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Facets of Nanotechonolgy in Dentistry-Nanodentistry

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Abstract

Nanodentistry is a field of technology that has revolutionized the use of biotechnology at the nanoscale, including tissue engineering and nanorobots. The advancement of science and technology in nanodentisry utilizes nanostructured materials to diagnose, treat, and prevent oral and dental problems, as well as alleviate pain and preserve and improve dental health. Nanodentistry offers a wide range of applications, including dental restorative materials such as dental nanocomposites, nanofillings, nanobonding systems, nanometals, and nanometallic alloys. However, the workplace exposure and health hazards of nanodentistry have to be assessed in terms of manufacturing exposure, toxicology of nanoparticles, biological and environmental impact, recyclability, and sustainability. Dental nanomaterials are yet to be studied for true breakthrough characteristics rather than a booming marketing technique for promised improved material properties. Hence, the increased efficiency of nanomaterials must be tested over time with robust scientific proof in clinical and real-world settings. For safer production, judicious utilization, and a higher quality of life for humans and other ecosystem components, an interdisciplinary effort of scientists, researchers, policymakers, safety officers, and environmental engineers, as well as their analysis in various aspects, are addressed in the work.

Keywords: Nanotechnology; Nanodentistry; Nanocomposites; Sustainability

Abbreviations: ACP: Aciduated Calcium Phosphate; TTCP: Tetracalcium Phosphate; DCPA: Dicalcium Phosphate Anhydrous.

Introduction

Biomedical sciences are remarkably influenced by the advances and advantages of nanotechnology. Dentistry greatly benefits from understanding the fundamental building blocks of the dental tissues until nanomaterial usage and beyond. Nanodentistry is that sphere of technology that has transformed the use of biotechnology on a nanoscale, including nanorobotics and tissue engineering. Nanodentistry is defined as the science and technology of employing nanostructured materials to diagnose, treat, and prevent oral and dental disorders, relieve pain, and preserve and improve dental health [1].

It was Freitas Jr., who coined the word ‘nanodentistry‘ in his cover story published in Journal of American Dental Association in early 2000’s and launched the new era of ‘nanodentistry’ [2]. Exploring the dental structures and surfaces at the nanoscale widens the understanding of functional and physiological interconnection that molecular or cellular level did not offer, enabling an enhanced and skilled approach to intervene in the disease treatment approach.

Applications of Nanodentistry

Application of nanotechnology goes back to the early 1970's with the beginning of the use of microfills especially in the field of prosthodontics [3-5]. Nanodentistry has a wide range of applications extending from dental restorative materials, i.e., dental nanocomposites, nanofills, nanobonding systems, nanometals and nanometallic alloys (Ti, Al, V, and Ni) in implants and dental bridges, nanocoating materials for dental implants, bioceramics, mouth washes, digital imaging, and drug delivery. Table 1 shows the application of nanodentistry, the respective types of nanomaterials, and the approach of application.

Nanomaterials in Dentistry Have Been Utilised in Two Ways:

- Bottom-up approach: Small components are assembled to form compound structures [6].
- Top-down approaches: Creating small structures by using larger ones to guide their assembly [7].

Application	Type of Nanomaterials	Nano-Particle	Approach of application
Composite resins	Nano composites, Nano Light Cured Glass Ionomer Cements,	Nano-Silicon dioxide , Nano-Zinc Oxide [8], Nano-silica [9], Nano-calcium phosphate and calcium fluoride [10], Nano-Titanium dioxide [11]	Top Down
Dental adhesives [12,13]	Nano solutions/ adhesives	Nano- Hydroxyapetite,	Top Down
Root canal fillings		Nano- Hydroxyapetite	
Bone restoration Materials Nano bones		Nano- Hydroxyapetite ,Nano-Zirconium dixode,Nano Hydroxyapetitie composite [14], Nano- Calcium Phosphate, Aciduated Calcium Phosphate (ACP), Tetracalcium phosphate (TTCP), Dicalcium phosphate anhydrous (DCPA)Nanometal and metal alloys - Titanium, Aluminium , Nickle	
Bioceramic		Nano- Zirconium oxide [15], Titanium Oxide, Plasma Coating	
Silicone elastomer Material[16]	Nano fillers incorporated impression materials	Noano sized Titanium, Zinc and Cerium oxide.	
Denture base materials		Nano-silver, Nano- poropus alumina, Nano-Zirconia, Nano- Calcium Phosphate.	
Dental Implant Coating Materials		Nano Zirconia,Nano-porous alumina [17],Nano-Calcium Phoapshate Nano- Zinc Oxide Nano-Hydroxyapetite	
Drug delivery Nano-thereupatics	Periodontal drug delivery Toothpastes & Mouth washes	ArestinR- (microspheres containing tetracycline) Silver nanoparticles Nano- Silica [18], Local Nano anesthesia Nano-Titanium Dioxide Nano Zincoxide	Bottom - Up
Tumor / cancer Diagnosis & imaging [19]		Nanoscale Cantilevers Nanopores Nanotubes Nano-Silica	Bottom Up
Nanorobots	(dentifrobots)		Bottom Up
Digital Imaging	nanophosphor scintillators [20] Quantum dots		Bottom Up
Orthodontic Wired	novel stainless steel material, Sandirk Nanoflex [21]		

