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Research Article

Nanoparticles: Advances of Medical and Dental Implant Surfaces

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ABSTRACT

Nanoparticles have huge scope in the research field of dentistry and also have a wide area of application. This review paper focused on the different types of applications of nanoparticles in dentistry, which kinds of nanoparticles show good antimicrobial properties, biocompatibility, good physio-mechanical properties, etc. It also focused on how restorative and therapeutic nanoparticles are used in dentistry and helped in dental implants. Different types of nano-coating can be widely used in dentistry for the structural improvement of teeth. More biocompatible materials can be researched and developed to prevent the failure of dental implants, which is a great area of research interest nowadays. Implant failure due to cytotoxicity and biocompatibility is a big challenge in dentistry that can be developed or solved by nanotechnology. The objective of this review paper is, therefore, to give an overview of the principles of nanomaterials and basic research and applications of dental nanomaterials.

Keywords: Antimicrobial; Metal nanoparticles; Restorative; Therapeutic; Biocompatibility; Nano-coatings; Dental Implant.

INTRODUCTION

Nanotechnology is a significant technology of the 21st century with a range of nanoscale atoms of 1–100nm. These nanoscale atoms are called nanoparticles. NPs can be obtained from a variety of sources, including natural sources, chemicals, or byproducts. Nano-dentistry refers to the application of implant nanotechnology in the dental field for purposes of disease prevention, diagnosis, and treatment. These nanoparticles have characteristics like bio-compatibility, a large surface area, and strong mechanical characteristics [1]. Those particles are mostly used in dentistry. The dental field has benefited much from nanotechnology; however, there are still challenges to be overcome in areas like orthodontics where issues like mouth infection, cytotoxicity, and root resorption might arise. Metal NPs, such as copper, zinc, titanium, zirconium, and silver ranging from 1 to 10 nm in size have been shown to have greater antimicrobial activity than larger particles. The atomic and molecular bonds can be altered by nanotechnology analysis. Numerous distinct types of nanoparticles exist, including nanopores, nanotubes, quantum dots, nanoshells, nanospheres, nanowires, nanocapsules, dendrimers, nanorods, and liposomes. These nanostructures might help in dental disease diagnosis and treatment. Due to their broad-spectrum bactericidal capabilities, metal and organic NPs have been used in several dental applications. Nanoparticle use in dentistry could therefore be very beneficial.

Nanoparticles' properties in dentistry

Nanoparticles are mostly used in dentistry as fillers in nanocomposites. When compared to bulk materials, the NPs offer more advantages since they are comparatively low-stability molecules with low coordination and unmet bonds, which enable them to interact with other particles efficiently and with ease [2]. In dentistry, nanoparticles are used in a variety of ways for therapeutic and diagnostic purposes. They have been employed in the delivery of local anesthetic, the treatment of dentinal hypersensitivity, and the diagnosis and treatment of oral cancer. Wound dressings have been developed using nanoneedles and nanofibers.

Antimicrobial Activities of nanoparticles in dentistry

Ion release directly correlates with nanoparticle antibacterial activity. Nanoparticles are commonly used in biomedicine and can be an effective antibacterial agent. Considering that their mode of action directly interacts with the cell walls of bacteria and concurrently targets several different biomolecules, the superior bactericidal activity of positively charged nanoparticles with antibacterial activities has the ability to slow or stop an increase in microbial resistance [3]. In order to reduce the production of biofilms, metal oxide nanoparticles like Cu NPs, Ti NPs, Zn NPs, Ag NPs, Zr NPs, etc. are beneficial. The management of oral biofilm and reducing demineralization within the brackets has both been made possible by using these nanoparticles as

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orthodontic adhesives, which has attracted a lot of interest. Recent research has shown that the inclusion of antimicrobial NPs has an important contribution to the treatment of primary and chronic infections in the teeth following treatment or decolonization of the network of filled canals . In order to increase the effectiveness of different antibacterial NPs and their uses in dentistry, these facts have sparked increased interest in their utilization [4].

Bonding agents

Dental bonding materials come into direct contact with teeth but are not in contact with saliva or the oral cavity. The most frequent cause of restorative failure is dental caries at the resin-teeth contacts. To increase their antibacterial action, dental adhesive test products now contain filler particles. Nano-silver is among the most commonly utilized antimicrobial particles. According to studies, dental adhesives containing 0.05% silver nanoparticles (particle size 2.7 nm) significantly reduce the survival of biofilms, counts of colony-forming units, and lactic acid synthesis, without weakening the dentin bond. Adhesives containing polyacrylic acid-modified copper iodide particles (1 mg/ml) reduced the number of Streptococcus mutans viable cells by 79-99%. Despite this, the experimental adhesives and matched controls showed no discernible variations in bond strength or cytotoxicity [5].

Nanopores

A nanopore is only a tiny hole with an inside diameter of about 1 nm. One of the most promising technologies being developed as a quick and affordable replacement for the traditional Sanger sequencing approach is nanopore sequencing. Nanopores can identify chemicals that cause oral cancer. The development of nano-sized particles on the implant surface has stimulated osteoblast growth. The cellular reaction that occurs in the tissue depends on the implant surface being roughened at the nanoscale level. Nanopores are positioned between the crystals of nanocrystals, which exhibit a loose microstructure. The inclusion of silica molecules changes the surface of the pores, causing them to adsorb protein. The HA NPs can be used to cure bone problems.

