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**Review Article**

# Nanorevolution: Unveiling the Future of Periodontology with Nanotechnology

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**Abstract:** ***Aim & Objective*:** Nanotechnology is a field growing as a major influencer in the health community in recent times. In dentistry, particularly Periodontics, nanotechnology promises great strides in diagnostics, therapeutic strategies and treatment efficacy. Using the specific features of nanomaterials, which involve, their small size, ability to cover large areas while occupying very little space and the chemical attributes that can be changed very easily by the scientists, are some of the innovative approaches towards nanomaterials being used to handle the multifaceted nature of periodontal diseases. This essay examines how nanotechnology is used in periodontology at the cutting edge level with emphasis on how it could redefine preventive practices, diagnostic procedures and curative interventions resulting in positive oral health outcomes. ***Material & Method*:** The review adopts a systematic approach to scrutinize the current literature on the employment of nanotechnology in periodontics. A rigorous search through reputable databases identified peer-reviewed articles that met established inclusion criteria. The use of terms such as nanomaterials in periodontal diagnostics, treatments and therapeutics was targeted for data extraction. The study reviews the incorporation of nanotechnology into periodontology with the aim of giving useful information on this new technology. ***Result*:** Nanotechnology is widely applied in periodontics and this can be seen from all the literatures. Nanomaterials help in diagnosis, deliver drugs to target cells, and improve tissue repair. Such a discovery points towards the probability of nanotechnology revolutionizing the dental care.

**Keywords:** Nanotechnology, nanoparticles, gingivitis, periodontitis, Periodontics.



## INTRODUCTION

Oral cavity is a complex structure comprised of soft and hard tissues, which have evolved to facilitate various essential functions such as chewing, speaking, swallowing, and prehension [1]. Numerous factors may contribute to the development of oral diseases and injuries. Regardless of their underlying causes, treating these conditions presents significant technical challenges, with the preservation of oral function being paramount [2]. Despite advancements in modern medicine over the years, effective modalities for regenerating lost oral tissues and treating certain disorders remain elusive, such as dental loss, periodontal cysts, and bone loss, large bone defects both in the mandible and maxilla, oral tumors, soft tissue degenerations and infections, congenital disorders (such as cleft palate), massive traumatic injuries, and burns [3].

Before the turn of the century, the term "pyorrhea" was commonly employed to describe periodontal disease, a condition marked by symptoms such as pus, periodontal pockets, bone loss, and ultimately, tooth loss. There was a prevailing belief that pyorrhea and the ensuing tooth loss were inevitable consequences of aging. Periodontal disease has become more important as a reason for tooth loss in recent years, especially while the occurrence of tooth decay has diminished among the general populace, the decrease in teeth lost to decay corresponds with an increase in the number of teeth susceptible to periodontal disease [4]. The hallmark features of periodontitis include destruction of periodontal ligaments (PDLs), formation of periodontal pockets with resorption of alveolar bone (Alv bone). This inflammatory disease of the gums undermines the structural foundation upon which teeth rely. The formation of pockets can lead to infection due to the proliferation of microflora, particularly anaerobic bacteria, which produce toxins, enzymes, and trigger immune system responses [5]. This microbial activity is associated with various clinical conditions, including

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gingivitis, deterioration of PDL, dental cementum, and loss of Alveolar bone. Gingivitis, an early stage of the disease if not treated, can progress to periodontitis [6]. Treatment approaches include pharmacological agents, mechanical therapy, and surgical interventions. Specific medications such as antimicrobials, which target microbial flora in periodontal environment, and host modulating agents, which regulate excessive enzyme levels, cytokines, prostaglandins, and osteoclast activity, play an essential role in enhancing the management of periodontitis. Osteoclasts, osteoblasts, and bone-marrow stromal cells were traditionally considered to regulate bone loss in periodontitis. In addition to starting the physiological bone remodeling, osteocytes have recently been discovered to help in inflammation-related bone remodeling [7].

Traditional treatments like scaling-root planing (SRP), periodontal flap surgeries have demonstrated effectiveness in managing periodontal diseases. Combining these interventions with appropriate supportive care after surgery reported to be beneficial in treating progressive periodontal diseases [8].

