. Strength and flexibility of CNTs are because of C22C covalent bond and hexagonal orientation. CNTs also have thermal and electrical conductivity (semi conductivity) [20]

Because of its excellent mechanical and electrical properties such as heat stability, heat transmission efficiency, high strength, and lower density, it is used as a candidate for teeth filling and various applications. CNTs needles are used for bringing active agents to live cells. [21].

B. Casein phosphopeptide (CPP) and amorphous calcium phosphate (ACP) nanocomplexes:[33]
Casein phosphopeptide and amorphous calcium phosphate are thought to accelerate the remineralisation of the enamel surface. CPP-ACP Nanomaterials are used for the prevention of enamel caries, remineralisation, and for the management of oral biofilm. Nanocomplexes in ACP-CPP are significantly smaller in size than microorganisms, therefore establishing an effective interaction with oral microorganisms and binding to the cell surface to interfere with their adherence with the tooth. This sequence delays formation of biofilm,inhibits demineralization and promotes remineralisation of initial carious lesions.

Furthermore, CPP-ACP Nanomaterials are used in sugar-free gums due to their proven role in preventing proximal caries.

C. Graphene:
Graphene consists in a single layer of carbon atoms with a hexagonal honeycomb lattice that was isolated for the first time in 2004 by Geim and Novoselov at The University of Manchester. Such structure makes Graphene the thinnest known material, also confers it some extraordinary properties such as very high mechanical strength, electricity, and heat conduction, having no effective mass [18]. Graphene based materials and their analogues have demonstrated to find important applications in nanomedicine and nanobiotechnology such as gene transportation, anticancer drug release, photothermal and photodynamic therapies, biosensor and tissue engineering being of course, most of them quite relevant in dentistry [19]. Graphene nanoparticles have the capacity to remove the biofilm of streptococcus mutans and prevent caries and also act as an antibacterial agent.[10]

Conducting electrons of Graphene, mostly behave like electrons or neutron which move like the speed of light. Thus, Graphene is used in photovoltaic, bio devices, ultra capacitors for diagnosis and detection of disease and building of anti-bacterial surfaces.[22]

Biofilms are important due to its implant failure nature. Graphene/zinc oxide nanocomposites has the potential to the biofilm caused by streptococcus mutans [23]. Antibiofilm assays show biofilm reduction in presence of GZNC. [23]. PCL/Graphene was also used for porous scaffolds formation. [24]

2. Hydroxyl apatite: hydroxyl apatite NPs has similar composition as teeth and bone which make it a biocompatible substance for the physiological process and has been used widely in the field of medicine and dental sciences. Enamel, the hardest tissue of human body has Hap nano crystals as the building blocks. It is a natural calcium phosphate ceramic, predominant in 97% enamel. HA nanocrystals powder can be prepared using the wet chemical process, that can be used to produce either microcrystalline HA (sintering at ~ 1100 C for 60 min) or nanocrytalline HA (hydrothermal treatment at 200 C for 24 hrs) . The nano-hydroxyapatite crystals have the capacity to enter the dentinal tubules [11]. The function of the dentinal tubules is to seal the opening and thus, prevents the nerves to expose towards external stimuli. Thus, HAp helps to reduce dental hypersensitivity. Their high biological activity and reactivity enables them to bind to the dentin apatite and tooth enamel and HAp also retard auxiliary erosive demineralization. Some scientists have shown that the hydroxyapatite as like tricalcium phosphate, do not go through any resorption [25]. HA powder deposited on the surface of implants at room temperature resulted in better adhesion of osteoblasts and more calcium deposition in the case of nanocrytalline HA coating when compared to traditional HA coating [30]. Carbonated hydroxyl apatite nanoparticles (20-100nm) were used to repair micron sized carious lesions [31]. Toothpastes used for prevention of carious contain needle-like hydroxyl apatite nanoparticles as an active constituent. Key benefits include ease of application (as the medium of delivery is toothpaste) and deposition of apatite nanoparticles in the defect. The remineralisation of decaying tissues was better in comparison to sodium fluoride-containing formulations. [32]

3. **Iron oxide:** There are two forms of iron oxide nanoparticles magnetite and maghemite which are non-toxic and biocompatible. These iron-oxide nanoparticles are utilized to remove biofilms [12]. Furthermore, iron oxide is well decomposable and thus helpful in favour of in vivo applications. Mostly used NPs in medical science are nanoparticles based on super-paramagnetic iron oxide [26]. Iron oxide nanoparticles are widely used to eradicate biofilms from the surface of implants.