Nanotubes

Nanostructured materials with controlled surface composition and shape include nanotubes. Dental applications for nanotubes include Titanium, carbon, and silver for a variety of purposes. Nanotubes can be used to examine the dentin collagen network, dentin pores, and how they affect tooth sensitivity and the surface of dental implants. Carbon nanotubes are created when graphene is folded up; as a result, carbon nanotubes and graphene-based materials share some similarities. Nanotubes can be constructed with a single or several walls. When composed of carbon, they are referred to as single-wall carbon nanotubes (SWCNT) or multi-wall carbon nanotubes [6]. Carbon nanotubes have a very high mechanical strength, making them particularly useful in the production of materials for dental applications. Additionally, smart coatings for the surface of Ti implants can be created using carbon nanotubes. The properties and uses of carbon nanotubes and graphene are quite similar. Both structures' shapes result in a higher number of reactive edge surface sites in graphene, which has a lot of uses in dentistry, particularly in implantology. Ti or Ti alloy, which is frequently utilized in dental applications and dental implants, can also be used to make nanotubes. These Ti-based nanotubes increase the surface roughness of the implant, which enhances osseointegration, has antibacterial qualities, and may also be functionalized in a variety of ways, opening up a wide range of possibilities.

Nanoshells

Sphere-shaped nanoparticles known as "nanoshells" have a dielectric core encased in a thin metallic shell (usually gold). Because of their possible uses for them, nanoshell materials have attracted a lot of attention recently. Fluorescent diagnostic markers, catalysis, protecting teeth from photo degradation, improving photoluminescence, producing photonic crystals, and the creation of bio-conjugates are just a few uses for these materials in dentistry [7]. Researchers have suggested that the core-to-shell ratio of nanoshells can be altered in order to make the shells absorb near-infrared light and produce a tremendous amount of heat that is lethal to cancer cells. A silica core and a metallic shell make up nanoshells.

Biogenic coating

Bone morphogenetic proteins (BMPs), liposomes, and other molecular and nanoscale-based biological materials have been approved for use in combination with calcium phosphate coatings and will likely continue to play a significant role in enhancing osseointegration of dental implants, possibly at a faster rate.

Commercial calcium phosphate ceramics sintered at high temperatures have exceptionally low specific surface area and surface reactivity. Although they have good osteoinductive properties, they are also good osteoconductive materials. Recent groundbreaking studies have brought up the fascinating idea that coating these ceramics with nanocrystalline carbonated apatite might enhance their surface and biological qualities. To enhance peri-implant bone regeneration, researchers and medical professionals have suggested using biomimetic calcium phosphate coatings and materials to give growth factors like BMP. In another study, coating dental implants with chitosan has also shown encouraging outcomes in several investigations [8,11]. Surface biological, mechanical, and morphological aspects might be influenced by the chitosan coating, which is in contact with the bone

One of the most effective nanometer-scale delivery systems for non-toxic and antifungal drugs, genes, and vaccines is the use of liposomes. Liposomes have an exceptional clinical profile as compared to alternative delivery systems because of their capacity to control size and surface as well as their biocompatibility, biodegradability, and decreased toxicity.

Several bioceramics, notable hydroxyapatite, have utilized stem cells. In an experiment, stem cells proliferated more quickly on HA- and tricalcium phosphate-nanocoated materials than on noncoated ones, leading to faster bone resorption and development.

Nanocomposite coatings

Nanocomposites and nanocomposite coatings are often made of two or more materials, comprising a matrix material and minute secondary particles. A matrix made of a biocompatible polymer, metal, or ceramic can be employed. By including secondary nanoparticles, it is possible to adjust the mechanical properties of composites such that they are more similar to those of real bone, such as strength and Young's modulus. A new generation of nanocomposite coatings containing nanomaterials like carbon nanotubes (CNTs) and bioglass is being developed using this technique to enhance osseointegration.

Applications of nanoparticles as dental implant

According to 10-year clinical findings, a dental implant treatment has a survival rate of roughly 95% and is quite predictable. Despite the positive clinical outcomes, difficulties with the mechanical, biological, and functional aspects of the implants still exist [9]. Peri-implantitis is a significant complication that can result in bone loss around the implant and ultimately results in implant failure. According to various reviews, peri-implantitis will develop within 5–10 years following implant placement in more than 20% of patients and 10% of implants. Some nanoparticle uses in dental implants are discussed next.

The emergence of nanotechnology has led to an increased focus in dental implant research on nanoscale modifications and the usage of nanomaterials. There are currently several research gaps regarding the clinical use of nanoengineered dental implants, even though many nanoengineering approaches have shown substantial promise in enhancing dental implants' bioactivity and therapeutic potency. For implants with nanoengineered coatings, prolonged masticatory loading during testing circumstances, pH variations, and physiological settings are crucial. Only a few efforts have been made to guarantee the effective production of durable commercial implants with enough mechanical stability and nano-engineered coatings since any nanoparticle delamination or release from implant modifications may result in a cytotoxic response. The notion of local drug release has attracted interest, but research into it has mostly been confined to brief in vivo investigations without mechanical stress or proof-of-concept in vitro research [10].

CONCLUSION

Biocompatibility and osseointegration play a major role in dental implants. The use of nanoparticles in this field to enhance or resolves issues in numerous other areas is extensive. Additionally, there is a lot of room for research in fields like therapeutic dentistry and bettering restorative dentistry, both of which have significant potential for the application of nanotechnology. Due to their excellent mechanical characteristics, high surface-to-volume ratio, ability to stop cracks from spreading, improved fracture toughness, etc., several types of metal nanoparticles are of significant interest to researchers. Nano-coatings come in a variety of forms and are a fantastic tool for dental research. To create the optimal dental implant with the use of nanotechnology, researchers are still investigating the development of metal and non-metal materials.

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