International Journal of Research in Health and Allied Sciences

Journal home page: www.ijrhas.com

Official Publication of "Society for Scientific Research and Studies" [Regd.]

ISSN: 2455-7803

Review Article

Nanotachnology in prosthodontics: A review

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Received Date: 16 April, 2024 Acceptance Date: 19 May, 2024

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This article may be cited as: Gupta R, Kanwar M, Vashist D, Sharma S, Kapila N. Nanotachnology in prosthodontics: A review. Int J Res Health Allied Sci 2024; 10(3):24-31.

INTRODUCTION

"Nanotechnology is already at the heart of nature. And we are starting to learn how to work with this tool."- Edilson Gomes De LimoNanotechnology is the product of functional materials and structures in the Nano scale, usingvarious methods. The particles of the length scale 1-100 nm are used. These are known asNanoparticles.[1] After Feynman's famous and visionary lecture "There's Plenty of Room atthe Bottom", nanotechnology has moved from the state of a "vision", or "science fiction", tobeing a "real thing".[2] Understanding, shaping and combining matter at the atomic and molecular scale is called nanotechnology.[3] Nanodentistry is still considered as an emerging field with a huge potential to yield new innovative generation of technologically advanced biomaterials in prosthodontics, orthodontics, periodontics, operatives, or restorative dental sciences.[4] New treatment opportunities in dentistry include local anesthesia, dentition renaturalization, permanent cureof hypersensitivity, complete orthodontic realignment during a single office visit, covalentlybonded diamondized enamel, and continuous oral health maintenance with the help of mechanical dentifrobots that destroy caries-causing bacteria and even repair blemishes on the teeth where decay has set in.[5]Prominent developments in prosthodontics are the nanocomposites, bonding agents,

emerging of link between biomolecules and nanotechnology through the generation of biomaterials.[6] Nanomaterials may have effects on health due to their size, shape, charge or other factors, which are not directly predictable from mass concentration measurements.[7]

Nanotechnology is set to revolutionize clinical dental practice. In no distant future, oral health care services will become less stressful for the dental surgeons, more acceptable to patients and the outcome will significantly become more favourable.[8]

WHAT IS NANOTECHNOLOGY

According to the definition of the national nanotechnology initiative, nanotechnology is the direct manipulation of materials at the nanoscale.[9]

One nanometer (nm) is one billionth, or 10–9, of a meter.[10] By comparison, typical carbon-carbon bond lengths, or the spacing between these atoms in a molecule, are in the range 0.12to 0.15 nm, and a DNA double-helix has a diameter around 2 nm.[7]

Nanoparticles are fabricated by two approaches:

Top-down approach: seeks to create many smaller devices using larger ones to direct theirassembly. Nano-dentistry as top-down approach[6] • Nanocomposites • Nanosolution • Impression materials	**Bottom-up approach**: seeks to arrange smaller components into a more complex assembly.[11] Nano dentistry as bottom-up approach[6] • Local anaesthesia • Hypersensitivity cure • Nanorobotic dentifrice

Others approaches include:[11]
Functional approach
Wet nanotechnology
Dry nanotechnology
Computational nanotechnology
Speculative approach

NANODENTISTRY

The application of the principles of nanotechnology in the field of dentistry has led to the conceptual development of "nanodentistry."[12]

Development of "Nano-dentistry" will make possible the maintenance of near-perfect oral health using nanomaterials, biotechnology including tissue engineering and nano robotics.[13]

Nano dentistry comprises of the following[14]

- Nanorobotics
- Nanodiagnostics
- Nanomaterials

NANOROBOTICS

Nanorobots have a diameter of about 0.5–3 microns and will be constructed of parts with dimensions in the range of 1–100 nanometers.[15] Their functions can be controlled by a nanocomputer that perform preprogramed instructions in response to local sensor stimuli by the operator.