4. **Zirconia:** zirconia nanoproducts have similar color and metallic properties as teeth. Zirconia is chemical oxide which is soluble in water. Thus, it reduces the bacterial adhesion and has low cytotoxicity[27]. This makes zirconia oxide as a widespread biomaterial for dental implants. High fracture resistance can be acquired by ZrO2 because of energy retention property throughout the conversion of polygonally shaped molecules into monoclinic ones [28]. Additionally, zirconia is Osseo conductive, thereby facilitates bone formation. Zirconia and alumina material possess the physical and chemical properties of ceramic material [13]. Hence, zirconia/alumina nanocomposites are new implant material which shows better efficacy as compared to the ceramic materials.

5. **Silica:**silica- based nanoparticles have a significant role in nanotechnology, due to its size, surface area, biocompatibility, low toxicity, low density and adsorption capacity. Thus, silica NPs used in biomedical research such as drug delivery, enzyme supporters and biosensors [29]. In the field of dentistry silica nanoparticles are used in dental fillers. [14] Hence, various dental filler products developed to improve their mechanical properties. Silica particles are also used for tooth polishing as polishing prevents dental caries, which act as as primary defence mechanism against the cariogenic bacteria.

6. **Titania:**Insertion of implants give rise to the allergic reaction by inducing antigen/antibody type 1 and type 4 complex reactions. However, adhesion of microbes on Titania implants has a strong effect on teeth healing process and show the long-term effect on implants. Adherent bacteria number reduces significantly on stable Titania (Titania/zirconia NP) rather than on polished Titanium [29].

7. **Silver:** Silver nanoparticles possess antibacterial activity [15]. Because of their minute structure they have the capacity to penetrate the bacterial cell membrane resulting in the production of bactericidal activity [16]. AgNPs have also been studied for use in several areas of dentistry which includes Endodontics, dental restorative materials, Prosthodontics, dental implants etc. because incorporation of silver NPs decreases microbial colonization over dental parts and promotes good oral health. Beside various advantages of using silver in dental materials , there is a disadvantage of using AgNP and it is, change in color of dental tissues.

Application in several spheres of dentistry

Nanodentistry for Diagnostics

Given the influence of nanotechnology on medication delivery and diagnostic and innovative material design for implantology and tissue regeneration, oneone may assume the same degree of involvement of this developing topic in dentistry. Still today, nonetheless, the scientific and clinical groups claiming an effect of nanotechnology on the diagnosis of dental diseases have made quite limited contributions.

One should should Oral malignant lesion diagnosis is one of the most important usesuses of nanotechnology in the area of dentistry. Imaging contrast enhancers Overall cancer treatment plan creation and general cancer care depend critically on our capacity to visualize these lesions. One may classify some conventional clinical imaging modalities like CT,MRI, and MRI, and ultrasonic waves as structural approaches. Thus, they can help with the detection of anatomical patterns as well as provide basic information about the size of the tumor, location,location, and dissemination depending on the endogenous contrast. These imaging methods become less accurate to differentiate between benign and malignant tumors, nevertheless, in cases with tumors less than 5 5 mm.

Strong X-ray absorption of gold as an element allows it to be utilized as a contrast agent in the form of gold nanoparticles. Hainfeld et al. have recently achieved advances in nanotechnology- based CT imaging in line with GNP [51] increased availability. Originally, their study concentrated on using GNPs to provide in vivo vascular contrast enhancement in CT imaging. The gold particles were not functionalized in their early study, so they did not bind to any particular cell receptor [52].

Prevention Dentistry

Prevention or treatment of biofilm--dependent oral disorders depends on a complete knowledge of bacterial adhesion, the primary determinant of bacterial colonization and pathogenicity, and bacterial nanomechanics [47]. Both from the same or other species and even from different substratessubstrates, e.g., teeth and implants, germs can stick to other bacteria [48]. AFM,AFM, with its ability to immediately interact with an image or live cells without any disturbance in their shape and characteristics, offers a breakthrough inthe characterization the characterization of bacteria as well as measurement of their adherence to various substratessubstrates using modern technologies [49].

A biofilm is therefore a highly ordered population of several bacterial species buried in a matrix of exopolysaccharides and proteins. Consequently, diversity of bacterial species in biofilm raises its resistance to antibiotics. AFM cantilever, real-time scanning of a live bacterial cell with great sensitivity made feasible using nanomechanical biosensors [50] By use of a ligandsuch as such as polyethylene glycol, the functionalization of GNPs fosters stability and persistence in circulation, therefore enabling larger accumulation in the tumor tissue. Furthermore,Furthermore, acting as a hydrophobic barrier for reticuloendothelial systems phagocytosis and absorption [53]

