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Nanotechnology – The New Era of Dentistry

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***Abstract**: Human characteristics of curiosity, wonder, and ingenuity are as old as mankind. People around the world have been harnessing their curiosity into the process of scientific methodology. Recently nanotechnology has emerged as a new science exploiting specific phenomena and direct manipulation of materials on nanoscale. Application of nanotechnology in dentistry holds promise for the maintenance of comprehensive dental care by employing nanomaterials including tissue engineering and ultimately nanorobots. This paper highlights the role of nanotechnology in dentistry and its future implications.*

I. Introduction

Science is presently undergoing a great evolution, taking humanity to a new era: the era of nanotechnology. The concept of nanotechnology introduced in 1959 by late Nobel Physicist Richard P Feynman in dinner talk said, "There is plenty of room at the bottom," proposed employing machine tools to make smaller machine tools, these are to be used in turn to make still smaller machine tools, and so on all the way down to the atomic level, noting that this is "a development which I think cannot be avoided[1]". He suggested that it could be used to develop a wide range of automically precise microscopic instrumentation and manufacturing tools could be applied to produce vast quantities of ultra small computers and various nanoscale microscale robots. The word "nano," which is derived from the Greek word (nannos) meaning "dwarf," is a prefix that literally refers to 1 billionth of a physical size.[2] According to the definition of the National Nanotechnology Initiative, nanotechnology is the direct manipulation of materials at the nanoscale.[3] Nanotechnology gives us the ability to arrange atoms as we desire and subsequently to achieve effective, complete control of the structure of matter. Nanotechnology is based on the idea of creating functional structures by controlling atoms and molecules on a one-by-one basis.[2] In general nanotechnology is translated as "the science of the small." However, in addition to creating small structures, nanotechnology involves inventing materials, devices, and systems with physical, chemical, and biologic properties that differ from those of large-scale structures.[3,4] With developments in materials science and biotechnology, nanotechnology is especially anticipated to provide advances in dentistry and innovations in oral health-related diagnostic and therapeutic methods.

Nanomedicine

Recent advances in the field of medicine and implementation of nanotechnology have resulted in the formation of a new field called nanomedicine.[5] This concept was first described in 1993 by Robert A. Freitas Jr. and was defined as observing, controlling, and treating the biological systems of the human body at the molecular level using nano-structures and nano-devices.[6] Nanomedicine consists of various applications ranging from drug release with nanospheres to tissue scaffolds based on nanotechnologic design that realize tissue formation, and even nanorobots for diagnostic and therapeutic purposes.[7] On the other hand, nanorobots can recognize unhealthy cells and can find and destroy them wherever they are located. Drug delivery to the exact target is of particular importance in cancer in order to destroy all of the cancer cells and at the same time avoid harming healthy cells.[8]

Nanotechnology in Dentistry

Similar to nanomedicine, the development of nanodentistry allows nearly perfect oral health by the use of nanomaterials and biotechnologies. The application of nanotechnology in dentistry includes tissue engineering, nanorobots, nanomaterials, pain reduction and prevention of dental caries.

II. Tissue engineering:

The applications of tissue engineering and stem cell research in dentistry include the treatment of orofacial fractures, bone augmentation, cartilage regeneration of the temporomandibular joint, pulp repair, periodontal ligament regeneration, and implant osseointegration. The biodegradable polymers or ceramic materials that are often preferred in bone tissue engineering may not have sufficient mechanical endurance despite their osteoconductive and biocompatible properties despite their osteoconductive and biocompatible properties. Studies performed in recent years indicate that nanoparticles can be used to enhance the mechanical properties of these materials. The main reason for preferring nanoparticles is that the range of dimension of these structures is the same as that of cellular and molecular components.[9]

III. Dental nanorobots:

Dental nanorobots are able to move through teeth and surrounding tissues by using specific movement mechanisms.Nanorobots (dentifrobots) left by mouthwash or toothpaste on the occlusal surfaces of teeth can clean organic residues by moving throughout the supragingival and subgingival surfaces, continuously preventing the accumulation of calculus. These nanorobots, which can move as fast as 1 to 10 micron/second, are safely deactivated when they are swallowed.[2]

