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Nanotechnology: The Next Generation Dentistry

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Abstract

Nanotechnology can be defined as the science and engineering involved in the design, synthesis, characterization, and application of materials and devices whose smallest functional organization in at least one dimension is on the nanometer scale (one-billionth of a meter). The growing interest in the dental applications of nanotechnology is leading to the emergence of a new field called nanodentistry which will make possible the maintenance of oral health using nanomaterials, biotechnology and dental nanarobotics. Present literature reviews various prospective aspects of the nanotechnology in dentistry.

Keywords: Nanotechnology, Nanodentistry, Nano, Dentistry

Introduction

Nanotechnology deals with the physical, chemical, and biological properties of structures and their components at nanoscale dimensions. Nanotechnology is based on the concept of creating functional structures by controlling atoms and molecules on a one-by-one basis. The use of this technology will allow many developments in the health sciences as well as in

materials science, biotechnology, electronic and computer technology, aviation, and space exploration.[1]

Nanotechnology is a terminology procured from a Greek locution called “Nanos” which is insinuated as a dwarf. Mr. Richard Feynman, who has earned a Nobel Award for Physics, in the late 1950’s addressed an oration describing the possibility that perhaps the particles could be exploited at the most basic molecular level as per our desire. Terminology “Nano-Technology” was primarily formulated by a scientist in Japan called Dr.Nori Taniguchi in the mid 1970’s. He went on to describe nanotechnology as the process of detachment, combination and deformation of any distinct material with the help of an atom or molecule.[2] Reviving the ideology of Mr. Feynman in the late 1980’s, a book was written and published by the Mr. Eric Drexler which played a vital role in popularizing the possibilities associated with the ideology of nanotechnology.[3, 4]

Nanotechnology is widely used in medicine in areas such as drug development, and imaging. Furthermore, the targeted delivery of drugs to diseased cells, such as cancer cells, this is an effective, and safer way of treating a disease. The potential applications of nanotechnology are very vast; however, one of the greatest values of nanotechnology will be in the development of new and effective medical treatments. The advances of nanotechnology in dentistry have been relatively slow in comparison to the application of nanotechnology in areas like medicine.[5,6]

The growing interest in the dental applications of nanotechnology is leading to the emergence of a new field called nanodentistry which will make possible the maintenance of oral health using nanomaterials, biotechnology and dental nanarobotics.[7] Nanodentistry is defined as the science and technology of diagnosing, treating and preventing oral and dental diseases, relieving pain, preserving and improving dental health using nanostructured material. There are varieties of new dental products available, ranging from implants to oral hygiene products that rely on nanoscale properties. Although the field of Nanodentistry is still developing and many issues are still to be resolved, the new era of nanotechnology in dentistry could change a common man’s view of dentist. It encourages the concept of minimally invasive dentistry, creating a more dentist friendly atmosphere. However, patient awareness and education is important to make them understand the developments in the field and the options available in the treatment.[8,9] Present literature reviews various prospective aspects of the nanotechnology in dentistry.

Application of Nanotechnology in Dentistry

Nanotechnology in Oral Hygiene

Nano-Toothbrush: A concept is in the developmental stages which suggest that if there is use of colloidal gold or colloidal silver between the bristles of the toothbrush, it could lead to tremendous decline or prevention of gingival inflammation as well periodontitis. Silver has significant affinity towards negative molecules like phosphates which helps them disrupt cell wall functioning leading to the removal of microbial plaque or bio-film.[10]

Nano-Toothpastes: It is highly exigent to thrive for an exorbitant quality of the toothpaste to improve the effectiveness of the oral health care. Nanotechnology in the form of nano-toothpastes seems to be an effective option. The agglomeration of the bacterial molecules in the porosities of the hydroxyapatite crystals is due to the porosity of the enamel prisms.[11] The nano-toothpaste would be effective to close the porosities and help in improving the shade of the tooth colour. Currently,

nanoparticles in the form of whitening agent are used as titanium oxide in the toothpastes.[4,12]