More recently many regenerative treatment techniques has evinced, enormous interest in the periodontists. Nanotechnology applied in various fields has also contributed in the field of periodontics especially its impact in the periodontal disease progression. Nanoparticles which are specialized having particlesize in nanometers could be engineered to target oral tissue including cell derived from periodontium.

**Nanotechnology**

Since evolution, nature uses nanotechnology to fabricate molecular structures within the body like enzymes, carbohydrates, proteins, and lipids. But the official identification of nanotechnology has been widely attributed to the American physicist and Nobel Laureate Dr. Richard Phillips Feynman who presented a paper called 'There's Plenty of Room at the Bottom' on December 29, 1959, at annual meeting of American Physical Society at California Institute of Technology [10].

Nanomaterials (Nms), in their true sense, are materials with measurement at nanoscale, typically ranging from 1 to 100 nanometers (nm). At this scale, Nms exhibit unique and improved properties compared to their larger counterparts. Examples of such enhanced properties include better conductivity, increased strength, and distinctive magnetic properties. One significant aspect of nanoscale materials is their substantially larger surface area in comparison to materials of larger scales with similar volumes. This larger surface area provides more opportunities for interactions with surrounding materials. The basic unit for nanomaterials is the nanometer (nm), obtained from Greek word for midget. In scientific terms, "nano" denotes a billionth part ($10^{\wedge -9}$) of a whole, emphasizing the minuscule scale at which these materials operate [11].

**Properties of nanomaterials**

Michael Farady (1847) was the first to propose properties of Nms during the preparation of gold nanoparticles [12].

1. The constituents of nanomaterials are<100 nm in a minimum one dimension.
2. They have better performance properties than traditional materials and display impressive quantum, size, and surface effects.
3. They have different chemical, magnetic, optical, and electro-optical properties
4. The significant property of nanomaterials is the self-assembly by which they independently organize themselves into patterns or structures without any others intervention [13].

**Approaches to Nanotechnology:**

In the field of nanotechnology, many strategies have been applied with great success, and as technology advances, more strategies might be developed. The available technology and the prior experience of the researchers have largely determined the approaches used thus far [14].

There are different approaches for manufacturing nanoparticles which include[15]

1) Bottom up approach
2) Speculative approach
3) Biomimetic approach
4) Top down approach
5) Functional approach

Of these the most conventional approach is top down approach.

**Generations of Nanomaterials**

1. **First generation (2000–2005):** Passive (steady function nanostructures), eg, invasive, noninvasive diagnostics for quick patient monitoring; nanostructured coatings – liposomes and contrast agents for imaging.
2. **Second generation (2005–2010):** Active (evolving function nanostructures), e.g., targeted cancer therapies; reactive nanostructured materials and sensors – quantum dots, nanoshells, and dendrimers
3. **Third generation (2010–15/20):** Integrated nano systems, such as nanoscale-constructed artificial organs, and evolving biosystems.
4. **Fourth generation (2015/20):** Heterogeneous nano systems, e.g., molecules intended to self-assemble themselves; nanoscale genetic therapies [16].

**Applications of Nanotechnology**

The areas of applications
Nanomedicine
Electronics
Military
Chemistry and environment
Energy

Information and communication
Heavy industry

**Nanomaterial in Dentistry**

Nanotechnology has its growing interest in future of dental application leading to emergence of new field called nano dentistry. The field uses nanomaterials, tissue engineering, and nanorobotics to enable the maintenance of nearly perfect dental health. It works at molecular level, atom-by-atom to form large structure with fundamentally new properties and functions. The research is directed towards the production of a wide array of different miniscale structure.

Nanorobotics described in the field have specific motility to crawl/ swim through human tissue and achieve penetrations at target tissues. They are controlled by onboard computers. Dentists will transmit orders directly to In vivo nanorobotics via acoustic signals. Monocrystal sapphire, carbon powder, and bulk teflon are the nonpyrogenic nanorobots that are currently utilised in vivo. Alumina, silica, and trace elements like copper and zinc are examples of pyrogenic nanorobots. In vivo medical nanorobots regulate the pyrogenic pathway. In order to specifically absorb the endogenous pyrogens, they are first chemically altered and then released back into the body in a safe, inactivated form. Nanorobots may release inhibitors and antagonists for the pyrogenic pathway in a targeted manner [17].

