International Arab Journal of Dentistry

Volume 14 | Issue 2 Article 19

2023

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REVIEW ARTICLE / *REVUE DE LITTÉRATURE*

Dental Materials / *Matériaux Dentaires*

NANOPARTICLES IN DENTISTRY: A REVIEW

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Abstract : Nanotechnology finds frequent application in everyday life, particularly in the field of medicine. Due to the capabilities of nanotechnology, examining and manipulating atoms, chemical bonds , and molecules between substances is a relatively straightforward task. When applied in the field of dentistry it is referred to as “nano dentistry”. Nanoparticles which are believed to possess superior efficacy, find significant usage in dentistry, primarily in the prevention and treatment of oral disorders, as well as the maintenance of good oral health and hygiene. Nanoparticles possess distinct characteristics such as their surface to volume ratio, antimicrobial activity, physical, mechanical and biological properties, as well as their particle size. This article provides an overview of the various nanoparticles utilized in dentistry and their respective contributions to the field.

Keywords: Nanoparticles, Nanodentistry, Dental Implant, Peri-implantitis, Dental caries

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Conflicts of interest:
The authors declare no conflicts of interest.

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LES NANOPARTICULES EN DENTISTERIE: UNE REVUE DE LITTERATURE

Résumé : La nanotechnologie trouve des applications fréquentes dans la vie quotidienne, en particulier dans le domaine de la médecine. En raison des capacités de la nanotechnologie, l'examen et la manipulation des atomes, des liaisons chimiques et des molécules entre les substances sont une tâche relativement simple. Lorsqu'elle est appliquée dans le domaine de la dentisterie, on parle de «nano-dentisterie». Les nanoparticules, dont on pense qu'elles possèdent une efficacité supérieure, trouvent une utilisation importante en dentisterie, principalement dans la prévention et le traitement des troubles bucco-dentaires, ainsi que dans le maintien d'une bonne santé et hygiène bucco-dentaire. Les nanoparticules possèdent des caractéristiques distinctes telles que leur rapport surface/volume, leur activité antimicrobienne, leurs propriétés physiques, mécaniques et biologiques, ainsi que leur taille. Cet article donne un aperçu des différentes nanoparticules utilisées en dentisterie et de leurs contributions respectives dans le domaine.

Mots Clés: Nanoparticles, Nanodentistrie, Implant Dentaire, Peri-implantite, Carie Dentaire

Introduction

Nanostructures are extensively used in dental advancements and dental diagnosis. In order to treat and prevent oral illnesses, certain nanoparticles are used in dental implants, prosthesis, and pharmaceuticals. Additionally, nanomaterials provide oral drugs or medicines for the prevention and treatment of various oral diseases, including cancer of the oral cavity, and maintaining oral health significantly [1]. Nanoparticles ranging from size 1 to 100 nano-meter are available naturally and are implemented in various aspects of our day-to-day life successfully [2]. Nanoparticles (NPs) are distinct clusters of atoms with multiple medical uses, including antibacterial agents, tissue engineering, drug delivery, regenerative medicine, cancer therapy, and biomolecules detection.

Due to their unique physicochemical and microbiological characteristics, including biocompatibility, shape, surface charges, extensive surface areas, toughness, solubility, chemical and surface interactions, hues, exceptional durability, and thermal expansion, nanoparticles are highly demanded in dentistry [3].

Different implementations of Nanoparticles that are frequently applied in the field of dentistry are [4].

1. Prevention of caries
2. Dental fillings
3. Polishing of enamel surface
4. Teeth whitening
5. Anti-sensitivity
6. Dental implants

Many dental applications employ various nanoparticles.

1. Hydroxyapatite
2. Titania
3. Silver
4. Iron oxide
5. Zirconia
6. Silica

Properties Of Nanoparticles and their Application

Carbon nanotubes : Carbon nanotubes show astonishing mechanical as well as chemical or electrical features. It is not only employed as a candidate for dental fillings but also for its other implications due to its superior mechanical and electrical characteristics. These include thermal stability, thermal transmission efficiency, high toughness, and reduced density [5].

*Graphene : T*his carbon allotrope, also known as graphene, has a homogeneous crystal structure devoid of gaps or structural alterations. This property gave graphene additional physical features. Graphene's conducting electrons travel very quickly. Graphene is utilized in photovoltaics, biodevices, ultracapacitors, and the building of anti-bacterial surfaces and six other fields [6].