Local anaesthesia[5]	**Hypersensitivity cure**
To induce anaesthesia in the era of nanodentistry, dentist developed a colloidal suspension that contains millions of active analgesic micrometer-sized dental nanorobot "particles" and administer it on the patient's gingivae. These nanrobots are guided by a combination of chemical gradients, temperature differentials which are all under the control of on board nanocomputer that is oriented by the dentist.	Hypersensitive teeth have dentinal tubules with surface number densities which are eight times higher than those of non-sensitive teeth, as well as tubules with diameters that are twice as large.[16] On reaching the dentin, the nanorobots enter dentinal tubular holes that are 1 to 4 μm in diameter and proceed toward the pulp.[7] These nanorobots can precisely occlude selected dentinal tubules in minutes offering patients a quick andpermanent cure to hypersensitivity.[5]
Dentifrobots	**Dental Biomimetics**
Dentrifobots nanorobotic dentifrice delivered by mouthwash or toothpaste could patrol all supragingival and subgingival surfaces at least once a day. These invisibly small (1-10 μ) dentifrobots, perhaps, numbering 103-105 nanodevices per oral cavity and crawling at 1-10 μ/s would be inexpensive purely mechanical devices that would safely deactivate themselves protect the supragingival and subgingival surfaces.[8]	The fabrication of a new tooth in the dentist's office within time & economic constraints of a complete dentition replacement therapy could become approachable by the discovery of biomimetics with nanotechnology.[14]

NANODIAGNOSTICS

Nanotubes	**Quantum dots**
Nanotubes are made up of carbon rods. They can not only can detect the presence of altered genes but also may help researchers pinpoint the exact location of those changes.[14]	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 tobe tracked.[17]
Nanopores	**Nanoscale cantilevers**
Nanopores are tiny holes that allow DNA to pass through them one strand at a time. These help in sequencing of DNA, improving the efficiency of the process.[15]	Nanoscale cantilevers consist of flexible beams that can be programmed to join the markers that are associated with cancer, helping with its diagnosis.[15]

NANOMATERIALS

Nanomaterials have unique and superior properties, making them highly advanced and vital for rapid diagnosis and beneficial in treatment of numerous diseases.[17]

NANOPARTICLES

Nanoparticles are seen either as agents of change of various phenomena and processes, or as building blocks of materials and devices with tailored characteristics. Use of nanoparticles aims to take advantage of properties that are caused by the confinement effects, larger surface area, interactions at length scales where wave phenomena have

comparable features to the structural features, and the possibility of generating new atomic and macromolecular structures.[18]