**Nanotechnology in Periodontics**

The periodontium consisting of supporting tissues of tooth: gingival and attachment apparatus-periodontal ligament, cementum and Alveolar bone. They all function together and in an integrated manner dynamically and influence each other. Correct physiologic function of periodontium can be achieved only through preservation of structural integrity and intricate interaction between its four varied components. The periodontium is susceptible to morphologic and functional alterations in addition to age-related changes. The traditional treatment SRP and flap surgery, followed by adequate post op supportive periodontal care has been successful in management of progressive periodontal diseases [8].

Nanoparticles (NPs) which are specialized having particle size in nanometers could be engineered to target oral tissues including cells derived from periodontium. Nanobiosensors are helpful in the diagnosis of periodontal diseases. These sensors detect the components present in body fluids like saliva, blood, GCF. They mimic to naturally occurring cellular mechanisms providing an effective and efficient method for diagnosing a condition/ disease within a patient and screen the biomarker likely to be present. They are also helpful to measure drug concentrations [18]. Nanoparticles offer many advantage for delivering bioactive agents and drug.

Nanorobotics are miniature form of actual machines at nanometer scale designed to operate in a molecular environment. These are used inside the periodontium to destroy the pathogens associated with the disease. They first detect the pathogens using nanobiosensors and later on injected onto patients gingival/ mucosa and are targeted at the diseased site. They are also used for drug delivery, injecting local anesthetics and diagnostic purposes. Nanorobots are regulated by onboard computers when dentist send signals for the respective treatment procedures [19].

Nanorobotic dentifrice (dentifrobots) are subocclusal dwelling devices delivered by moutwash/toothpaste. They possess the ability to inspect all areas above and below the gingival margin on a daily basis, transforming trapped organic substances into odorless vapors while continuously removing calculus. These are nearly invisible (1 to 10nm) perhaps numbering 103 to 105 per mouth and crawling at 1 to 10micro meter per seconds might have motility like amoebae. They are avoided on the occlusal surfaces as they can be crushed by dental grinding. Dentifrobots can recognize and eliminate harmful bacteria dwelling in the plaque and elsewhere while allowing 500 and more species of harmless oral microflora to flourish in a healthy ecosystem. It provides a consistent barrier against halitosis, as bacterial decay represents the primary metabolic process contributing to oral malodour. Invisibly small dentifrobots (1-10 µ), crawling at 1-10 µ/s, have the advantages of being inexpensive and safe as they are solely mechanical devices that would safely deactivated if swallowed [20].

**Nanodentifrices and Mouthwash**

Leeds dental institute, US made mouthwashes that kills plaque making bacterias when light is shown into the mouth, they act by photo dynamic therapy. The mouthwash uses specific molecules which can be absorbed by bacteria in mouth and destroy the pathogens. Mouthwashes with local anesthetic tetracaine as one of its constituent are used for patients with head and neck cancer who might have received radiation therapy and are prone to have mucositis. The rinse alleviate the pain and are effective, faster with prolonged action than lidocaine containing mouthwashes. They are used 30minutes before and after meals for six times per day. Bionic mouthwashes contain silver particles at nanometer scale which are helpful to kill bacterias causing periodontal diseases.

Nanorama toothpaste contain nano-sized gold, effective in disinfecting oral bacteria and also contain acid-tocopherol, hydrated silica, fluorine, phosphoric acid sodium etc. The toothpaste is most effective in whitening and cleaning to improve the aesthetic appearance and health of the teeth. They aid in the removal of stomatitis and masks halitosis. Hydroxyapatite crystals known to be one of the constituent of tooth enamel are synthesized as nanosized crystals which have been used in the toothpaste as nanohydroxyapatite crystals. These form a protective film on tooth enamel and even restores surfaces of damaged areas [12].

**Nanomaterials for Oral Hygiene Maintenance and Dentinal Hypersensitivity**

Nanorobots are being integrated into mouthwash formulations for efficient detection and eradication of pathogenic bacteria that can cause gingivitis and periodontitis thus leaving behind harmless oral flora to flourish in the oral ecosystem. In the near future, nanorobots embedded in toothpaste are anticipated to provide continuous removal of supra and subgingival calculus. They will additionally offer a continuous defense against halitosis by targeting the bacteria responsible for generating volatile sulphur compounds that contribute to bad breath [21].

