

UPSURGING NANOTECHNOLOGY IN DENTISTRY

Abstract

Nanotechnology has emerged as a groundbreaking field in dentistry, offering novel solutions to traditional challenges in oral healthcare. Nano-sized particles, often referred to as nanoparticles, have demonstrated unique properties that make them exceptionally well-suited for applications in dental medicine. This abstract provides an overview of the key roles played by nanoparticles in dentistry, emphasizing their diverse applications in diagnosis, treatment, and prevention.

Nanoparticles have revolutionized diagnostic imaging in dentistry, enabling more precise and early detection of dental diseases through advanced imaging techniques. Moreover, their antimicrobial properties have paved the way for innovative approaches in combating oral infections, while targeted drug delivery systems utilizing nanoparticles enhance the efficiency of therapeutic interventions.

This abstract explores the integration of nanoparticles in restorative dentistry, demonstrating their potential in improving the mechanical properties of dental materials and promoting tissue regeneration. Additionally, the use of nanomaterials in preventive dentistry, such as the development of nano-based oral care products, underscores their role in maintaining optimal oral health.

In conclusion, nanoparticles have ushered in a new era in dentistry, offering unparalleled opportunities for diagnosis, treatment, and prevention. As research in this field progresses, the potential for further innovations and applications continues to grow, promising a brighter future for oral healthcare.

Keywords: Nanoparticles, Dentistry, Diagnostic Imaging, Drug Delivery, Restorative Dentistry, Preventive Dentistry.

I. INTRODUCTION

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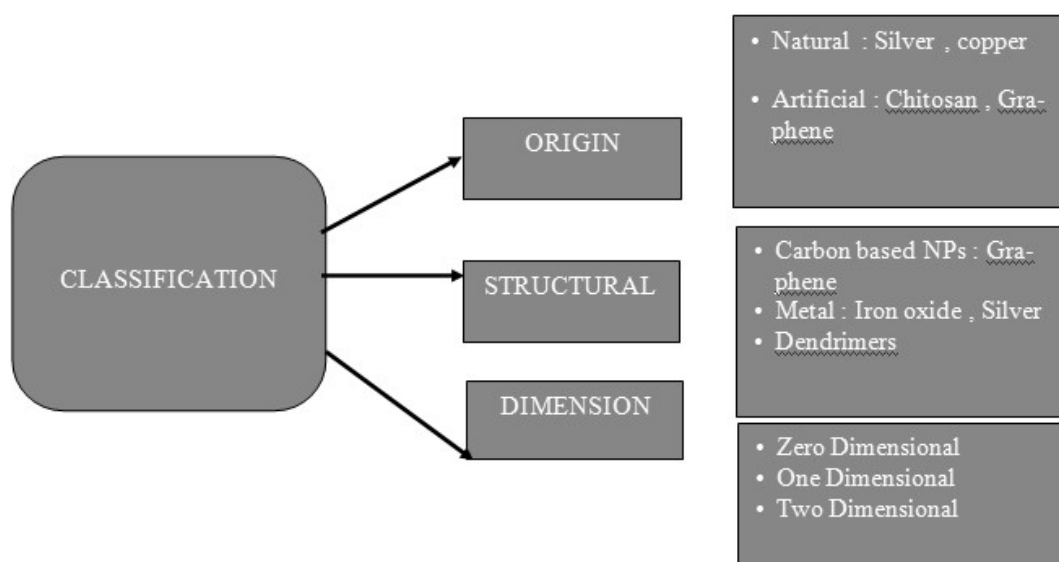
The vast majority of microbes reside within the oral cavity. The primary objective of treating endodontic disease, that is an infection made easier by biofilms, is to get rid of the biofilms in the endodontic canals. The term "biofilms" implies microbial populations in which cells are frequently immersed in a self-produced matrix of extracellular polymeric substances (EPS) that are adhering to one another and/or a surface. Numerous research have been conducted that concentrated on antibacterial solutions to address this issue, however the majority of the studies fell short of the anticipated outcomes due to the antibacterial agents' quick release and degradation, which resulted in inefficiency and safety alerts^[1].