Hydroxyapatite : The usage of hydroxyl apatite nanoparticles in medical management and dentistry is widely applied. It is a naturally occurring calcium phosphate ceramic that predominates in the outermost surface of the tooth, which is the enamel at 97 percent. The dentinal tubules may readily incorporate the nanosized Apatite particles. The purpose of the dentinal tubule is to close off the opening and keep the nerves from being exposed to outside stimuli. Therefore, Hydroxyapatite aids in lowering dental hypersensitivity [7]. It can create chemical connections and ensure the quick integration of titanium implants to the teeth and peri-implant structures around them because of the chemical characteristics and capacity to produce crystals that bear in-organic parts of teeth [8].

Zirconia : The use of zirconia has grown in the dental industry. It is an insoluble chemical oxide with a tooth-colored hue. Low cytotoxicity and reduced bacterial adherence are its benefits. Zirconia is now a widely used material for implants in dentistry. Zirconia implant features outstanding corrosion and resistance to wear as well as acceptable bio-compatibility. Additionally, ZrO2 has a strong fracture resistance due to its energy retention feature [9].

Silica : Considering their dimensions, contact area, biomedical applications, decreased toxicity, reduced density, and the ability for surface adsorption, silica-based Nanoparticles play a vital part in nanotechnology. Dental fillers made of silica nanoparticles are used in dentistry. Because they are inexpensive and biocompatible, silica particles are utilized in polishing. Studies have demonstrated that polishing with silica results in a lower surface roughness, which lowers the risk of caries. Dental hypersensitivity is treated using modified silica nanoparticles [10-11].

Silver : There is evidence that silver compounds have antibacterial properties. Additionally, silver nanoparticles have been investigated for usage in endodontic therapy, restorative dental materials, prosthetics, and implants. Incorporation of Ag nanoparticles improves oral health by decreasing microbial colonization over dental components. Because of their small size, silver Nanomaterials can quickly begin to kill bacteria because they can easily pass through their cell membrane [12].

Application of Nanoparticles

Dental caries

Dental caries is a complex condition influenced by multiple factors that is typically brought about by biofilm formation and microorganisms which form colonies on the tooth surface. The oral cavity's bacteria stimulate sugar metabolism, producing acidic byproducts that significantly lower the oral pH. Cavities develop when the pH becomes too acidic. This causes the teeth to become de-

mineralized, which leads them to lose calcium, fluoride, and phosphate ions. Fluoride applications, as well as the use of fluoride containing toothpaste and mouthwash, can stop this process. The employment of Nanoparticles is a critical element that can support this kind of therapy [13]. To enhance the fluoride levels in the buccal cavity, calcium fluoride nanoparticles have been widely used. According to Kulshrestha et al., Calcium fluoride nanoparticles have the ability to reduce the formation of exopolysaccharides by Streptococcus mutans [14].

Peri-implantitis and implant failures

One of the most frequent reasons for implant failure is peri-implantitis, which is brought on by an inflammatory microbial biofilm that surrounds the implant surface. To lessen surface contaminants and the development of peri-implantitis, many Nanoparticles have been explored. Studies have demonstrated the antibacterial action of Nanoparticles against peri-implantitis-related organisms, such as S. gordonii, S. mutans, P. gingivalis, Staphylococcus aureus. The surface properties of titanium implants, which can impact cell attachment, multiplication, maturation, and integration with neighboring tissues [15].

Dental prosthesis failures

Typically, dentures are constructed from traditional heat-polymerized polymethyl methacrylate. The poor mechanical qualities of PMMA, however, poor flexural and impact resistance, high fracture susceptibility, inadequate mechanical characteristics, fatigue failure, and surface finish that encourages bacterial adhesion are only a few of these factors [16]. The inclusion of organic and inorganic Nanoparticles into acrylic resins has been suggested. As the concentration of nano-ZrO2 grows, ZrO2NPs may greatly improve the dimensional stability, increase the fracture resistance, and Improve the tensile strength of the acrylic used for the denture base, while simultaneously reduce the transparency of the PMMA material. [17]. It has also been discussed in the literature how adding silica nanoparticles to PMMA affects the material. When compared to PMMA alone, this integration into acrylic resin lessened its flexural strength [18].

Hyposalivation

Hyposalivation is the medical term for low or inadequate salivation [19].The preservation of the oral mucosa's moisture can be greatly aided using nanoparticles. Even in humid environments like that of the oral cavity, it showed how well liposomes adsorb, desorb, and diffuse in water. To extend the time that liposomes stay in the oral cavity, mucoadhesive polymers such as pectin, chitosan, and hydroxyethyl cellulose can be added to them [20]. Through the use of certain chemicals, nanoparticles can be employed to avoid damage from radiation to the salivary glands and the resulting hyposalivation.

