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Review Article

Nanotechnology in dentistry

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Nanotechnology refers to the field of science and engineering focused on designing, synthesizing, characterizing, and applying materials and devices whose fundamental structural components are organized at the nanometer scale—approximately one billionth of a meter—in at least one dimension. The application of nanotechnology is expected to drive significant progress across multiple fields, including health sciences, materials science, biotechnology, electronics, computing, aviation, and space exploration. In particular, advancements in materials science and biotechnology position nanotechnology as a promising tool in dentistry, where it is anticipated to introduce innovative diagnostic techniques and therapeutic approaches for improving oral health care.

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Corresponding Author: Mohammed Nasr, BDS, Bachelor degree in Dental Surgery, Al Farabi Colleges, Riyadh, Saudi Arabia**This article may be cited as:** Nasr M, Awad K, Awad A. Nanotechnology in dentistry. J AdvMed Dent Scie Res 2025; 13(10):5-7.**INTRODUCTION**

Conventional dental practices have long served as the primary setting for educating patients and providing preventive and therapeutic care for oral, dental, and craniofacial conditions. Within this environment, effective communication between dentist and patient plays a key role in motivating positive behavioral changes toward better oral health. However, advancements in technology have extended dental care beyond the traditional clinic, enabling remote monitoring, virtual consultations, and continuous support for treatment adherence. Patients now have greater access to their treatment plans and health records, often from the comfort of their own homes, which particularly benefits individuals with physical limitations, those in rural or underserved areas, or communities lacking adequate local healthcare facilities.¹⁻³

While this expansion has enhanced access and improved the reach of dental care, it also brings new challenges. Ensuring timely clinical responses to important changes in a patient's health status, integrating medical and dental information across multiple specialists, and developing sustainable financial models to support this broader, technology-

driven approach are critical issues. Thus, although technology has strengthened patient autonomy and improved care delivery, it requires careful adaptation of healthcare systems to maintain efficiency, coordination, and long-term viability.⁴⁻⁶

NANOTECHNOLOGY

Nanotechnology has gradually but profoundly transformed industries across the globe, with its impact most evident in developed nations where nano-scale markets have expanded rapidly over the last decade. Although often described as revolutionary, nanotechnology is no longer a novel idea but has evolved into a general-purpose technology. Over time, four generations of nanomaterials have been introduced—passive and active nanoassemblies, general nanosystems, and small-scale molecular nanosystems—each contributing to advancements across multiple scientific disciplines.⁷

The swift progress in nanoscience indicates that nano-scale manufacturing will soon become integrated into nearly every area of science and technology. Applications now extend to agriculture, food, cosmetics, medicine, healthcare, automotive, energy, and engineering industries. Alongside its benefits,

each field also faces specific drawbacks and risks that must be acknowledged. Nanotechnology operates at the scale of nanometers, where physical size is reduced, chemical bonds and properties are altered, and biological actions—such as targeted drug delivery—are enabled. By bridging classical and quantum mechanics within mesoscopic systems, it facilitates innovations ranging from nanomedicine and diagnostic tools to agricultural enhancements and industrial production. Importantly, this approach employs nature's principle of building from the atomic level upward, enabling precise engineering of products and offering solutions once thought impossible, including therapies for previously untreatable diseases.⁷

NANOMEDICINE

The integration of nanotechnology into medicine has given rise to the specialized field of nanomedicine. This discipline is defined as the observation, regulation, and treatment of biological systems within the human body at a molecular level through the use of nanoscale structures and devices.⁸

Nanomedicine encompasses a wide range of applications, from controlled drug release using nanoscale carriers to the development of tissue scaffolds that promote regeneration, and even the design of nanorobots capable of diagnostic and therapeutic functions. Unlike conventional drug delivery, where circulating molecules may affect healthy tissues, nanorobots and nanoscale carriers can specifically target diseased cells, minimizing side effects and maximizing treatment effectiveness. This precision is particularly valuable in oncology, where the ability to selectively destroy cancer cells while preserving healthy tissue is critical.^{8,9}

Basic nanodevices and nanomaterials already available today demonstrate the capacity to address many pressing medical challenges. Research in nanomedicine has advanced rapidly, with numerous findings approaching real-world clinical application. These developments suggest that the transition from laboratory innovation to clinical practice is both imminent and inevitable. Nanomedicine not only refines existing therapeutic techniques but also introduces entirely new strategies for diagnosis and treatment, paving the way for transformative progress in healthcare.^{10,11}