Using near-infrared (NIR) luminous quantum dots (QDs) is another way nanotechnology helps to identify oral cancers. Exposed to an excitation wavelength, QDs—nanometer- scale semiconductor crystals made of elements of group II-VI or III-V—act as inorganic fluorophores. fluorophores. Like GNRs. Coupled with biomolucles, these functionalized QDs efficiently become luminous probes that can bind with sensitivity and specificity to a range of targets,targets, like immunoglobulin H, antigens, glycoprotiens,glycoprotiens, and receptors. With wide continuous excitation and photostable luminescence with narrow, symmetric emission spectra, QDs allow excitation of many QDs using a single wavelength [54]. Independent reports of the use of QDs for imaging of cells and tissues made by Nie and Alivisatos in 1998 have spurred investigation of QD application in life science [55]. Apart from cancer detection, this technique has been applied in more common conditions,conditions,such as such as dental caries and periodontal disorders,disorders, where biofilms and bacterial infections are crucial. QDs are not limited in their usage. Kleopfer et al. used QDs for bacterial labeling first in 2003 [56].

The third is is Biochips are extremely tiny devices on which a microarray—a collection of miniature test sites—is set. Salivary biomarkers The key benefit of the biochips over more conventional methods is that teststests may be conducted concurrently to get better throughput and speed. Emerging and developing biochips [57] represent maybe one of the most fascinating applications of nanotechnology in oral health diagnostics. Gau and Wong proposed in 2007 thatthe oral the oral fluid nanosensor test is meant for point-of- care multiplex detection of salivary biomarkers for oral cancer [58]. Using two salivary proteomic biomarkers (thioredoxin and interleukin-8 [IL-8])[IL-8]) and four salivary mRNA biomarkers (SAT, ODZ, IL-8, and interleukin-1 beta [IL-1β]),[IL-1β]), they showed in their study that oral cancer may be highly sensitively and specifically detected. Another endeavor in biochips results from the work started by Weigum et al.al. on the creation of a diagnostic cytology-on-a-chip approach that promptly identifies premalignant and malignant cells with great sensitivity and specificity [59].

Christodoulides et al. have devised an electronic microchip assay to detect C-reactive protein (CRP), a biomarker for inflammation related toto periodontal disease,disease, at the pictogram per millilitermilliliter level [60]. Known to be a systemic maker generated in response to inflammatory stimuli, CRP may be utilized to differentiate the serum between a healthy condition and the presence of periodontitis and saliva [61]. Developed to perform immunological tests in less than 10 minutes with minimal sample volume and concentration requirements to test for periodontal disorders, another device named the integrated microfluidic platform for oral diagnostics [62]

Therapy Nanodentistry

Therapeutic dentistry uses nanotechnology to treat dentin hypersensitivity, root canaldisinfection, and disinfection, and oral malignancies, and their use has been expanded to the most current uses in tissue engineering and drug delivery systems.

One couldsay dentin say dentin is the second layer of the tooth and is shielded fromthe outside the outside oral environment/stimulus by enamel inthe coronal the coronal region and cementum inthe radicular the radicular part. Dentin hypersensitivity is thought to be caused by any damage to the protective enamel covering exposing underlying dentinal tubules, therefore altering the fluid pressure hydrodynamics of the fluid inside the dentinal tubules. Since GNPs were discovered to be readily absorbed on the inner dentinal tubule walls, they are used in therapy for dental hypersensitivity. To aid inin closingclosing the open tubules and lower the dentin hypersensitivity, silver staining was applied. Shortly after highly concentrated GNP brushed the opening tubules, laser irradiation encouraged the agglomeration of nanoparticles to occlude the exposed tubules [63]. With the selective and exact occluding of the tubules within minutes utilizing biological materials [64], nanorobots assist to permanently heal dentin hypersensitivity.

The third is that, as is that, as was already shown, nanotechnology is applied in the detection and treatment of oral cancer. GNPs were proposed as a radiosensitizer\ in cancer radiation treatment, and they induced cell death following gamma gamma radiation. In cancer treatment, nanodelivery systems [e.g.,[e.g., using using naringenin--loaded nanoparticles in 7,12- dimethylbenz(a)anthracene, chemotherapeutic medication targeted and controlled delivery was improved along with stability [68].

Apart from treating cancer, nanotechnology has also has also been applied to provide efficient control of the breakthrough pain related to cancer. Developed to quickly and effectively provide the upload analgesia at a constant and regulated diffusion into the target tissue was a nanodelivery transbuccal device. Using this approach has benefits in that it guards patients from needle injection and reduces their chance of overdose. It also prevents the medication related toot oral delivery from undergoing enzymatic and spontaneous breakdown [69].