Nano toothpaste contain calcium peroxide used in miniature form which penetrates into the tiniest of interdental gaps and ensures effective bleaching. Nanosilver is also added in which silver act as an antimicrobial agent. BiominF is one type of tooth paste which promotes tooth mineralization. This type can be used to revitalize teeth making it less sensitive. Theramed s.o.s sensitive toothpaste with calcium phosphate nanoparticles, uses a unique nanotechnology based dentin repair technology to build a protective film on tooth surface and it reduces tooth sensitivity to tooth's nerves to pain.

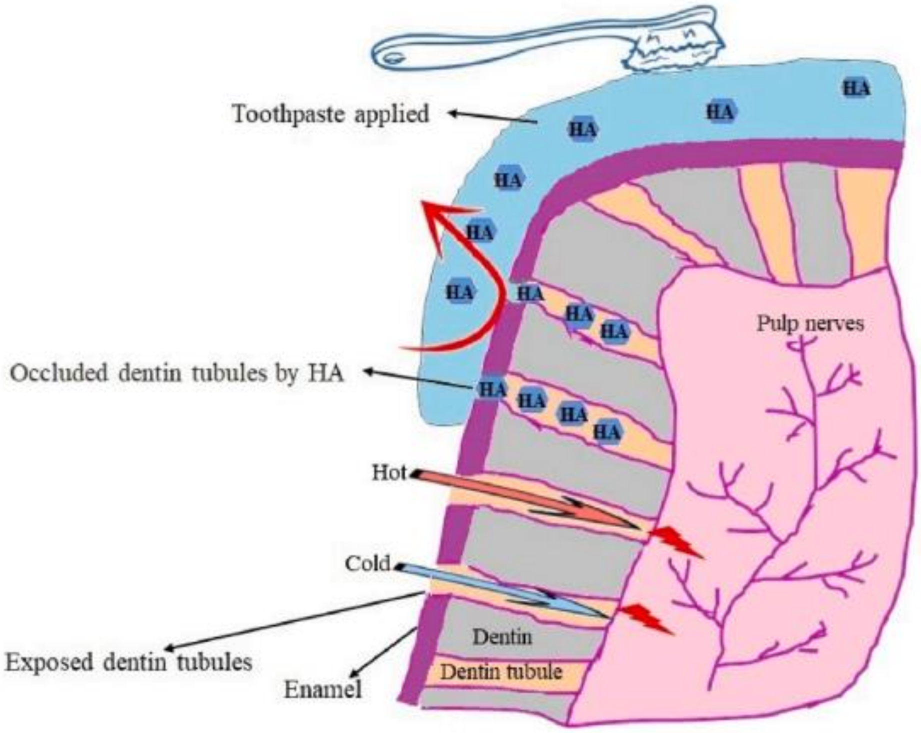



**Fig. 1: Nano-HAP toothpaste in reducing dental hypersensitivity**

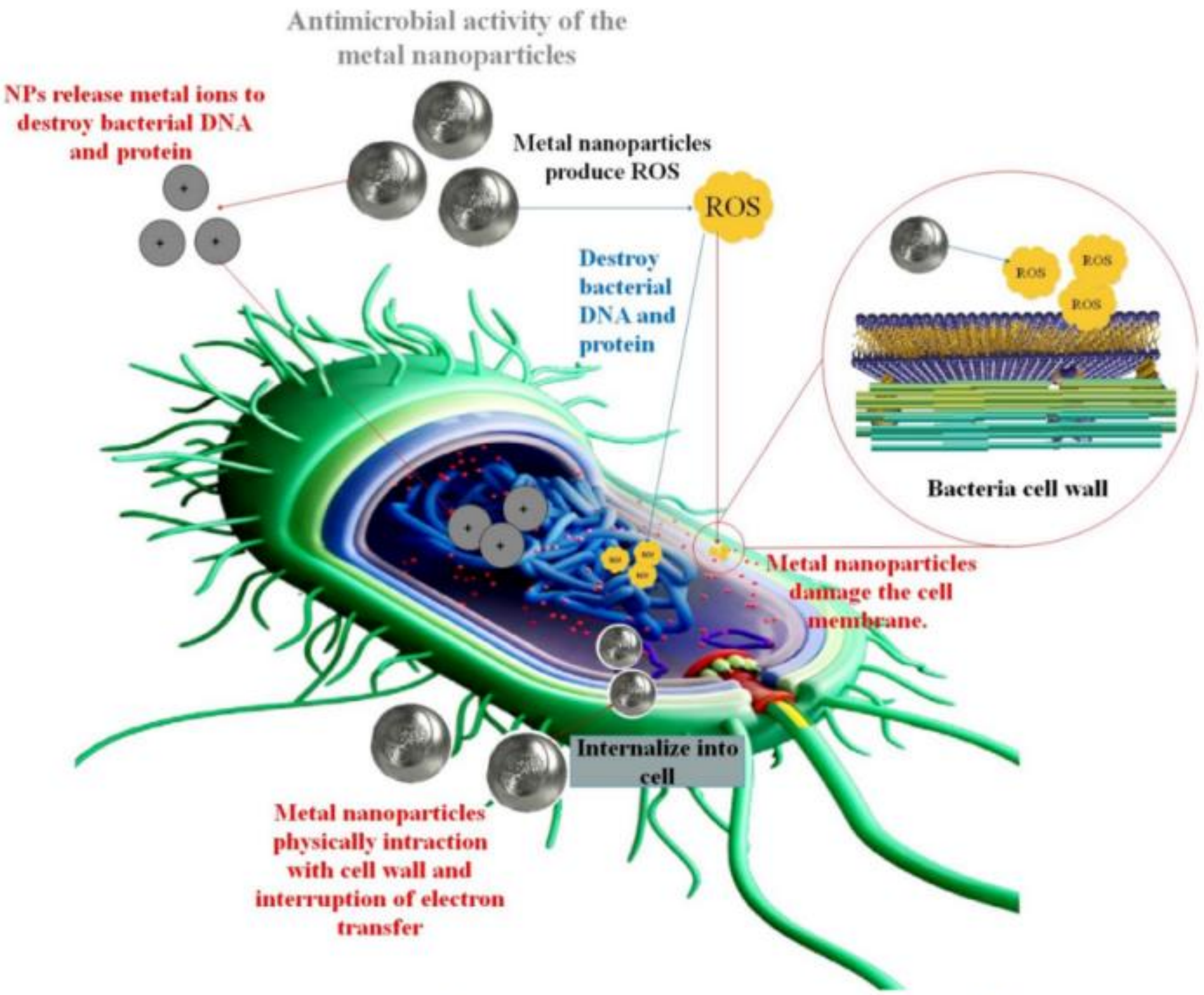
Utilizing nanotechnology in nano toothpaste presents a viable solution. The pores within the enamel surface prisms facilitate bacterial buildup within the porosities of the hydroxyapatite (HAP), [Fig. 1] which constitute a substantial portion of the dentin enamel (approximately 70–80% dentin and 97% enamel). Nano-toothpaste holds promise in sealing micropores, improving tooth aesthetics, and bolstering teeth resilience against cavities [22, 23]. Within toothpaste, nanoparticles, including whitening agents like TiO2, HAP, charcoal, carbon nanotubes, among others, are currently employed [24-26].

Swissdent nano whitening toothpaste cleans and strengthens gums and teeth and whitens without chemicals and bleaching also removes tartar. It aid in the healing of oral infections and sweetens the breath.

**Nanobrush:**

Nano Enabled toothbrush majorly cuts down on bacteria both within the mouth and the tooth brush itself. The bactericidal property of gold NPs is due to its penetration in bacterial cell walls and killing them instantly [Fig. 2]. This nano enabled tooth brushes effectively helps in removing plaque in people with limited mobility. When compared to uncoated toothbrushes, nano-enabled brushes decrease Streptococcus mutans count significantly and also enable low plaque scores. The bristles of these brushes were also found to have more nonviable bacteria than conventional nylon bristles. Although there are many advantages, the main disadvantage is the release of nanoparticles from toothbrush bristles. These released NPs could pose to be a risk factor causing potential environmental hazard and cytotoxicity [27].

- Gold nano enabled toothbrushes are particularly useful for people looking for white teeth in a natural way. It also get added antibacterial properties of gold [28].
- Zinc oxide nanoparticles are known for their excellent antimicrobial and antioxidant activity. Zinc oxide nanoparticles can thus be used embedded in tooth brush in order to render its antimicrobial activity to both the oral cavity and the toothbrush bristles [Fig. 3]. Green zinc oxide nanoparticles are also known to counteract all the side effects of chemically prepared zinc oxide nanoparticles [27].