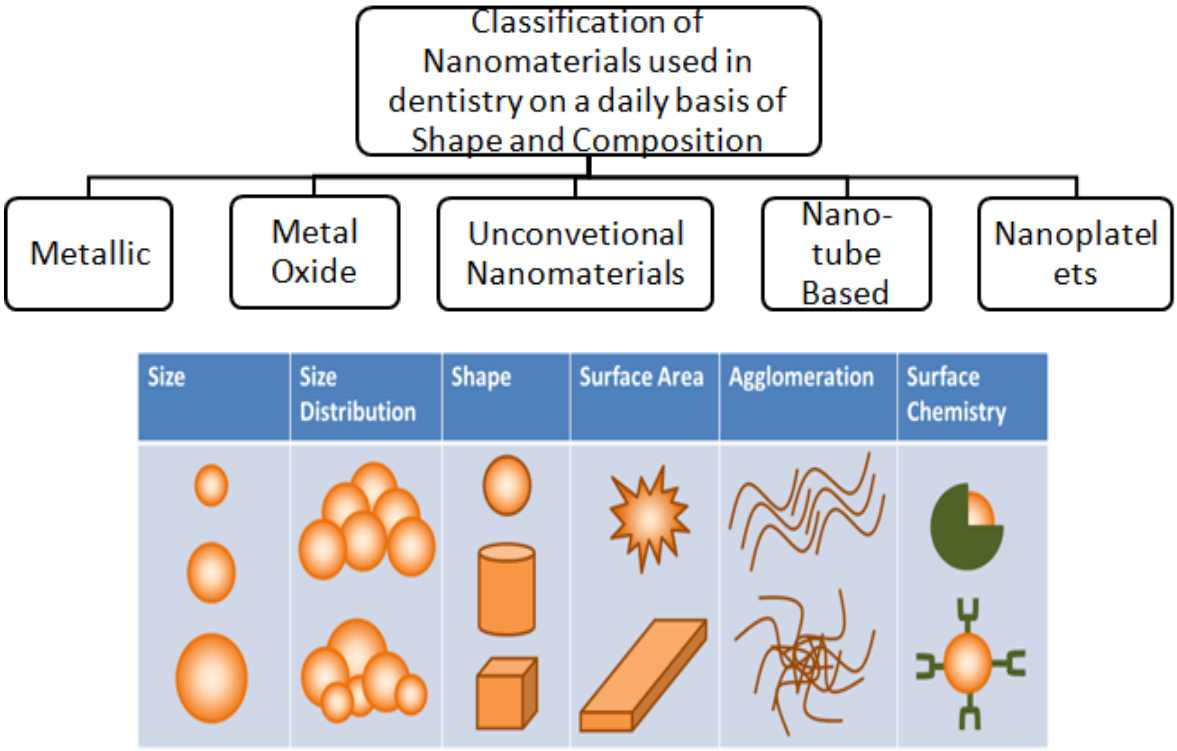


Figure: Classification of nanoparticles

APPLICATIONS OF NANOTECHNOLOGY IN PROSTHODONTICS

Prosthodontics as a speciality includes diagnosis, treatment planning, oral rehabilitation, and preservation of the normal oral function of patients with missing teeth or oral and maxillofacial tissues using biocompatible substitutes.

Materials reduced to the nanoscale can suddenly show very different properties enabling unique applications.[3]

NANOCOMPOSITES

These are the materials to which nanoparticles are exclusively added. The nanofiller used in composite includes an aluminosilicate powder. "Nanocomposites" are actually "nano-hybrids" that contain much larger volume fractions of non-nano sub-micron or micron-sized particles. Nanotechnology may provide composite resin with filler particles that are dramatically smaller, can be dissolved in higher concentrations, and are polymerized into the resin system with molecules designed to be compatible when coupled with a polymer, and provide unique physical, mechanical, and optical characteristics.[19]

The advantages of nanocomposites are[3]

- Superior hardness
- Superior flexural strength
- Superior modulus of elasticity
- Superior translucency and esthetic appeal

NANOCOMPOSITE DENTURE TEETH

Artificial teeth made from acrylic or porcelain have their own disadvantages. Acrylic teeth abrade quickly and discolour over a period while, porcelain having high wear resistant are brittle and lack bonding ability to the denture base.

Nanocomposite denture teeth are made of polymethylmethacrylate and homogeneously distributed nanofillers. The advantages of nanocomposite teeth over other artificial teeth

- are has better flow
- improved hydrophilic properties hence fewer voids at margin
- better model pouring.[3]

NANOCERAMICS

"Nanoceramic" refers to "the ceramic material with nanoscale dimensions in the microstructures phase.[12] These nanoceramics demonstrates improved toughness and ductility, that is attributed to the atomic arrangement in nanoceramic interface. The hardness and strength of many nanoceramics are four to five times higher than those of the traditional materials.[3] The strength of composite porcelains with particles dispersed in the glass matrix is enhanced by the suppression of cracking through deflection, bowing, and pinning mechanisms.[2]

Advantages:

- Nanoceramics have super plasticity.
- Show good toughness an ductility.

- Superior mechanical properties: The hardness and strength of many nanoceramics are 4–5times higher than those of the traditional materials.
- Improved translucency and corrosion resistance.

NANORESINS

The addition of nanoparticles to PMMA displayed superior properties. Nanoparticles of metal oxides are included during suspension polymerization and resulted in biocompatible of the material.[20]

Introduction of metalnanoparticles is a suitable means for the improvement of conventional acrylic dental resins demonstrating enhanced photocatalytic activity, hence increasing their disinfection effect.[19]

Figure 5.3: Nanoresins

Micro-additions of 0.125–0.5% of carbon nanotubes are added to monomer byultrasonic agitation. Augmentation of polymethylmethacrylate (PMMA) resins with carbon nanotubes improves the strength of the prostheses to better withstand the forces of mastication. Carbon nanotubes have tensile strengths up to 4000 times stronger than steel andas much as 200 times stronger than carbon fibres.[12]

IMPRESSION MATERIALS

Nanomaterials can be used to customize impression materials. Nanofillers have been conjugated with vinylpolysiloxanes, producing a unique siloxane impression material.[12]Thismaterial is claimed to have better properties such as flow, adhesiveness. It also has improved hydrophilic properties hence fewer voids at margin and better model pouring and enhanced detail preciion.[21]

Advantages of these impression material are[3]

- Betterflow characteristics.
- Reduced number of voids because of enhanced hydrophilic properties.
- Improved accuracy