Nanotechnology is currently being used in a wide variety of scientific domains, even though it provides many helpful solutions to scientific and medical concerns. At scales less than 100 nm, nanotechnologies operate. Viruses can be as tiny as 100 nm. Dendrimers, nanotubes, nano capsules, nano shells, nano rings, nano belts, nano spheres, nanowires, nanorods, liposomes, and quantum dots are just a few examples of the various nanomaterials that can be categorised based on their shape and the presence of nanopores.

II. HISTORY

Dr. Richard Feynman proposed the concept of nanotechnology for the first time in 1959. Dr. Sumio Iijima initially put forward the idea of nanotubes in 1991. Dr. Freitas Jr. first employed the phrase 'nano-dentistry' in the year 2000. He produced nano materials and nanorobot, assisted in tooth regeneration, and created dentifrobots, or robots used in the field of dentistry^[2].

III. CLASSIFICATION



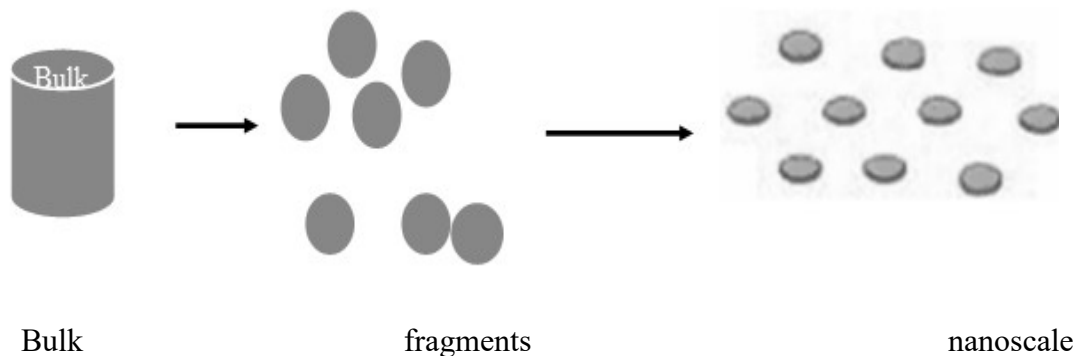
IV. MECHANISM OF ACTION

- Electrostatic interaction leading to cell membrane disruption
- Production of reactive oxygen species
- Production of reactive oxygen species
- Protein and enzyme dysfunction
- Genotoxicity and inhibition of signal transduction
- Metal ion homeostasis

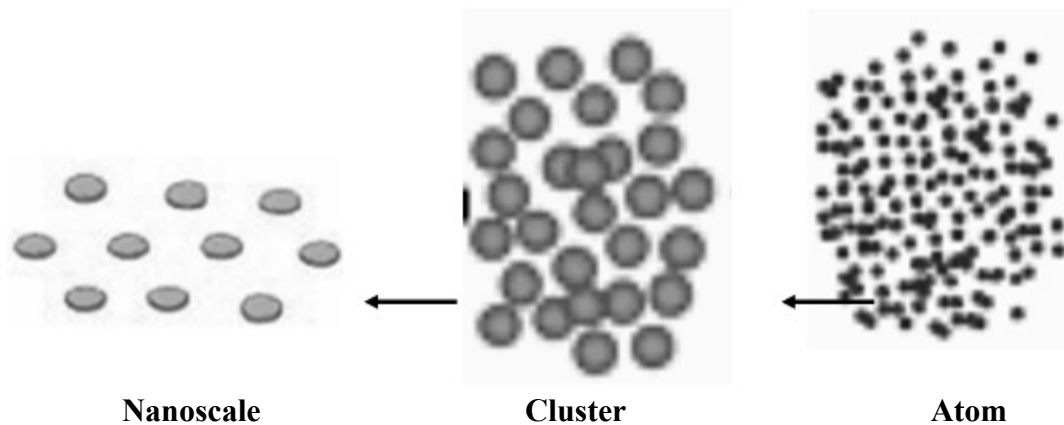
V. APPROCHES TO NANOTECHNOLOGY

- Top down approach
- Bottom up approach
- Speculative approach
- Functional approach
- Biomimetic approach