OPERATIVE NANODENTISTRY – NANO-GLASS IONOMER

Nano-glass ionomers are advanced restorative materials created by incorporating nanoparticles into traditional glass ionomers. This modification enhances their strength, elasticity, translucency, and wear resistance while maintaining fluoride-releasing ability, making them effective in caries prevention and restoration. They also demonstrate improved polishing and aesthetic qualities, and their applications extend to fillings, core buildups, and

restorative systems. Incorporation of bioactive nanomaterials such as hydroxyapatite, fluorapatite, and chitosan nanoparticles further improves their clinical performance and suitability for preventive dentistry.¹²

NANOCOMPOSITES

Dental nanocomposites combine resin matrices with nanoscale fillers to improve hardness, translucency, elasticity, and color stability while reducing polymerization shrinkage. They mimic enamel properties, provide ion release for remineralization, and strengthen restorations. Nanocomposites are widely used in restorative dentistry for their caries-preventive properties, resistance to fractures, and long-lasting aesthetics. Advanced formulations such as nano-dicalcium phosphate or nanoceramic fillers enhance remineralization and durability, while examples like Filtek Supreme demonstrate their versatility and clinical acceptance.¹³

NANOTECHNOLOGY APPLICATIONS IN PROSTHODONTICS

In prosthodontics, nanoparticles incorporated into polymethyl methacrylate (PMMA) dentures or cements improve antimicrobial properties, biocompatibility, strength, and wear resistance. Materials like silver, zirconium oxide, and titanium dioxide nanoparticles reduce microbial colonization and enhance durability. Nano-glass ceramics and resin nanoceramic CAD/CAM blocks offer high strength, excellent aesthetics, and reduced abrasiveness to enamel. These innovations extend denture lifespan, enhance oral health, and provide cost-effective alternatives, though safety evaluations remain essential.¹⁴

NANOTECHNOLOGY APPLICATIONS IN ENDODONTICS

Endodontics benefits greatly from nanoparticles used in fillers, sealers, irrigants, and root repair materials. Nanoparticles such as silver, calcium phosphate, and bioglass improve antimicrobial action, sealing ability, remineralization, and bonding to dentin. Modern endodontic sealers like GuttaFlow Bioseal or nanodiamond-modified gutta-percha provide excellent flow, adaptability, and antibacterial effects. These advances help overcome challenges like resistant biofilms in root canals, making endodontic treatments more effective and durable.¹⁵

NANOTECHNOLOGY APPLICATIONS IN ORTHODONTICS

Nanotechnology enhances orthodontics through nanorobots, smart brackets, and nanoparticle-coated appliances that improve efficiency, reduce side effects, and minimize plaque buildup. Nanoparticle-based elastomeric ligatures deliver fluoride or therapeutic agents for anti-cariogenic and anti-inflammatory effects. Brackets with nanocoatings

reduce biofilm formation and enamel demineralization while providing real-time feedback for force adjustment. These advancements make orthodontic treatments faster, safer, and more biologically compatible.¹⁶

NANOTECHNOLOGY APPLICATIONS IN PERIODONTICS AND IMPLANTOLOGY

In periodontics and implantology, nanomaterials are used to regenerate tissues, treat infections, and improve implant integration. Nanoparticles such as hydroxyapatite, nanodiamonds, and titanium oxide promote bone growth and osseointegration, while nanoporous coatings enhance implant surface area and healing. In drug delivery, tetracycline- or triclosan-loaded nanoparticles provide sustained antibacterial effects, while fullerene-based materials act as antioxidants. Nano-based scaffolds and coatings improve periodontal regeneration, and titanium implants enhanced with nanostructures demonstrate superior bone bonding and antimicrobial resistance. These technologies are transforming implantology and periodontal therapy into minimally invasive, regenerative approaches with long-term success.¹⁷

CONCLUSION

Nanotechnology in dentistry involves the development of advanced materials, techniques, and drugs at the nanoscale to improve restorative and surgical practices. Although still emerging, it holds significant potential for innovation, particularly in creating more biocompatible, durable, and effective dental solutions. With its success in areas like drug delivery and toxicity reduction, nanotechnology has drawn strong interest from clinicians, researchers, and manufacturers. Current efforts focus on enhancing the quality, safety, and performance of next-generation dental materials and technologies.

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