Various mechanisms of antimicrobial activity of the metal NPs. Native bacteria without metal NPs. **c** metal NPs destruct DNA.

**Figure 2**

**Flossing**

Dental floss were also designed by nanotechnology. They are made with patented polymer material providing an ultra-high tech, ultra thin, ultra gliding flossing experience. Nanoparticles are impregnated in the flossing material making it more precise for using far reaching areas.

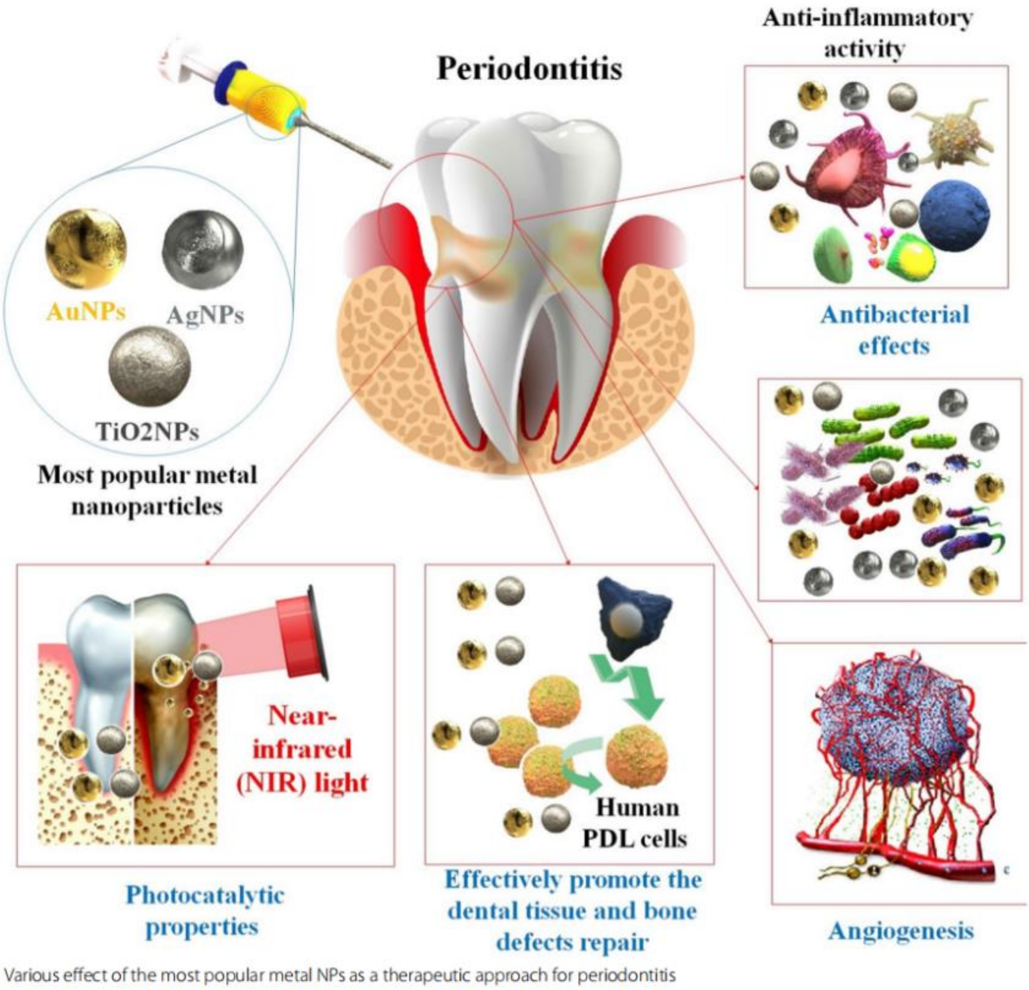



**Figure 3**

**Nanotechnology Applied on Implant**

Nanotechnology in implantology minimized the time needed for the placement. Implant success is contingent upon the strength of the osseointegration, or link that forms between the implant surface and bone. Dental implant employing nanotechnology substantially reduces the time and speeds up the osseointegration. It effectively accelerates bone growth and enhances predictability.