Fourth, nanotechnology Fourth, nanotechnology in tissue engineering has made notable progressing making in making these scaffolding materials possible to provide special 3D matrix conditions conditions for cells and tissues [70]. Like other medical fields, tissue engineering in dentistry has been investigated to mix the technologies of scaffold matrices with the regenerative potential of stem cells, which may be mostly derived from dental tissues like dental pulp, periodontal ligament, and alveolar bone [71]. The scaffolding matrices must have particular utility in order to offer surfaces that allow cell attachment, proliferation, proliferation, and differentiation, differentiation, as well as to show porosity networks that let nutrients and cells pass through [72]. More definite physicochemical signals from the nano topological surfaces help cells to identify their adherence and differentiation by means of their nano scale structures. Moreover, numerous biological proteins and active chemicals may be spatially controlled in controlled in the cellular behavior and show therapeutic efficacy by means of nano scale integration with the scaffolding materials. Thus, the nanotechnology-driven tissue engineering may accomplish native tissue imitating structures or can evoke the phenomena that happen in nature, finally to develop constructions equal to tissues in dentistry, including dentin, pulp, PDL, cementum, and alveolar bone.

Five. Five. Drug delivery systems are designed technologies meant for controlled release or focused distribution of medicinal medicines. Effective treatment of illness and the enhancement of the regeneration capacity of damaged tissues depend on the supply of therapeutically appropriate molecules. Usually packaged in carriers like scaffolds or nano particles, these compounds allow regulated and steady release, therefore impacting a sequence of biological events including cell homing, adhesion, proliferation, and differentiation. Two key strategies define the treatment plan for periodontal disease: the therapeutic molecules should be loaded in great volumes and then supplied in a regulated and targeted manner. A] Eliminating germs will help to stop sickness from spreading. B] The treatment with regeneration. Thus, the process of regeneration of periodontal tissue is performed by means of therapeutic substances delivered from nanoparticles. Minocycline was encapsulated,encapsulated, and PLGA nanoparticles were shown to treat periodontal diseases. Comparatively to minocycline-free nanoparticles, the drug release was proven to be maintained for weeks and produced notable antibacterial activity. 72]

Preventive Nano-Dental Work

Modern dentistry aims to prevent rather than treat biofilm-dependent oral disorders, e.g., dental caries and endodontic and periodontal diseases. As mentioned, prevention is better than cure. Nanotechnology offers several ways to avoid oral disorders, including dental caries and periodontal diseases.

One could say One of the most common damaging diseases compromising tooth structures, dental caries is brought on by bacteria like streptococcus mutans, streptococcus sobrinus, and lactobacillus. Thus, by stopping the bacterial activity, reversing the demineralization process, and encouraging remineralization, one can control tooth caries.

Dental composites or dental adhesives and cements contain multiple nanoparticles (silver, zinc oxide, and polyethylenimine) to stop bacterial development by different means. Effective in killing bacteria as well as in preventing bacterial adherence and preserving integrity in the presence of biological fluids, antibacterial nanocoating was discovered to be applied on tooth surfaces [41]. Calcium carbonate nanoparticles have high retention on oral surfaces due to their colloidal particle size and possibility for calcium ion transport. They therefore serve as a delivery mechanism for gradual, continuous release of high quantities of

Calcium ions enter the surrounding oral fluids [42]. Incipient enamel lesions were effectively remineralized when CC nanoparticles were included in an experimental tooth dentrifice, as they also have the capacity to raise the surrounding fluid PH [43]. Thanks to their chemical binding capacity, e.g., carbonate hydroxyapatite, these NPs attach to damaged enamel and dentin to provide a protective layer and subsequently counteract the action of acid or bacterial assault [44].

Nanotechnology has shown great success in preventing certain periodontal diseases. Local use of nanostructured doxycycline gel [45] helps to reduce bone loss in an experimental periodontal disease model. With their continuous and quick motions over the supra and subgingival surfaces, nanorobots mouthwash and toothpaste left on the occlusal surfaces of teeth constantly eliminate the organic residues and inhibit the calculus buildup. Should they be ingested, these robots may be securely turned off [46].

In nanodentistry, bionanostructures:

The main goal of dentistry is to restore either partial or total tooth loss, and dental composites and implants help to do that. Mostly, micromechanical retention helps to retain dental composites or dental implants. The effectiveness of these restorations depends thus on the interaction between resin composites and dental tissues or between dental implants and bone.

