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NANOTECHNOLOGY: A BRIEF REVIEW OF NANOPARTICLES USED IN DENTISTRY

Dental Science

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ABSTRACT

The thought of "nanomaterials" fashioned within the early nineteen eighties, has captured a substantial quantity of attention owing to its distinctive structures and properties. At present, the revolutionary development of technology has become the foremost extremely energized discipline in science and technology. The thought of nanotechnology was initially elaborated in 1959 by Richard Feynman. This article is a brief review of use of nanoparticles in dentistry.

KEYWORDS

Nanomaterials, Nanorobotics, Nanocomposites

Introduction

The word 'nano' is derived from the Greek word "dwarf". Nanoscale materials area unit is outlined as those whose characteristic length scale lies at interval of the nanometric range1. National Technology Initiative Outlined Technology states that the "Research and technology development at the atomic, molecular and molecule levels within the length scale of roughly 1-100nm vary. It is well-tried to supply an elementary understanding of phenomena and materials at the nanoscale and to form and use structures, devices, and systems that have novel properties and functions owing to their little and intermediate size."According to GPT-92, it is outlined as a unit of length used to measure the wavelength of light. It is equivalent to $1^{X}10^{9}$ m or 1 angstrom. Nanotechnology was introduced into dentistry initially as nanocomposites within the year 2002 by 'Filtek Supreme'.

Approaches

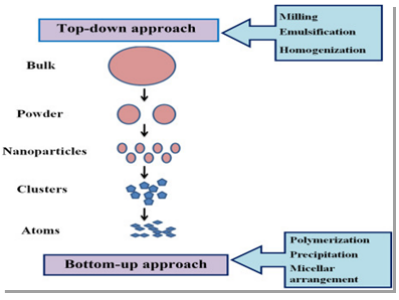

Figure-1 Two different approaches used in formation of nano-particles

Two different approaches used by the nanotechnology create structures: top-down and bottom-up.

'Top-down approach' involves the creation of little structures by exploiting larger ones in guiding their assembly.

'Bottom-up approach' involves manipulating little parts into compound structures[3].

Bottom-up approaches	Top-down approaches
Local anesthesia	Nano-composites
Hypersensitivity cure	Nano-impression materials
Tooth repositioning	Nano-solutions
Nano-robotic dentifrice (dentifrobots)	Nano-encapsulation
Dental durability and cosmetics	Nano-needles
Orthodontic treatment	Bone substitutes
Nano-diagnostics (photosensitizers and carriers)	Implants
Nano-therapeutics/drug delivery	Surface disinfectant
Bionic mandible	Decay resistant tooth
Skin grafts	Salivary diagnostics

Figure-2: Different approaches used in dentistry in fabrication of various materials[9].

Classification

Nanodentistry is often classified into four basic teams that being Nanorobotics, Nanodiagnosis, Nanomaterials and Regenerative technology.

Nanorobotics works by the 'bottom-up approach' in which it utilizes its size of 1-100 nm in order to work at inaccessible areas like the dental pulp and therefore the periodontium during a painless and convenient method[3]. The nanorobots will therefore be used to provide local anesthesia, cure dentin hypersensitivity, tooth location, dentrifices, and might enhance the sturdiness of the superficial enamel layer with materials like sapphire and diamond[9]. In Nanodiagnosing & treatment of cancer and alternative diseases caused by chromosomal mutation is heading towards a dramatic improvement by the utilization of quantum dots, nanoscale cantilevers, nanotubes, and nanopores[4].

Nanomaterials made by exploitation technology have revolutionized dental medicine by providing us with 'nanofillers'. These filler particles utilize the 'top-down approach'. The technique of regenerative technology is sure to improve the sector of dentistry[5].

Advancement of technology in dental materials is specially categorized into 2 ways:

1.The preparation of recent inorganic nanoparticles
2.To change the surface with inorganic nanofillers and thereby to develop ultralow shrinkage rate of repair organic compound.

Various nanoparticles are being used in the manufacturing of acrylic resin, tissue conditioner, dental adhesives, dental composites, dental cement, dental porcelain, implants, and maxillofacial prosthesis,nanohydroxyapatite.

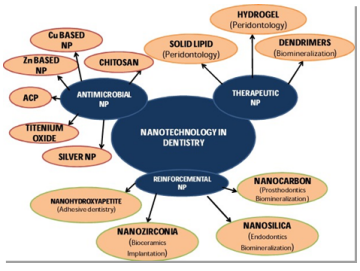

Figure:3 Various Nanoparticles used in dentistry

Most commonly incorporated nanoparticles are being described below:

1. Gold Nanoparticles

Gold has many advantages such as:

- biocompatibility,
- easy synthesis,
- ability to undergo surface chemical modification and the fact that characterization can be done simply under the phenomenon of surface plasmon resonance.

The chemical and physical properties of gold nanoparticles depend on the type, shape, size, and also the composition of its surface. By reducing the size of these particles to the nanoscale, a fundamental property of gold, its yellow color in the macrostate, is changed in solution and gold nanoparticles can acquire colors ranging from red to

purple. Gold nanoparticles have been used as vehicles for anticancer drugs, antibodies and antibiotics[6]. Depending on the gold, precise structure targeting they lead to the death of cancer cells, diseased host cells, and pathogenic microbial cells hence decreasing their count[7].

2. Silver Nanoparticles

Silver is considered an excellent metal for broad-spectrum activity against bacteria, fungi, viruses, and even some protozoa.