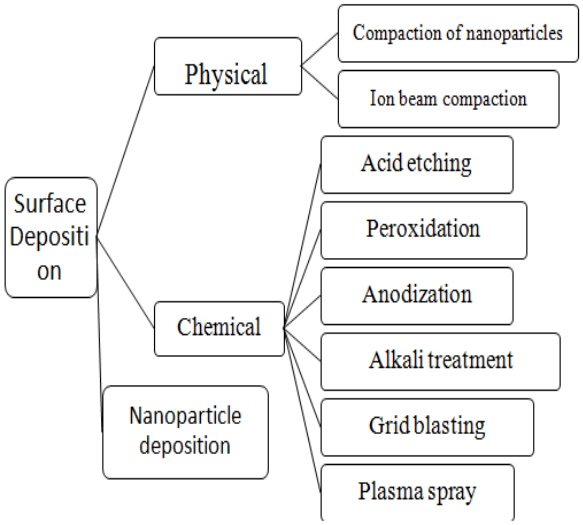
NANO-METALOXIDES TO SILICONE ELASTOMER

Silicone elastomer is the most preferred material for maxillofacial prosthesis. Addition of nano-titanium particles to silicones improves the physical properties of the materials. Even the anti-thermal aging properties are markedly increased.[12] 1% nano-CeO2 and 2% and 2.5% nano-TiO2 by weight used as opacifiers for silicone A-2186 maxillofacial prostheses with mixed pigments exhibited the least colour changes when subjected to artificial aging.[22]

DENTAL IMPLANTS

Dental implants are an alternate to restoring teeth via crowns and bridges. The invent of nanotechnology and its conjugation to implant dentistry produces implants surfaces with controlled architectural geometry and chemistry.[4]

Coating implants with nanotextured titanium, hydroxyl apatite and pharmacological agents such as bisphosphonates may induce cell differentiation and proliferation, and promote greater vascularity in cortical bone thereby improving conditions for early and long-term bone remodelling.[3]



NANOMATERIALS IN MAXILLOFACIAL MATERIALS

Meran et al conducted an in-vitro study to check the efficacy of silver nanoparticles against C. albicans by coating it on silicone, the study was carried out of human fibroblasts. He observed that the AgNP coating effectively prevented the fungal growth as determined by measurements of ethanol production by the yeast, without any cytotoxic damage to the fibroblasts.[12]

NANOSOLUTIONS

Nanosolutions produce unique and dispersible nanoparticles, which can be added to various solvents, paints, and polymers in which they are dispersed homogeneously.[3] Nanoparticles have also been used assterilizing solutions in the form of nanosized emulsified oil droplets that bombard pathogens.[5]

MATERIALS TO INDUCE BONE GROWTH

The nanocrystallites show a loose microstructure, with nanopores situated between the by pores in the micrometer area.[11] A rough surface area is formed on the boundary layer between the biomaterial and cell.[5]

Hydroxyapatite nanoparticles that are added to treat bone defects are[5]

- Ostium (Osartis GmbH, Germany)
- HA VITOSSO (Orthovita, Inc, USA)
- HA + TCP NanOSSTM (Angstrom Medica, USA)

NANOENCAPSULATION

SWRI [South West Research Institute] has developed targeted release systems that encompass nanocapsules that could be engineered to target oral tissues, including cells derived from the periodontium.[5]

Other products included within nanocapsulses are[15]

- Protective clothing and filtration masks, using antipathogenic nanoemulsions and nanoparticles
- Medical appendages for instantaneous healing nanocrystalline silver particles with antimicrobial properties on wound dressings
- Bone targeting nanocarriers

NANONEEDLES

These are used to execute the surgery on a single living cell and are nano-meter wide in dimension. Suture needles incorporating nano-sized stainless-steel crystals have been developed. Trade name: Sandvik Bioline, RK 91 needles.[11]

Polyhedral oligomeric silsesquioxanes (posss) Reinforced Silicone elastomers

Polyhedral oligomericsilsesquioxanes (POSS) is one typical organic–inorganic hybrid nanocomposite, which has been developed since the end of last century. POSS is a nanostructural chemical whose molecule is 1.5nm isotropic in structure.[13]

It is a new approachthat has the potential to improve polymeric materials is the use of polyhedral oligomericsilsesquioxanes (POSSs) as a reinforcing agent.