One. Different adhesive resin systems, depending on either independent or combined usage of etchant, primer, and adhesive resin, allow bonding of dental composites to tooth structures [34]. The etchant preferentially dissolves the HA crystals, a natural cover over demineralized dentin rich in collagen [35]. The primer facilitates the latter adhesive resin penetration. The long-term effectiveness of resin composites depends on the integrity and longevity of the adhesive resin- dentin interface, and the polymerized adhesive resin helps to shield the collagen from enzymatic degradation. Compromised interface integrity results in nanoleakage, seen as spotted, reticular type, and water tree at the adhesive layer [36]. The nanoleakage is constantly connected with discomfort, sensitivity, recurring degradation, and eventually failure of repair. The lifetime of the resin-dentin bond has been extended using nanotechnology via:

a. Reinforcement, cross-linking, and biomimetic remineralization protect exposed collagen.

b. stopping MMPs from acting and,

c. Changing the adhesive rein monomer. [37] [38]

The second is that the tissue-implant interaction determines whether dental implants are successful. From recruitment and migration of bone cells to the implant surface, peri-implant healing advances from the action of persistent blood clots, i.e., the osteoconduction phase, to de novo bone formation and eventually bone remodeling. Providing contact osteogenesis depends on both de novo bone formation and osteoconduction [38]. Prevention of bacterial invasion and growth depends on the implant's tight contact at its neck with surrounding gingival tissue.

Indirectly affecting implant osseointegration, microscale variation of topography and chemistry of the implant surface might surely cause changes at the nanoscale level [39]. Since cells may interact directly with nanoscale characteristics, nanotechnology has been proposed to control bone growth and implant osseointegration. Several techniques, e.g., lithography, ionic implantation, anodization, and radiofrequency plasma treatments, have been employed to produce controlled nanosurface characteristics on dental implants with relation to their surface topography. Furthermore, tried is immobilizing therapeutic substances that encourage osteogenesis, e.g., bisphosphates and simvastatin, or to prevent bacterial infection, e.g., silver and zinc oxide nanoparticles, within the biofunctionalized implant surface [40].

Future of nanotechnology:

To preserve oral health, nanodentistry makes use of dental nanorobotics, biotechnology, tissue engineering, and nanomaterials. Local anesthetic, dentition renaturalization, permanent hypersensitivity cure, orthodontic realignments, covalently bonded diamondized enamel, and ongoing oral health maintenance using mechanical dentifrobots are just a few of the novel therapeutic options it provides. Dental nanorobots can detect, perceive, and change their environment by crawling through human tissue using unique motility mechanisms. They can enhance dental durability and aesthetics, induce anesthesia, and fix teeth. Utilizing the atomic or molecular characteristics of materials, nanotechnology has the ability to enhance the qualities of different kinds of fibers. Paints, polymers, and solvents can all benefit from the distinctive and dispersible nanoparticles that are produced by nanosolutions.[41] However, before molecular nanotechnology can offer high-quality dental treatment to the 80% of the world's population that lacks access to it, societal challenges of public acceptance, ethics, legislation, and human safety must be addressed.

Conclusion

Because of its many uses in engineering and health, nanotechnology—a field of science that focuses on dimensions smaller than 100 nm—has attracted a lot of interest. Dendrimers, dendritic copolymers, nanorods, nanospheres, nanotubes, and nanofibers are examples of nanostructures utilized in dentistry. There are two types of nanodentistry approaches: top-down and bottom-up. Since carbon-based nanomaterials have good electrical, mechanical, and thermal conduction properties, they are employed in dentistry. Examples of these materials are carbon nanotubes, casein phosphopeptide, and ACP nanocomplexes. For physiological processes, hydrophobic apatite nanoparticles, iron oxide nanoparticles, and zirconia oxide are biocompatible materials. Biosensors, medication administration, enzyme support, and biomedical research all employ silicon-based nanoparticles. The use of gold nanoparticles with imaging contrast enhancers to identify lesions has had a substantial influence on the detection and treatment of oral malignancies thanks to nanotechnology. Oral malignancies are treated with nanotopological surfaces and nanodelivery vehicles. The goal of preventive nanodentistry is to stop oral disorders including periodontal disease and dental caries that are dependent on biofilms. Dental nanorobotics, biotechnology, tissue engineering, and nanomaterials for local anesthetics, dentition renaturalization, and continuous oral health maintenance are examples of future nanotechnology.

References:

1. Erkoç Ş. Nanobilim ve Nanoteknoloji. 1.Baskı, Ankara:ODTÜ Yayıncılık; 2007;1-10.
2. Abou Neel EA, Bozec L, Perez RA, Kim HW, Knowles JC. Nanotechnology in dentistry: prevention, diagnosis, and therapy. Int J Nanomedicine. 2015 Oct 8;10:6371-94.
3. Malek M, Farzaneh F, Samani Y, Pachenari F, Pachenari H. The applications of nanotechnology in restorative dentistry: a review study. Nanomed J. 2019; 6(4): 241-4.
4. Karimi Zarchi AA, Amini SM, Jomehfarsangi Z, Mohammadi E, Moosavi Z, Ghadiri Harrati P. A study on the possibility of drug delivery approach through ultrasonic sensitive nanocarriers. Nanomed J. 2018; 5(3): 127-37.
5. Kachoei M, Divband B, Eskandarinejad F, Khatamian M. Deposition of ZnO nano particles on stainless steel orthodontic wires by chemical solution method for friction reduction propose. Res J Pharm Biol Chem Sci. 2015; 6(3): 104-122
6. Feynman R. There’s plenty of room at the bottom. InFeynman and computation 2018 Mar 8 (pp. 63-76). CRC Press.
7. Taniguchi, N., 1974. On the Basic Concept of ‘Nano-Technology’ Proceedings of the International Conference of Production Engineering. Society of Precision Engineering, Tokyo, Japan
8. Lieber, C.M., 1998. One-dimensional nanostructures: chemistry, physics & applications. Solid State Commun. 107, 607-616.
9. Arcıs R.W., Lo´pez-Macipe, A., Toledano, M., Osorio, E., Rodrı´guez-Clemente, R., Murtra, J., et al., 2002. Mechanical properties of visible light-cured resins reinforced with hydroxyapatite for dental restoration. Dent. Mater. 18, 4957
10. Mota, E.G., Oshima, H., Burnett Jr., L.H., Pires, L., Rosa, R.S., 2006. Evaluation of diametral tensile strength and Knoop microhardness of five nanofilled composites in dentin and enamel shades. Stomatologija 8, 67-69
11. Turssi, C.P., Ferracane, J.L., Vogel, K., 2005. Filler features and their effects on wear and degree of conversion of particulate dental resin composites. Biomaterials 26, 4932-4937.
12. Mota, E.G., Oshima, H., Burnett Jr., L.H., Pires, L., Rosa, R.S., 2006. Evaluation of diametral tensile strength and Knoop microhardness of five nanofilled composites in dentin and enamel shades. Stomatologija 8, 67-69
13. Ray, S.S., Okamoto, M., 2003. Biodegradable polylactide and its nanocomposites: opening a new dimension for plastics and composites. Macromol. Rapid Commun. 24, 815-840

14. Zhang, L.; Webster, T.J. Nanotechnology and nanomaterials: Promises for improved tissue regeneration. Nano Today 2009, 4, 66–80.

15. Roszek, B.; De Jong, W.; Geertsma, R. Nanotechnology in Medical Applications: State-of-the-Art in Materials and Devices; Rijksinstituut voor Volksgezondheid en Milieu RIVM: Bilthoven, The Netherlands, 2005.

16. Wickson, F. Narratives of nature and nanotechnology. Nat. Nanotechnol. 2008, 3, 313–315

17. Kasraei, S.; Sami, L.; Hendi, S.; Arkani, M.Y.; Rezaci-Soufi, L.; Khamverdi, Z. Antibacterial properties of composite resins incorporating silver and zinc oxide nanoparticles on Streptococcus mutans and Lactobacillus. Restor. Dent. Endod. 2014, 39, 109–114.

18. Carpio IE, Santos CM, Wei X, Rodrigues DF. Toxicity of a polymer–graphene oxide composite against bacterial planktonic cells, biofilms, and mammalian cells. Nanoscale. 2012;4(15):4746-56.

19. Kulshrestha, S., Khan, S., Meena, R., Singh, B. R., & Khan, A. U. (2014). A graphene/zinc oxide nanocomposite film protects dental implant surfaces against cariogenic *Streptococcus mutans*. *Biofouling*, *30*(10), 1281–1294.

20. Ajayan PM, Zhou OZ. Applications of carbon nanotubes. CNT: Springer; 2001:391–425.

21. McINTYRE RA. Common nano-materials and their use in real world applications. Sci Prog. 2012;95:1–22

22. Priyadarshini S,Mukherjee S.Nanoparticles used in dentistry: A review.Journal of Oral Biology and Craniofacial Research 8 (2018) 58–67

23. Kulshrestha S, Khan S, Meena R, Singh BR, Khan AU. A graphene/zinc oxide nanocomposite film protects dental implant surfaces against cariogenic Streptococcus mutans. Biofouling. 2014;30:1281–1294.

24. Bartolo P, Kruth J-P, Silva J, et al. Biomedical production of implants by additive electro-chemical and physical processes. Cirp Ann Manuf Technol. 2012;61:635–655

25. Pepla E, Besharat LK, Palaia G, Tenore G, Migliau G. Nano-hydroxyapatite and its applications in preventive, restorative and regenerative dentistry: a review of literature. Ann Stomatol. 2014;5:108.

26. Motte L. What are the current advances regarding iron oxide nanoparticles for nanomedicine. J Bioanal Biomed. 2012;4.