- 1. Top Down Approach:** In the top-down strategy, particles are synthesised traditionally and are reduced in size by lithography, grinding, or milling. Additional miniaturisation leads to the nano dimension. To control their assembly, it precisely separates tiny devices from larger ones. NEMS (nano electromechanical systems), which are employed in cancer diagnosis, can also be made using these solid state materials. To create functional structures at the micro- and nanoscale, "top-down" methods like chemical vapour deposition, monolithic processing, wet etching, and plasma etching are used. These techniques are successfully applied in the electronics sector as well as for covering stents and implants used in medicine to improve blood flow and biocompatibility.



- 2. Bottom up Approach:** Nanoscale structures are created using "bottom-up" production techniques, which entail highly organised chemical synthesis and material development processes, such as protein synthesis and cell, tissue, or organ system repair. These are synthesised at the atomic or molecular level, where the covalent bonds are exceedingly strong, and are then organised into more intricate assemblies.



- 3. Speculative Approach:** Richard Zsigmondy developed the idea of nano materials around the beginning of the 20th century, at a time when new ways of thinking were being developed. Applications of nanotechnology were developed subsequently by modifying matter at the atomic and molecular levels. This method frequently takes a broader perspective on nanotechnology and places more focus on its social ramifications than on the specifics of how such products might be made.

Numerous dental applications, including dental diagnosis, materials, and treatments, have found usage for nanotechnology^[3].

- 4. Functional Approach:** This strategy is centred on creating components with the needed functionality without taking into account how they were put together. It places a focus on creating nanoparticles with a specific function in mind.
- 5. Biomimetic Approach:** Use of biomolecules for applications in nanotechnology^[3].

VI. APPLICATIONS OF NANOTECHNOLOGY IN DENTISTRY

Clinical dentistry will undoubtedly be significantly impacted by the interesting new uses for nanotechnology, such as nano surgery, nano drugs, nano diagnosis, nano materials, nano robotics. More with bigger particles, the different types of nanoparticles have different chemical, magnetic, and electro-optical properties that influence their solubility, bioactivity, and antibacterial activities. Dental treatments that could be made possible by nano dentistry include dentition re naturalisation, permanent hypersensitivity treatments, the development of artificial bones and teeth, local anaesthesia, orthodontic realignments, oral health maintenance, tissue engineering, and drug delivery methods^[4].

1. Application by Top down Approach

- Coating agents
- Nano composite
- Salivary diagnostic
- Nanotechnology for glass ionomer cement
- Dental durability
- Nanotechnology for impression material
- Nanoceramic technology

- Implants
- Laser plasma application for periodontia
- Nanoneedles
- Nano bone replacement materials , nanotechnology based root end sealant
- Nanotechnology as anti-microbial agent

2. Application by Bottom Up Approach

- Inducing anaesthesia
- Nanotech floss
- Diagnosis and treatment of oral cancer
- Orthodontic nanorobot
- Hypersensitivity cure
- Photosensitizer and carrier

VII. APPLICATION OF NANOTECHNOLOGY IN OPERATIVE DENTISTRY

For the restoration of decayed, missing, and broken teeth, several nano-dental materials can be employed. Clinical dentistry now uses nano composites, nano impressions, and nano ceramics thanks to recent developments in nano materials. To produce different kinds of nanostructure, the nano materials can be divided into zero-dimensional, one-dimensional, two-dimensional, and three-dimensional categories. The nanoparticles are smaller, have a larger surface area, a higher percentage of surface atoms, and improved surface energy than ordinary conventional materials. There are currently no dental materials with the optimal characteristics for any dental applications, despite the fact that the demand for dental biomaterials is growing quickly. Nano materials have great promise for both the creation of new materials and the major enhancement of the properties of already existing materials^[5].