NANOCARE gold[12]

Nanocare gold dental material is used directly before embedding dental films, ceramic or porcelain crowns, bridges, porcelain veneers inlays or onlays.

Advantages:

- Provides antimicrobial effect.
- Improves adhesion to tooth tissues which greatly increases durability of dental restorations.

BIORESORBABLE MATERIALS

Bioresorbable polymers are currently being used in degradable medical applications such as sutures and orthopedic fixation devices. With new production methods, nanostructures are being fabricated which could be used as temporary implants, Nanostructured implants are beingdesigned to degrade at a rate that will slowly transfer load to a healing bone that it is supporting.[23]

RECENT APPLICATIONS OF NANOTECHNOLOGY IN DENTISTRY

Dental diagnostics

Lab-on-a-chip (LOC) is a device which integrates several laboratory functions on a single chip. LOC methodologies have been used to assess the levels of interleukin-1beta (IL-1beta),C-reactive protein (CRP), and matrix metalloproteinase-8 (MMP-8) in whole saliva, whichare potential use of these biomarkers for diagnosing and categorizing the severity and extent of periodontitis.[14]

Probe Encapsulated By Biologically Localized Embedding (PEBBLES), developed by Raoul Kopelman, introduces dye-tagged nanoparticles introduced into living cells. This helps tracks the metabolism and other disease conditions.[24]

Nanotechnology microscope is anewly developed deep probe detectors consisting of the electromagnetic spectrum will beavailable to screen the human body to reveal hidden matter such as, deep tumors and occultcaries in teeth.[11]

AESTHETIC DENTISTRY

Polishing the teeth results in roughness, this provides medium for biofilm formation. Ultra-fine polishing of teeth leads to nanoscale roughness which is few in nanometers as it protects the teeth from cariogenic bacteria.[11]

Tooth whitening agents were additionally nano-modified to increase their whitening efficiency and minimise their harmful side effects. Calcium peroxide nanoparticles, for instance, were able to penetrate deeper into the tooth structure through micro and nano cracks, leading to a longer surface contact and therefore an increase in the effectiveness of the whitening agent.[25]

ADHESIVE DENTISTRY

Bonding of dental composites to tooth structure is obtained through different adhesive resin systems that depend on separate or combined use of etchant, primer, and adhesive resin The durability of resin–dentin interface can be jeopardized by: degradation of collagenmatrix, incomplete penetration and polymerization of resin monomer and hydrolysis of theresin monomer.[26]

Nanotechnology has been adopted to extend the longevity of resin–dentin bond via[26]

1. protection of exposed collagen through reinforcement, cross-linking, and biomimetic remineralization
2. inhibiting the action of MMPs
3. modifying the adhesive resin monomer

Addition of polyurethanenanocapsule loaded with the core materials of triethylene glycol dimethacrylateis used as a major ingredient in the self-healing bonding resin and shown to enhance bondstrength.[4]

TOOTH RENATURALIZATION

Dentition renaturalization procedures may become a popular addition to the typical dental practice, providing perfect treatment methods for esthetic dentistry and replace the conventional operative dental procedures.[16] Full coronal renaturalization procedures in which all fillings and crowns are removed, and the affected teeth are remanufactured to become indistinguishable from the original teeth.[14]

CRANIOFACIAL BONE TISSUE ENGINEERING APPROACHES USING NANOCERAMICS

Nano biomaterials have played a significant role in fabricating materials. The increased surface area of these nanoscale bioactive glasses has two significant effects, faster dissolution and therefore release of ions and higher protein adsorption.[16]The ability to develop molecular sensitive polymers using the optical properties of nanoparticles as control system, manipulating the stiffness, and strength of scaffolds using hybrid nanostructures and use of nanotechnology to prepare molecular imprints to maximize long-term viability and function of cells on scaffold surfaces require further understanding and research.[12]

HA has been considered an osteoconductive material and thus is used as bone grafting substitutes or carriers of bone inductive biomolecules.49 The addition of nanohydroxyapatite,a simple operation, can not only fill the bone defects and avoid the infection problems, butalso obviously induce new bone induction, which suggests that it should have high potentialto be widely used in oral surgery.[20]

Nanosized crystals of conventional CaSO4 bone grafts have now developed, with particulate size ranging from 200nm-900nm, which are more resistant to degradation and last longer. Nanoparticles can also be designed -using ultrasonic assessment of bone quality and structure- to stimulate bone.[27]