Additionally, new coating techniques are developed to attach the mineral of bone, hydroxyapatite, and related calcium phosphates (CaP) to the surface of implants. Numerous investigations have shown that these CaP coatings gave titanium implants a surface that was osteoconductive [29, 30]. After implanting, the peri-implant area's dissolution of CaP coatings raised blood saturation and ionic strength, leading to biological apatite nanocrystals to precipitate onto implant surfaces. The extracellular matrix of bone tissue is produced by osteoprogenitor cells, which are encouraged to adhere to this layer of biological apatite by the incorporation of proteins. Furthermore, it has been also shown that osteoclasts, the bone resorbing cells, are able to degrade the CaP coatings through enzymatic ways and created resorption pits on coated surface. Finally,the application of CaP coatings to metal surfaces expedites the osseointegration of implants through direct bone bonding in contrast to uncoated surfaces. In order to obtain direct bone contact on implant surfaces, the issue is to manufacture CaP coatings that would degrade at a similar pace as bone apposition [31].

Numerous studies have demonstrated that the first events that follow the insertion of dental implants, such as the adsorption of proteins, the development of blood clots, and cell behaviors, are greatly influenced by surfaces with nanoscale control. These initial events have an effective impact on the migration, adhesion, and differentiation of Mesenchymal stem cells. In the end, nanostructured surfaces may dictate the characteristics of peri-implant tissues by regulating differentiation pathways into particular lineages [31].

**Periodontal Drug Delivery**

Periodontitis can be managed by local drug delivery which does not have side effects of systemic drug delivery like antibiotic resistance, adverse drug reactions and high dosage. Local drug delivery has the advantage of site-specific delivery, low dose requirement, bypass of first pass metabolism, reduction of gastrointestinal side effects and decreased dosing frequency. Various polymer-based delivery technologies, such as films, chips, strips, fibers, nanoparticles and nanofibers are available. These systems have excellent mucoadhesive properties and are biocompatible and biodegradable. Pinon Segundo *et al.*, (2005) developed a new drug delivery system containing nanospheres which was composed of biodegradable polymer [32, 33]. Poly D lactide, Coglycoside, Poly D L Lactide, cellulose acetate phthalate, and poly vinyl alcohol were used as stabilizers in the preparation of nanoparticles. Tetracycline has been incorporated into microspheres for drug delivery by local means and used in a periodontal pocket. Future medication delivery systems such as hollow spheres, nanotubes and nano composites could be used in periodontal treatment. Local injection of nanoparticles loaded with curcumin in a periodontal disease model demonstrated a notable decrease in the alveolar bone loss [34, 35].

The Potential advantages in nano-drug delivery compared to emulsion-based carriers and microparticles are:

1. Controlled release characteristics, enhanced stability and dissolution in aqueous medium.
2. Increased transportation throughout the cell membrane which reduces clearance and enhances bioavailability.
3. Improved drug loading ability due to increased surface area per unit mass and higher surface reactivity [36].

**Nanotechnology Coupled Laser Plasma Application in Periodontics:**

Nanoparticles of titanium dioxide (TiO2) when applied on human skin surface by means of gel-like emulsion, exhibits extraordinary properties and effects-like shock wave, microabrasion, and stimulation of collagen production by degradation when irradiated with laser pulse. The unique characteristics of TiO2-based nanoparticles combined with laser irradiation can be applied to a number of treatments, including the treatment of periodontal disease, the depigmentation of gingiva, and soft-tissue incisions without the need for anesthesia [37].

# Conclusion

Today, nanotechnology stands as the most energized field within science and technology, propelled by its pioneering advancements. It encompasses various research areas where dimensions are characterized by being less than 1,000 nanometers in size. Nanotechnology serves as the foundation for numerous technological breakthroughs in the 21st century. An emerging area termed nanomedicine resulted from the increased interest in the potential medicinal applications of nanotechnology. By the invention of nanorobots the field was envisioned that it could destroy viruses, cancer cells and repair damaged structures. In periodontics although in the goal of complete regeneration of periodontal tissue like cementum, periodontal ligament and bone may not be possible, but recent advancements in nanotechnology and nanomaterials offer hope for better periodontal disease treatment. It is anticipated that this trend will continue to evolve positively in the future, with further advancements expected as more nanotechnologies are commercially explored.

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