1. **Nano Composite:** Newer materials offers better polishing qualities and mechanical strength. The nano composites have three different fillers - barium glass, non-agglomerated discrete silica nanoparticles, and prepolymerized fillers^[6,7].
2. **Coatings Agents:** Various restorations are being finished up with light-cured treatments that incorporate nano sized fillers. Better gloss and wear resistance are features of these coating agents. To get beyond the limits of liquid polishers, a nanotechnology-based liquid polish method was recently developed. Impression-making tools. The advantages of the siloxane impression materials with nano fillers combined with vinyl polysiloxanes include greater hydrophilic characteristics, better flow, better model pouring, and increased precision.
3. **Bonding Agents:** Nano solutions act as bonding agents by containing stable nanoparticles that are uniformly disseminated throughout the solution. The silica nano filler technology improves bond strength performance and inhibits clustering or settling out of dispersion, resulting in the formation of an insoluble calcium compound that is resistant to degradation by oral enzymes^[8].
4. **Glass Ionomer Cement:** The aesthetic qualities and surface finish of traditional glass-ionomer cements are noticeably worse. The more recent composites, called "nanoiono-

mers," which include acid reactive fluoro alumina silicate glass and nano fillers, have been developed to address these issues. These offer a better surface polish that is closer to a hybrid composite ^[9].

VIII. APPLICATION IN PROSTHODONTICS

Traditional polymethyl methacrylate, which is used to make removable dental prosthesis, has some drawbacks, including poor strength and low fracture resistance. TiO₂ and Fe₂O₃ are two examples of nano structuring materials that are added to polymethyl methacrylate to increase strength, aesthetics, and antimicrobial qualities. Dentures and dental crowns made of nanozirconia ceramic have improved hardness and fracture toughness to overcome the drawbacks of conventional materials. Excellent corrosion resistance, translucency, and great fracture toughness are all displayed by nano ceramic grains. A more recent breakthrough is the use of nano composites to create artificial teeth and dental implants; nano inorganic fillers are combined with the matrix of a composite to produce teeth that are more resilient and extremely abrasion-resistant, with superior colour. Insufficient bone development surrounding the implant is a common cause of dental implants failing. Better and more rapid osseointegration of implants is achieved by altering their surface properties employing nanoscale topography and/or coatings. Nanozirconia-Alumina alloys and nanostructure ceramic implants have the necessary hardness and are resistant to hydrothermal instability^[10].

IX. APPLICATIONS IN PREVENTIVE DENTISTRY

- 1. Nanosized Antimicrobial Agents:** Nanoparticles, such as silver nanoparticles and nanostructured antimicrobial agents, have potent antimicrobial properties. They can be incorporated into oral care products like toothpaste, mouthwashes, and dental floss to enhance their ability to combat harmful bacteria responsible for dental caries (cavities) and periodontal diseases.
- 2. Nano-Hydroxyapatite in Toothpaste:** Hydroxyapatite is a natural component of tooth enamel and plays a crucial role in remineralizing and repairing damaged enamel. Nano-sized hydroxyapatite particles can be used in toothpaste formulations to facilitate better enamel remineralization, providing an added layer of protection against tooth decay and sensitivity.
- 3. Nanosensors for Early Detection:** Nanoscale sensors can be developed to detect specific biomarkers associated with early dental disease, such as caries or periodontitis. These nanosensors could be used in saliva tests or intraoral devices to provide timely diagnostic information, enabling early intervention and treatment.
- 4. Nanoparticles in Dental Sealants:** Dental sealants are used to protect vulnerable tooth surfaces from decay-causing bacteria. The incorporation of nanoparticles in sealant materials can improve their strength, adhesion, and longevity, leading to more effective protection of susceptible teeth.
- 5. Nanostructured Remineralizing Agents:** Beyond hydroxyapatite, nanotechnology has facilitated the design of other remineralizing agents, such as amorphous calcium phosphate (ACP) nanoparticles. These agents can help repair early enamel lesions and improve the mineral density of tooth structures.