DRUG DELIVERY

Nanoparticles can be used as carriers systems to delivery medication in patients. Microsphere formulations provide protection for agents susceptible to denaturation or degradation in regions of harsh pH, and prolong the exposure of drug by increasing retention of the formulation through bioadhesion.[24]

Tetracycline incorporated into microspheres is available as Arestin for drug delivery by local means into periodontal pocket. A nanostructured 8.5% doxycycline gel was observed to afford periodontal surface preservation.[10]

ROLE IN BIOIFLM IDENTIFICATION

Nanotechnology provides an insight on the interaction of microbial species in initiation and progression of the biofilm.[11] Nanotechnology has been used to study the dynamics of demineralization/remineralization process in dental caries by using tools, such as atomic force microscopy (AFM) which detect bacteria induced demineralization at an ultrasensitive level. These include liquids and pastes that contain nanoparticles for biofilm management at the tooth surface, and products that contain nanomaterials for the remineralization.[7]

LASER PLASMA TECHNOLOGY

When TiO2 particle sizes are reduced to nanoscale (20-50 nm diameter particles), and presenton the human skin in the form of a gel-like emulsion and irradiated with laser pulses, theseparticles can be optically broken down

with accompanying effects like shock wave, microabrasion hard tissue and stimulation of collagen production.[11] This property of TiO2 coupled with laser irradiation can be utilized in variety of procedures such as depigmentation of gingiva, soft tissue incision without anaesthesia and periodontal disease treatment.

HAZARDSINNANOTECHNOLOGY

Safety of consumer products containing nanomaterials was always an early societal concern. American health association concluded that short-term exposure to elevated particulate matter concentrations in outdoor air significantly contributes to increased acute cardiovascular mortality, particularly in at risk subset of the population.[28]

For the reduction of hazard due to exposure to nanoparticle, source reduction in production, e.g. by internal recycling, and ‘built in’ hazard reduction is important.

The use of nanomaterials in dentistry remains an area of debate due to their toxicological concern. Several nanoparticles such as metal nanoparticles i.e Gold, Silver, metal oxide nanoparticles TiO2, Fe2O3 were explored for different dental applications.[20] However studies have shown significant association of increased cardiovascular mortality, other extra pulmonary effects, tissue damage, systemic effects due to increased rate of absorption of non-degradable nanoparticles by skin, lungs, etc.[11]

With such growing concerns, studies are being conducted on the methods that could be taken by individual to reduce their risk to exposure or reduce such industrial production totally.

Air-displacement ventilation in an industrial setting was accomplished by introduction of supply air that entered at low velocity at the floor level and was cooler than room air. A well-designed exhaust ventilation system with a HEPA filter should effectively capture airborne nanoparticles. Major types of respiratory protection include dust masks, filtering facepiece respirators, chemical cartridge/ gas mask respirators, and powered air-purifying respirators.[29]

The selection of laboratory coat materials can greatly influence the potential penetration of ENMs much more effective to protect workers from exposure than

woven fabrics however, they are much less comfortable to wear.[29,30]

Nitrile, latex, and neoprene gloves have shown to prevent ~10 nm nanomaterial penetration. Secondary prevention in prevention and exposure control includes biological monitoring and medical examination, the early detection of asymptomatic disease, and prompt intervention Secondary prevention in prevention and exposure control includes biological monitoring and medical examination, the early detection of asymptomatic disease, and prompt intervention.[29]

CONCLUSION

Nanotechnology is the production of functional materials and structures in the range of 0.1 –100 nanometers – nanoscale – by various physical and chemical methods.[31]

The entering of nanotechnology onto dentistry led to the development of "Nano dentistry." Nanodentistry will provide an effective and better dental treatment and enhance the dentist's skill.

Fate of expansion of prosthodontics technology is interlinked with the development of material science. Nanomaterials have been the forerunner in basic scientific innovation.

Incorporation of nanoparticles enhance many mechanical properties of various dental materials applied in the field of prosthodontics.[6]

Nanotechnology has tremendous potential, but social issues of public acceptance, ethics, regulation, and human safety must be looked into[6] As this growing field features the application of nanoparticles, production of nanomaterials and devices in various areas of dentistry and nanodevices that are of great interest to prosthodontist as these materials in hands of a skilled professional can be used to improve dental care services.

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