Head, Neck, and oral cancer

Several malignant cell types, including human Caucasian dysplastic oral keratinocytes, mouth epidermoid carcinoma (KB) [21], and murine AT-84 oral squamous carcinoma cells, were shown to be sensitive to a wide range of NPs.There are numerous uses for silver nanoparticles and nanorods in the detection and identification of tumor margins. Air scanning electron microscopy is one diagnostic technique and tool that these nanoparticles have been linked to 43, enzyme-linked immunosorbent assay (ELISA) [22].

Oral Mucosa drug delivery

The mucoadhesive formulation administration into the buccal soft tissues has garnered the most attention recently in the fields of pharmaceuticals and among dentists. Due to its various benefits, such as low enzymatic activity, availability, and patient acceptability, this route of administration is beneficial. However, there are significant challenges that must be overcome when administering medications through the oral mucosa. Involuntary swallowing may result from the salivary flow's short residence time. Additionally, only modest amounts can be given, and problems with drug permeability, controlled drug release, and targeting still exist [23]. The use of Nanoparticles to increase buccal delivery represents a promising strategy to address these issues. Nanoparticles are capable of holding high-concentration drugs, increasing water solubility and drug dissolution rates, and guarding against drug deterioration in the oral environment. Additionally, the capacity to enhance formulations' mucoadhesive characteristics can result in a lengthened residence period in the oral cavity. To achieve this, it is possible to use polymeric NPs, liposomes, chitosan NPs, lipids, and polysaccharides [24].

Application of Nanotechnology In Orthodontics

Fixed orthodontic appliance therapy works mainly on the correction of malposed teeth by applying mild and continuous forces on teeth by arch wires through orthodontic brackets [25]. Orthodontic brackets and other removable and fixed appliances are more likely to promote enamel demineralization, often known as white spot lesions, which is the early stage of caries activity caused by organic acids released by the biofilm of microbes on the teeth. Though mechanical therapy and oral hygiene instruction can prevent and eliminate plaque biofilm more effective methods that are independent of patient cooperation should be developed to stop white spot lesions. According to studies, adding antimicrobial nanoparticles to orthodontic adhesives and resin-modified glass ionomer cement will lessen the likelihood of plaque buildup and bacterial adherence [26]. Orthodontic bands and brackets that are cemented with conventional GIC have shown the highest microleakage scores in comparison with those

cemented with Nano-HA-modified GIC [27]. Some commonly used nanoparticles with antimicrobial activity are titania, silver, copper, gold, silica, and zinc oxide.

Nano-coatings in archwires and brackets to reduce friction

One of the main obstacles to tooth alignment is friction. Applying more forces is one way to overcome it, although doing so could result in unwanted anchoring loss. Other options include adjusting the bracket design, changing the size and shape of the wires, or applying various materials to the wire surfaces to overcome slide resistance. These coatings have either been applied to the surface of the brackets or the NiTi or S.S. wires. Multiple research experiments have been done to experiment with tungsten disulfide (WS2) as a surface lubricant in the past. Due to relatively high toxicity of WS2, new self-lubricating layers comprising of other metals have been used.[28]

Orthodontic brackets

To create braces, UC3M created a novel material in 2012 that contains polysulfone embedded with tough alumina nanoparticles. The novel material preserved the bracket's transparency while exhibiting strength, reduced friction, and biocompatibility. Antimicrobial properties: Brackets for orthodontic treatment have been implanted in rats and coated with nanosilver. Friction and mechanical resistance between orthodontic wires and bracket can be made less by applying a coat of nanoparticles. The integration of antimicrobial nanoparticles into orthodontic materials offers the potential to inhibit the accumulation of dental plaque around orthodontic appliances, consequently lowering the risk of dental caries linked to orthodontic procedures. In 2006, Kachoei et al. [29] provided substantiating evidence showcasing a reduction in frictional resistance between archwires and self-ligating brackets by employing a nanocoating infused with spherical metal nanoparticles.The nanoparticles act as a spacers which reduce the surface roughness. Metal nanoparticles coating act as a solid lubricant that allows reduced friction as well as convenient sliding of wire over bracket. White spot lesions during fixed orthodontic treatment may be prevented by using nanosilver-coated orthodontic brackets as an antibacterial agent [30].