X. APPLICATION IN PERIODONTOLOGY

Nano bone graft materials can fit some of the requirements for treating bone defects, such as osteoconductivity, nanostructure, and high porosity, which can absorb natural proteins that osteoclasts can destroy. For periodontal therapy, triclosan-loaded nanoparticles that function as nano drugs may be employed. In the near future, it is believed that a variety of nanostructure, including nano tubules, hollow spheres, core-shell structures, and nano composites, will be employed as periodontal drug delivery systems.

The following HA nanoparticles are utilised to treat osseous defects: Nano-Bone®, Ostim® HA, VITOSS® HA+ TCP, and NanOss™ HA. Periodontia laser plasma application

The following effects on the oral cavity may result from the use of nano sized titania particle emulsion:

1. Applications in the Clinic:

- Periodontal treatment
- removing melanin
- Soft tissue incision not requiring general anaesthesia
- Cutting enamel and dentin during cavity preparation^[11].

2. Application in Oral Surgery: In the near future, cell surgery should be possible thanks to the development of nano needles and nano tweezers, which are now being used to create the surgical instruments needed to perform operations at the nano- or cellular level. Additionally, nanosized stainless steel crystals are being used in the construction of suture needles to perform cellular incisions. The targeted cell manipulation and surgery performed with molecularly sized devices will be useful, particularly in cancer tissue surgery.

3. Application in Orthodontics: The periodontal tissues, including as the gingiva, periodontal ligaments, cementum, and alveolar bone, may be directly manipulated with nano-robot or dentifrobots. Applications could include painless teeth straightening that happens quickly, as well as rotating and vertical repositioning that happens in minutes to hours as opposed to months with current methods. Orthodontic wires made of Sandirk Nanoflex, a unique stainless steel material, have a very high strength as well as a superb surface finish, corrosion resistance, and deformability^[12].

4. Applications in Oral Radiology: By utilising nano phosphor scintillators, digital dental imaging may provide high-quality images while requiring less radiation. Additionally, the nanoparticles can be employed to make instruments or materials radio opaque without affecting their properties or posing a risk of heavy metal toxicity or cancer.

5. Nano-Sanitising Agent: A new sterilising solution has been created by Gandly Enterprises Inc. in Florida using the nano emulsion idea.

Advantages: Hypoallergenic and wide-spectrum, Environmentally friendly, noncorroding, not requiring protective clothes, not staining fabrics, and compatible with a range of imprint materials^[11].