Mechanism of action

Its antimicrobial action, however, increases when it is in the form of nanoparticles. Silver nanoparticles adhere to the outer membrane of bacterial cell structure, thus inactivate enzymes and prevent the replication of bacterial DNA and its action. They promote changes in bacterial cell structures and modifying its permeability. Silver is a broad-spectrum antimicrobial agent, with the capacity to kill or inhibit the growth of both Gram-positive and Gram-negative bacteria.

Uses

- Silver has been used for a long time as an antibacterial filling agent in dental materials.
- When used to modify dental materials, nanoparticles lead to a significant increase in the mechanical properties and color stability of these materials.
- Silver nanoparticles can also decrease the metabolic activity of various microbial cells. The problems that have been reported regarding the dental use of nanoparticles are due to the release of free silver ions, which affects the hardness of the material.
- To provide antimicrobial activity, studies show that the silver particles can be incorporated into dental resins and polymers (Polymethyl methacrylate) and it was further shown this did not promote the development of resistant bacterial strains.
- Silver nanoparticles are added to adhesives and primers, denture cleansers, and denture adhesives to inhibit microorganism growth on the tooth surface, and also away from the surface.
- The addition of 0.3% or 0.6% of silver to dental composites can reduce up to 70% of the number of adhering streptococci. Ag particles are also added to composite resins as an antibacterial agent.
- The incorporation of silver nanoparticles (0.1% by weight) to an adhesive system did not affect the strength of the bond to the dental substrate, at the same time succeeded in decreasing the metabolic activity of the biofilm. These nanoparticles could reduce CFU (colony-forming units) for total microorganisms, total streptococci, and mutans streptococci.

3. Titanium Oxide Nanoparticles

Uses

- Titanium dioxide nanoparticles were incorporated into glass ionomer cement and they showed increased resistance to the antimicrobial properties.
- The antibacterial ability of these nanoparticles has been reported by analysis of different bacterial species such as Escherichia coli, S. mutans, Candida albicans, Staphylococcus aureus, and Pseudomonas aeruginosa.
- Composite resins, orthodontic resins, dental adhesives, and glass ionomer cement, all containing nanoparticles of titanium oxide, have shown antibacterial properties, especially against S. mutans.
- The addition of titanium oxide provides antibacterial effects without compromising mechanical properties.
- Adding a small proportion of nanoparticles to the dental resin leads to an increase in the degree of conversion and the mechanical properties of the resin.
- Nanofillers can decrease the demineralization of enamel without affecting the physical properties of the composite.
- The addition of materials used in the fabrication of maxillofacial prosthesis such as Obturator also contribute to an antibacterial effect.

Zinc Oxide Nanoparticles

Zinc oxide nanoparticles are dental materials exhibiting an antibacterial effect by direct contact in both planktonic suspensions and bacterial biofilms.

Mechanisms of Action

Their antibacterial action can be classified broadly into two classes:
(1) Oxidative stress generated by particles in solutions
(2) Attack of nanoparticles physically on the bacteria.

Other mechanisms of actions that are reported such as -
(a) Deactivation of enzymes of the bacterial respiratory chain
(b) Changes in the structure of bacteria caused by the nanoparticles
(c) Interaction with bacterial DNA

The antimicrobial property of the zinc oxide nanoparticles was found to result in the assembly of reactive oxygen species destroying the bacterial cell elements and harm the electron transport chain and also bacterial plasma membrane. Zinc oxide nanoparticles also have antibacterial effects when they are incorporated in composite resins[7].

Nanotechnology in Implants

Several nanotechnology ways are applied to implant surfaces: ionic beam deposition, nanoparticle compaction, controlled chemical oxidation, peroxide application, anodization, lithography, sinterization, nanoparticle deposition, and layer-by-layer assembly. In these ways, many nanomodified involving nanostructures, nanoparticles, nano coatings, nano crystals, nano dots, nano grooves, nano pits, nanowires, nano needles, nanosheets, nanorods, nanotubes, and nanofibers are obtained. In general, wetting can be reduced on microstructured surfaces created by blasting, etching, or anodization. The presence of microscale structures and superimposed nanoscale options, as found on freshly developed surface modifications, may additionally modulate wetting and also the corresponding biological response.[6] Incorporation of Zirconium nanoparticles shows a rising tendency in osseointegration so improve early loading of the implant.

Harmful Effects of Nanoparticles

The extensive application of nanomaterials in a wide range of products use for human, possesses a potential risk for human health and the environment. According to The American Health Association, short-term exposure to elevated particulate matter concentrations in outdoor air significantly contributes to increased acute cardiovascular mortality, particularly in the risk subset of the population. Nanoparticles have a large surface area volume ratio. The greater the specific surface area, the more chance it could lead to an increased rate of absorption through the skin, lungs, or digestive tract. This might cause unwanted effects within the lungs and different organs throughout the body, as non-degradable nanoparticles might accumulate. Most nanosized spherical solid materials can simply enter the lungs and reach the alveoli. This foremost toxic effect is to induce inflammation in the respiratory tract, causing tissue damage and subsequent systemic effects.

Conclusion

Although nowadays the impact of engineering science on nanotechnology in dentistry is somewhat restricted due to the dependency to use materials that are currently available in the market. In the future development in field of nanodentistry, procedures such as coronal renaturalization and tissue regeneration, there are capabilities to mimic the structures present in the human tooth. The incorporation of nanotechnology in the field of dentistry is still at a very nascent stage. Thus, nanotechnology is foreseen to change the present scenario of health care by incorporating materials and methods which are highly durable and efficient.

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