Nanotechnology in Restorative Dentistry

Nanocomposite: Nano Products Corporation has successfully manufactured non-agglomerated discrete nanoparticles that are homogeneously distributed in resins or coatings to produce Nano Composites. The nanofiller used includes an aluminosilicate powder having a mean particle size of about 80 nm and a refractive index of 1.508. Superior hardness, superior flexural strength, superior modulus of elasticity, superior translucency and esthetic appeal, excellent colour density, high polish and polish retention, about 50% reduction in filling shrinkage, and excellent handling properties, all these characteristics make the nanocomposites superior to the conventional composites and blend with natural tooth structure much better.[13]

Nano-filled resin-modified GICs: Resin-modified GICs also have a polymer resin component, which usually sets by a self-activated (chemically cured) or light-activated polymerization reaction. To develop the mechanical properties of a resin composite with the anticaries potential of GICs, these were developed. However, compared to composites, resin-modified GICs have reduced mechanical properties, including brittleness and inferior strength along with aesthetics. To overcome these drawbacks, there have been attempts to incorporate nano-sized fillers and bioceramic particles to RMGICs.[14]

Nano Bonding Agent: It is a nano particulate reinforced adhesive system. These new bonding agents are prepared from nano solutions which contain homogenous nanoparticles dispersed in the solution. Silica nanofillers are stable and do not cluster in the solution so provide the superior bond strength values.[7]

Nanotechnology in Prosthodontics

Impression Materials: Nanofillers are integrated into vinylpolysiloxanes, producing a unique siloxane impression material. The material has better flow, improved hydrophilic properties, hence fewer voids at margin and better model pouring and enhanced detail precision when compared to the other conventional impression materials used.[15]

Dental Implants: Dental implant-tissue interface is the key factor in success of implant which depends primarily on peri-implant healing process.[16]

Nanoscale changes in topography and chemistry of the implant surface play a most crucial role in increasing the implant osseointegration. Nanoscale topographic modification consists of procedures such as ionic implantation, anodization, lithography, and radiofrequency plasma treatments, which are used to induce controlled nanosurface features on dental implants such as tubes, dots, and nodules. While nanoscale chemical modification of implant surface includes biofunctionalization of implant surface, i.e., immobilization of specific, active biomolecules known for their central role in osteogenesis on the surface of implants (e.g., Alkaline phosphatase, calcium phosphate (CaP), extracellular matrix proteins, adhesion molecule peptide (RGD) and coating and bone morphogenetic protein.[17-19]

Nanotechnology in Oral Surgery

Local Anesthesia: Lidocaine-loaded poly (carpo-lactone)-poly (eethylene glycol)-poly (carpo-lactone) (PCL-PEG-PCL) Nano particles in hydrogel was prepared of size 200 nm. This has been shown to be superior in terms of onset of anesthesia and efficacy. Once drug is injected, it is directed through Nano-computer to the specific site where action is required. It

is kept at that site for wanted time and removed from body when not required.[20]

Nanotechnology or nanorobots are used to induce anesthesia, the gingiva of the patient is instilled with a colloidal suspension containing millions of active, analgesic, micron-sized dental robots that respond to input supplied by the dentist. Nanorobots in contact with the surface of the crown or mucosa can reach the pulp via the gingival sulcus, lamina propria, or dentinal tubules. Once in the pulp, they shut down all sensations by establishing control over nerve-impulse traffic in any tooth that requires treatment. After completion of treatment, they restore this sensation, thereby providing the patient with anxiety-free and needleless comfort. The anesthesia is fast acting and reversible, with no side effects or complications associated with its use.[21]

Nanotechnology in Orthodontics

Orthodontic Elastomeric Ligatures: Orthodontic elastomeric ligatures (OEM) are synthetic elastic modules of polyurethane material, with advantages such as the quickness of application and patient's comfort; they are often a wise solution in clinical practice because they are inexpensive.[22]