- 6. Tooth Dentifrices:** In order to metabolise trapped organic matter into un harmful and odourless vapours and to continuously remove calculus, nano robotic dentifrice, or dentifrobots given by mouthwash or toothpaste, will patrol all supra gingival and sub gingival surfaces at least once per day. The 500 species of benign oral microflora that are necessary to maintain oral homeostasis will increase at the same time as the pathogenic bacteria found in plaque and the mouth cavity are identified and eliminated^[11].
- 7. Replacement Therapy to Repair the Entire Tooth or Dentition:** The potential for full tooth repair or the creation and implantation of an autologous tooth has been demonstrated through nano dentistry. To replicate the structure of teeth, hydroxyapatite nano rods with enamel prism-like features have been created. Nanotechnology may make it possible to regenerate tooth tissue, create a brand-new tooth in a dish, and then implant it^[13].
- 8. Tooth Hypersensitivity:** In order to provide patients with a speedy and effective treatment for the hypersensitivity brought on by variations in pressure that are hydrodynamically communicated to the pulp, biological materials are now being researched. Dental nano robots are predicted to be able to selectively and precisely block certain tubules in a matter of minutes; this analgesic method, which is patient-friendly, will lessen anxiety and needle fear with entirely reversible effects.
- 9. Dental Durability and Cosmetics:** Covalently bound synthetic materials, such as sapphires or diamonds in carbon nanotubes, make up the fracture-resistant nano structured composite material, which may be utilised to replace the top enamel layers. To increase the durability and aesthetics of teeth, these materials may have 20–100 times the hardness of enamel^[14].
- 10. Nano Diagnostics (Photosensitizers and Carriers):** Utilising intrinsically fluorescent proteins for intracellular imaging has allowed researchers to better understand the diverse metabolic processes. Nano diagnostics (photosensitizers and carriers). Additionally, after the quantum dots bind to the antibody through the target cell and are stimulated by UV light, reactive oxygen species are produced, which kill the target cells.
- 11. Wound Healing:** Dr. Friedman asserts that the healing of wounds can benefit from the usage of nano materials. Mice's burn wounds healed more quickly after being treated with curcumin nanoparticles. It might be applicable to people in the not too distant future.
- 12. Stem Cells Tracking and Imaging:** Following transplantation, the transplanted stem cells can be tracked in vivo using various labelling techniques, such as fluorescent dyes or magnetic nanoparticles, such as super paramagnetic iron oxide, to assess their therapeutic efficacy, survival, migration, fate, and regenerative impact in vivo. The labelled cells can also be visualised using imaging systems like MRIs^[15].
- 13. Local Nanoanesthesia:** Local anaesthesia could be produced by a colloidal fluid containing millions of anaesthetic dental nano robots. Once introduced to the gingival tissue, they would go into the pulp via the dentinal tubules under the control of a nano computer, which would use temperature gradients, positional steering, and chemical differentials to shut down all feelings in the tooth. The nano robots may be instructed to remove themselves after the process is finished and restore all tooth sensations. This method is speedier, makes people feel less uneasy, and is completely reversible.

- 14. In oral Cancer Diagnosis and Treatment:** Less invasive methods for diagnosing cancer, tracking recurrence, or identifying the locations, biologic types, and behaviours of malignancies may be made possible by nanotechnology.
- 15. Therapy for Oral Cancer:** Nano materials for brachytherapy: 32P is delivered by BrachySil™ (Sivida, Australia).
- 16. Gene therapy Nano Vectors Non Viral Gene Delivery Methods:** The properties of dendrimers, such as multivalency, rotund shape, well defined molecular weight, and high degree of branching, make these an ideal candidate for cancer therapy. Nano shells are tiny bead-like structures with superficial metal layers that may imbibe selective wavelengths of radiation to produce heat for specific devastation of the tumour cells sparing the normal cells.
- 17. Gene Treatment:** Nanotechnology-based gene therapy can be used to replace or fix damaged genes in order to prevent or treat genetic illnesses. In general, there are three different types of gene delivery systems: direct inoculation of genes into tissues (gene guns), non viral vectors, and viral vectors^[16].
- 18. Challenges with Nanotechnology:** Precise positioning and production of nanoscale components; proper assembly of molecules to create a functional unit; cost-effective mass manufacturing of nanorobot; synchronisation of numerous independent nanorobot; issues relating to biocompatibility; financial and operational issues; inadequate incorporation of clinical research; and social issues relating to public acceptance, ethics, regulation, and human safety.

XI. CONCLUSION

Although there have been many concepts for nano dentistry, some of them are not feasible because of different biological, engineering, and social issues. Although nanotechnology plays a part in making dentistry more efficient and practical, there are certain safety issues. Both the potential advantages and the potential risks have not yet been fully realised. The actual potential and dangers of nanotechnology in dentistry will only be determined by additional studies, clinical trials, and extensive clinical application. The applications that will continue to be used will depend on human requirements, technological advancements in dentistry, and available resources.

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