Nano-Materials as Nanofillers in Orthodontics

The glass ionomer cement and composite matrix both contain nanoscale filler particles. Nanoparticles and nanoclusters are the two different types of nanofillers. Fillers are added to reduce polymerization shrinkage and improve mechanical strength. Nanocomposites and nano ionomers have undergone extensive testing to determine their bond strength, and studies have found that they are suitable for use in orthodontic bonding. Silica nanosized filler particles are also included in orthodontic adhesives [31].

Enamel Remineralizing Agents

Nanoparticles have been employed to remineralize decalcified enamel in addition to being antibacterial agents. Nano particles have been used as disinfecting agents as well as agents for remineralization of decalcified enamel. Nano-hydroxyapatite is a recent advancement which has been introduced for the remineralization of enamel and is in the form of a paste. Medeiros et al. [32] proved that calcium nanophosphate produces a protective barrier on the enamel surface and offers care against enamel disintegration.

Application Of Nanoparticles In Endodontics

All procedures in clinical practice, from endodontic files to filling materials, is being improved through research and development in the field of endodontics. To reduce the likelihood of instrument failure during root canal therapy, it is suggested that the surface of the rotary nickel-titanium files now in use be modified with smaller nanoparticles. These materials are more resistant to wear and fatigue. Due to their size and potential for dispersion in intricate root canal anatomies, certain nanoparticles having antibacterial capabilities may be able to improve the effectiveness of irrigants and intracanal medications. Various nanoparticles used in this field are chitosan, graphene, poly (lactic) co-glycolic acid, silica, silver, zirconia, and titanium oxide nanoparticles. AdiRam Adini et al [33]. examined the effects of cobalt coatings with impregnated WS2 nanoparticles on file fatigue and failure , it was discovered that the coated files had significantly improved fatigue resistance, probably as a result of less friction between the coated files and surrounding tissues.

Root canal sealers

To effectively seal the root canal system in three dimensions, endodontic sealers and obturating materials are utilized together. Guttapercha cannot be retained in the root dentin despite being warmed in the canal to promote its flowability. Because of this flaw in GP obturating material, to produce a fluid-tight closure, the spaces between the obturating substance and root dentine must be filled with a sealant. A research was performed by Kishen et al. [34] where the obturating sealers containing nanoparticles of chitosan and zinc oxide was included. The findings indicated that these NPs prevented microbial infiltration into the pulp cavity, concluding that their incorporation in the sealers produced a beneficial result.

Intracanal medicaments

Omid Dianat et al [35]. evaluated the antibacterial effectiveness of calcium hydroxide in nanoform against E. faecalis. The antimicrobial activity of nanosized Calcium hydroxide particles was found to be higher when compared to that of conventional Calcium Hydroxide.

Summary on applications of nanoparticles

Discipline	Applications
Periodontics	When treating periodontal disorders like deep periodontal pockets
Prosthodontics	Nano apetites are used in the management of plaque to adhere on the surface of the teeth Remineralisation Coatings made of nanocomposite materials are used to stop pathogenic microorganisms from adhering.
Oral and Maxillofacial surgery	Anti-neoplastic drug delivery, Employed as optical tools for the early identification of oral cancer Utilized as frameworks to support the development of new bone tissue.
Conservative Dentistry and Endodontics	Drug and gene delivery, Tissue engineering, disinfecting agents in root canal sealers, irrigation of pulp cavity
Restorative Dentistry	Remineralizing Composite resin Nano filled bonding agents and Nano filled glass ionomer cements Treatment of dentinal hypersensitivity
Orthodontics and Dentofacial Orthopaedics	Spherical metal nanoparticles are applied as a coating on both brackets and archwires with the intention of diminishing surface irregularities and minimizing friction. To make it easier for the orthodontic wire to slide over the bracket, metal NPs coating acts as a thick lubricant film.
Oral Medicine and Radiology	Therapeutic application
Preventive Dentistry	Used as the final rinse after a root canal, Low surface tension makes it possible for NP to access the system's tiniest crevices and tooth ducts. Used directly before dental fillings,
Dental Implant	Dental implants' surface modifications involve the deposition of CaP NP using the discrete crystallization deposition (DCD) sol-gel technique on a double acid-etched surface.

Conclusion

To prevent, decrease the length of treatment, or eliminate oral health issues such as tooth decay, gum diseases, peri-implantitis, oral thrush, and decreased salivation, one promising technique is to use NPs. To enhance the qualities of dental prosthesis and restorations, NPs can also be added to some dental materials, such as PMMA and glass ionomer cement. Because of their greater physical, mechanical, chemical, and biological capabilities, nanomaterials (NMs) have recently become more significant in technological breakthroughs. When compared to their conventional counterparts, these qualities have led to improved performances.

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