It has been proposed that elastomeric ligatures can act as a support for the transport of nanoparticles, which can be molecules with anti-cariogenic or anti-inflammatory characteristics and/or antibiotic drugs (such as benzocaine) incorporated into the elastomeric matrix. Additionally, medicated wax applied to orthodontic brackets that reduces the pain associated with mucosal irritation caused by the brackets by slowly and continuously releasing benzocaine was shown to be significantly more effective.[23]

Nano-particles Coated Orthodontic Wire: Friction is one of the major issues affecting the alignment or retraction of teeth during orthodontic treatment. This issue in the past was overcome by applying higher forces resulting in undesirable anchorage loss. Recent advances in knowledge of orthodontics and nanotechnology had paved an alternate path to counteract these undesirable issues, and one such advancement is Nano-coated arch wires and brackets to reduce undesirable friction. Promising results have been obtained by in-vitro experiments being carried out by coating Nickel-Titanium (NiTi) and stainless steel wires with nanoparticles of tungsten disulfide (WS2) and Nickel-phosphorous Nano particles.[24]

Nanotechnology in Periodontology

Tissue Regeneration: Currently, tissue engineering concepts for periodontal regeneration are focused on the utilisation of synthetic scaffolds for cell delivery purposes. Although the usage of such synthetics scaffold systems offers promise, it is very likely that the next generation of materials will rely mainly on nanotechnology and its potential to produce nonbiologic self-assembling systems required for tissue engineering purposes. The clinical utility of these nanoconstructed self-assembling materials is their capacity to be developed into nanodomains or nanophases, leading to unique nanobuilding blocks with inbuilt nanocontrol and nanodelivery capabilities.[25]

Miscellaneous Application of Nanotechnology

Dentinal Hypersensitivity: Dentine hypersensitivity is an acute pain condition that typically occurs when the surface of the root becomes exposed. Among the many approaches to treating dentine hypersensitivity, one primary approach is occluding dentine tubules, open tubules are sealed and isolated from external stimuli,

preventing fluid movement from triggering a pain response.[26]

Dental nanorobots can selectively and precisely occlude the specific tubules within a minute, offering patients a quick and permanent cure. Gold nanoparticles, the world's smallest gold fillings, so to speak are used by researchers to fill the affected dentinal tubules.[13,27]

Nanotechnology in Local Drug Delivery: Nanotechnology has proved itself as a potential frontier in drug delivery to specific cells or localized area of interest using nanoparticles. Localized and controlled drug delivery may significantly reduce drug dosage-related side effects by selectively depositing the controlled amount of drug in close proximity of the area of interest. This in the future may play an important role in reducing the cost and human suffering. One of the most important implications of such nanotechnology based drugs is cancer treatment which shows tremendous side effects and financial burden.[28]

This nanotechnology based local drug delivery system behaves as a homogeneous polymer matrix type delivery system, in which drug molecules are encapsulated with biodegradable Nanospheres which can be controlled externally for timely release of drugs by controlled disintegration in a particular location and time. One such good example is arestin which consist of tetracycline incorporated into biodegradable microspheres for local drug delivery targeted to periodontal pockets.[29]

Scope of Nanotechnology: As of now, the use of nanotechnology is limited to the available sources of materials. In the future there will be more developments which will lead to better outcomes. The future utilisation of nanotechnology will yield better results in improvement of oral health status.

Although we have numerous ideas and dreams for nanodentistry, actually most of them in reality are not possible till the date due to various challenges such as engineering challenges, biological challenges and social challenges. It is really challenging to position and assemble the nano molecular scale part precisely. Biological compatible molecules which are environmentally friendly, economically and ethically acceptable still are a distant site in the field of nanodentistry.[4,16, 25]

Conclusion

Nanodentistry is a new revolutionary approach. It incorporates the advanced methods of nanotechnology into the conventional materials to enhance the properties of the dental materials. The emerging science of nanotechnology, especially within the dental and medical fields, sparked a research interest in their potential applications and benefits in comparison to conventional materials used. Therefore, a better understanding of the science behind nanotechnology is essential to appreciate how these materials can be utilized in our daily practice. Nanodentistry has strong potential to transfigure dentists to diagnose and treat disease in future.

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