27. Lughi V, Sergo V. Low temperature degradation-aging-of zirconia: a critical review of the relevant aspects in dentistry. Dent Mater. 2010;26:807–820

28. Akagawa Y, Hosokawa R, Sato Y, Kamayama K. Comparison between freestanding and tooth-connected partially stabilized zirconia implants after two years' function in monkeys: a clinical and histologic study. J Prosthet Dent. 1998;80:551–558

29. Priyadarshini S,Mukherjee S.Nanoparticles used in dentistry: A review.Journal of Oral Biology and Craniofacial Research 8 (2018) 58–67

30. Michiko Sato, Marisa A. Sambito, Arash Aslani, Nader M. Kalkhoran, Elliott B. Slamovich, Thomas Jay Webster,Increased osteoblast functions on undoped and yttrium-doped nanocrystalline hydroxyapatite coatings on titanium,Biomaterials,Volume 27, Issue 11,2006,Pages 2358-2369,

31. Roveri N, Battistella E, Bianchi CL, Foltran I, Foresti E, Iafisco M, Lelli M, Naldoni A, Palazzo B, Rimondini L. Surface enamel remineralization: biomimetic apatite nanocrystals and fluoride ions different effects. Journal of Nanomaterials. 2009;2009(1):746383.

32. Lv KL, Zhang JX, Meng XC, Li XY. Remineralization effect of the nano-HA toothpaste on artificial caries. Key Engineering Materials. 2007 Feb 11;330:267-70.

33. Muhammad S. Zafar, Ahmad A. Alnazzawi, Mothanna Alrahabi, Muhammad A. Fareed, Shariq Najeeb, Zohaib Khurshid.Nanotechnology and nanomaterials in dentistry,Advanced Dental Biomaterials,Woodhead Publishing,2019,Pages 477-505.

34. Ozer F, Blatz MB. Self-etch and etch-and-rinse adhesive systems in clinical dentistry. Compend Contin Educ Dent. 2013;34(1):12–14.

35. Yoshihara K, Yoshida Y, Nagaoka N, et al. Nano-controlled molecular interaction at adhesive interfaces for hard tissue reconstruction. Acta Biomater. 2010;6:3573–3582

36. Malacarne-Zanon J, de Andrade E Silva SM, Wang L, et al. Permeability of dental adhesives – a SEM assessment. Eur J Dent. 2010;4(4): 429–439

37. Abou Neel EA, Bozec L, Perez RA, Kim HW, Knowles JC. Nanotechnology in dentistry: prevention, diagnosis, and therapy. Int J Nanomedicine. 2015 Oct 8;10:6371-94.

38. Davies JE. Understanding peri-implant endosseous healing. J Dent Educ. 2003;67(8):932–949

39. Albrektsson T, Sennerby L, Wennerberg A. State of the art of oral implants. Periodontol 2000. 2008;47:15–26.

40. Abou Neel EA, Bozec L, Perez RA, Kim HW, Knowles JC. Nanotechnology in dentistry: prevention, diagnosis, and therapy. Int J Nanomedicine. 2015 Oct 8;10:6371-94.

41. Allaker RP. The use of nanoparticles to control oral biofilm formation. J Dent Res. 2010;89(11):1175–1186.

42. Shvero DK, Davidi MP, Weiss EI, Srerer N, Beyth N. Antibacterial effect of polyethyleneimine nanoparticles incorporated in provisional cements against Streptococcus mutans. J Biomed Mater Res B Appl Biomater. 2010;94(2):367–371.

43. Kasraei S, Sami L, Hendi S, Alikhani MY, Rezaei-Soufi L, Khamverdi Z. Antibacterial properties of composite resins incorporating silver and zinc oxide nanoparticles on Streptococcus mutans and Lactobacillus. Restor Dent Endod. 2014;39(2):109–114.

44. Chen C, Weir MD, Cheng L, et al. Antibacterial activity and ion release of bonding agent containing amorphous calcium phosphate nanoparticles. Dent Mater. 2014;30(8):891–901.

45. Botelho MA, Martins JG, Ruela RS, Queiroz DB, Ruela WS. Nanotechnology in ligature-induced periodontitis: protective effect of a doxycycline gel with nanoparticules. J Appl Oral Sci. 2010; 18(4):335–342.