Table 1: The application of nanodentistry and respective type of nanomaterials, nano-particle and approach of application.

Work Place Exposure and Health Hazards of Nanodentistry

The information addressing the relative health hazards and environmental impact of nanodental materials is still sparse. Yet the risk assessment cannot be ignored. It has to be assessed in terms of manufacturing exposure, toxicology of nanoparticles, biological and environmental impact, recyclability, and sustainability.

Nanodentistry particles are aerosols, and their toxic effects depend on the particle size, exposure method, and dose. The risk assessment has to be estimated based on the type of nanoparticle material, placement, removal method, and removal tools used, as well as the wear, abrasive, and erosive properties of the nanoparticle material. Nanoparticles can be released from dental materials in the mouth and enter the bloodstream directly or through the oral mucosa, when they are eaten or breathed in. This can happen when dental drills or burs are used. The prosthetic nanomaterials in metallic or non-metallic form, before crossing the blood-brain barrier, may get directly translocated through the nerves to get deposited in the brain.

Metal nanoparticles (Aluminum Oxide, Silver Oxide, Ti Oxide, and Zinc Oxide) that have been engineered are said to damage cells, raise oxidative stress, change how mitochondria work and cause cytotoxic, genotoxic, and mutagenic effects on different cell lines and test animals. Most of the studies done are in vivo and are animal experiments. The real-time effects on human beings are to be anticipated.

Nanodentistry has enhanced the efficiency of the dental treatment modality and improved patient satisfaction. However, the downsides of nanotechnology cannot be underestimated. Nanoparticles of the non-maetallic substances silica, polymers, and carbon-based nanomaterials are comparitively least toxic; however, their cumulative effect cannot be ignored [22].

The size of the particles has a significant effect on the human system. Nanoparticles are capable of undermining the immune system of humans and gaining access to the entire body without limitation. The laboratory technicians have a higher rate of exposure to nanoparticles in the form of polished dust. This would have serious effects on sensitive and vital organs like the brain, liver, heart, lungs, and kidneys. Biodegradable nanoparticles could undergo decomposition and exit the human body. However, the fate of non-biodegradable materials is still inconclusive. They may remain in a specific human organ or be excreted from the body to remain as micropollutants in the environment.

Challenges and Considerations:

- Green synthesis of nanomaterials
- Dental nanomaterials are yet to be investigated for their real breakthrough characteristics, rather than a buzzing marketing strategy for claimed superior material properties. The improved efficiency of the nanomaterials has to be time-tested with clear scientific evidence in clinical or real-life situations [23].

Sustainability in Nanodentistry: Nanodentistry is still in its infancy, and the knowledge, data, and information available are limited and ambiguous. Yet nanodentistry is considered a sustainable source due to its potential to produce efficient products in terms of material, product production, energy efficiency, and result orientation. However, the data available is insufficient and largely based on in vivo studies and animal experiments. The cold reality is that nanoparticles are ultimately going to remain an environmental, non-recyclable byproduct, which offers a wide opportunity in the field of nanotoxicology. So the green synthesis and innovation of greener nanomaterials endure challenges. Irrespective of the technology used, we are in the era of fostering and embracing sustainability in the fields of medicine and technology. An interdisciplinary effort of the scientists, researchers, policymakers, safety officers, and environmental engineers and their analysis in different facets needs to be emphasized, rather than the hope of 'nanomiracle' for safer production, judicious utilization, and a better quality of life for humans and other components of the ecosystem.

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