46. Saravana KR, Vijayalakshmi R. Nanotechnology in dentistry. Ind J Dent Res. 2006;17:62–65.

47. Chen C, Weir MD, Cheng L, et al. Antibacterial activity and ion release of bonding agent containing amorphous calcium phosphate nanoparticles. Dent Mater. 2014;30(8):891–901

48. Subramani K, Jung RE, Molenberg A, Hammerle CH. Biofilm on dental implants: a review of the literature. Int J Oral Maxillofac Implants. 2009;24(4):616–626

49. Yang X, Yang W, Wang Q, et al. Atomic force microscopy investigation of the characteristic effects of silver ions on Escherichia coli and Staphylococcus epidermidis. Talanta. 2010;81(4–5):1508–1512

50. McKendry RA. Nanomechanics of superbugs and superdrugs: new frontiers in nanomedicine. Biochem Soc Trans. 2012;40(4):603–6

51. Hainfeld JF, O'Connor MJ, Dilmanian FA, Slatkin DN, Adams DJ, Smilowitz HM. Micro-CT enables microlocalisation and quantification of HER2-targeted gold nanoparticles within tumour regions. Br J Radiol. 2011;84(1002):526–533

52. Hainfeld JF, Slatkin DN, Smilowitz HM. The use of gold nanoparticles to enhance radiotherapy in mice. Phys Med Biol. 2004;49(18): N309–N315.

53. Cho WS, Cho M, Jeong J, et al. Size-dependent tissue kinetics of PEG-coated gold nanoparticles. Toxicol Appl Pharmacol. 2010;245(1): 116–123.

54. Chan WCW, Nie SM. Quantum dot bioconjugates for ultrasensitive nonisotopic detection. Science. 1998;281(5385):2016–2018.

55. Kloepfer JA, Mielke RE, Wong MS, Nealson KH, Stucky G, Nadeau JL. Quantum dots as strain- and metabolism-specific microbiological labels. Appl Environ Microbiol. 2003;69(7):4205–4213. 127.

56. Bruchez M, Moronne M, Gin P, Weiss S, Alivisatos AP. Semiconductor nanocrystals as fluorescent biological labels. Science. 1998;281(5385): 2013–2016

57. Christodoulides N, Mohanty S, Miller CS, et al. Application of microchip assay system for the measurement of C-reactive protein in human saliva. Lab Chip. 2005;5(3):261–269

58. Pederson ED, Stanke SR, Whitener SJ, Sebastiani PT, Lamberts BL, Turner DW. Salivary levels of alpha(2)-macroglobulin, alpha(1)- antitrypsin, C-reactive protein, cathepsin G and elastase in humans with or without destructive periodontal disease. Arch Oral Biol. 1995; 40(12):1151–1155

59. Herr AE, Hatch AV, Giannobile WV, et al. Integrated microfluidic platform for oral diagnostics. Ann N Y Acad Sci. 2007;1098

60. Fuentes L, Yakob M, Wong DTW. Emerging horizons of salivary diagnostics for periodontal disease. Br Dent J. 2014;217(10): 567–573

61. Abou Neel EA, Bozec L, Perez RA, Kim HW, Knowles JC. Nanotechnology in dentistry: prevention, diagnosis, and therapy. Int J Nanomedicine. 2015 Oct 8;10:6371-94

62. Abou Neel EA, Bozec L, Perez RA, Kim HW, Knowles JC. Nanotechnology in dentistry: prevention, diagnosis, and therapy. Int J Nanomedicine. 2015 Oct 8;10:6371-94

63. Liu CHC. Filling in dentinal tubules. Nanotechnology. 2007;18: 475104.

64. Freitas RA Jr. Nanodentistry. J Am Dent Assoc. 2000;131(11): 1559–1566

65. Kishen A, Shi Z, Shrestha A, Neoh KG. An investigation on the antibacterial and antibiofilm efficacy of cationic nanoparticulates for root canal disinfection. J Endod. 2008;34(12):1515–1520.

66. Lu Z, Rong K, Li J, Yang H, Chen R. Size-dependent antibacterial activities of silver nanoparticles against oral anaerobic pathogenic bacteria. J Mater Sci Mater Med. 2013;24(6):1465–1471

67. Monzavi A, Eshraghi S, Hashemian R, Momen-Heravi F. In vitro and ex vivo antimicrobial efficacy of nano-MgO in the elimination of endodontic pathogens. Clin Oral Investig. 2015;19(2):349–356.

68. Zhang XD, Wu D, Shen X, et al. Size-dependent radiosensitization of PEG-coated gold nanoparticles for cancer radiation therapy. Biomaterials. 2012;33(27):6408–6419.

69. Sulfikkarali N, Krishnakumar N, Manoharan S, Nirmal RM. Chemopreventive Efficacy of Naringenin-Loaded Nanoparticles in 7,12-dimethylbenz(a)anthracene Induced Experimental Oral Carcinogenesis. Pathol Oncol Res. 2013;19:287–296.

70. Langer R, Vacanti JP. Tissue engineering. Science. 1993;260: 920–926.

71. Chan BP, Leong KW. Scaffolding in tissue engineering: general approaches and tissue-specific considerations. Eur Spine J. 2008; 17(suppl 4):467–479.

72. Balasundaram G, Webster TJ. Nanotechnology and biomaterials for orthopedic medical applications. Nanomedicine (Lond). 2006; 1:169–176.