IV. Nanomaterials:

One of the most significant contributions to dentistry has been the development of resin based composite technology. There was a need to develop a composite dental filling material that could be used in all areas of mouth with high initial polish and superior polish retention as well as excellent mechanical properties suitable for high stress-bearing restoration. The latest advance in composite resins is the implementation of nanoparticle technology into restorative materials.[10] Nanotechnology has enabled the production of nano-dimensional filler particles, which are added either singly or as nanoclusters into composite resins.[11] When the filler for traditional composites is produced, large particles are minified by pinning; however, these methods cannot reduce the size of a filler that is smaller than 100 nm.[11] Nanoparticles allow the production of composites with a smooth surface after the polishing process and confer superior esthetic features to the material. The area of use of resins containing nanoparticles is wider than that of composites containing hybrid and microfill fillers.[12] Nanofiller technology has enabled the production of nanofill composites by bringing together the esthetic features of microfill composites and the mechanical features of hybrid composites.[12,13]

A new nano-filled RMGI restorative material has been introduced for restoration of primary teeth and small cavities in permanent teeth. It is based on a prior RMGI with a simplified dispensing and mixing system (paste/paste) that requires the use of a priming step, but no separate conditioning step. Its primary curing mechanism is by light activation, and no redox or self curing occurs during setting. Apart from the user-friendliness, the major innovation of this material involves the incorporation of
nano-technology.

Pain reduction

The most common procedures in dentistry is the injection of local anesthetic, which can involve long waits, varying degrees of efficacy and patient discomfort. Well-known alternatives, such as transcutaneous electronic nerve stimulation, cell demodulated electronic targeted anesthesia and other transmucosal intraosseous or topical techniques are of limited clinical effectiveness.[2,5] To induce oral anesthesia in the era of nanodentistry, dental professionals will instill a colloidal suspension containing millions of active analgesic micrometer-sized dental nanorobot particles on the patient's gingival. After contacting the surface of the crown or mucosa, the nanorobots reach the dentin by migrating into the gingival sulcus and passing painlessly through the lamina propria or the 1 to 3µm thick layer of loose tissue at the cemento-dentinal junction.[14,15] On reaching the dentin, the nanorobots enter dentinal tubule holes that are 1 to 4 µm in diameter and proceed toward the pulp, guided by a combination of chemical gradients, temperature differentials and even positional navigation, all under the control of the onboard nanocomputer, as directed by the dentist.[16,17] Tubule diameter increases nearer the pulp, which may facilitate nanorobot movement, although circumpulpal tubule openings vary in number and size.[18]

V. Nanotechnology for maintainance of oral hygiene and prevention of caries:

Nanorobotic dentifrice delivered by a mouthwash or toothpaste could patrol all supragingival and subgingival surfaces, at least once a day, metabolizing trapped organic matter into harmless and odorless vapors and performing continuous calculus debridement. The use of a toothpaste containing nanosized calcium carbonate enabled remineralization of early enamel lesions.[19] Nano-whitening toothpaste is toothpaste that contains synthesized hydroxyapatite, a key component of tooth enamel, as nanosized crystals. This toothpaste contains ingredients such as patented nano technology aka nanoxyd, calcium peroxide, contains enzymes such

as (papain and bromelain), fluoride combination, co enzyme Q10 and vitamin E.[5] A study that investigated the bacteriostatic effects of silver, zinc oxide, and gold nanoparticles on Streptococcus mutans, which causes dental caries, reported that compared to the other nanoparticles, silver nanoparticles had an antimicrobial effect in lower concentrations and with lower toxicity.[20]

VI. Nanotechnology and biofilm:

Nanotechnology is a promising field of science which offers better insight into the spatial relationship between different species and how their diversity increases over time. Nanotechnology can guide our understanding of the role of interspecies interaction in the development of bio-film. Nanotechnology has been used to study the dynamics of demineralization/remineralization process in dental caries by using tools such as atomic force microscopy (AFM) which detect bacteria induced demineralization at an ultrasensitive level. Another nanotechnology application used so far is O^{16} /O^{18} reverse proteolytic labelling to determine the effect of biofilm culture on the cell envelope proteome of oral pathogen, Porphyromonas gingivalis sp. which is linked to chronic periodontitis. New silver nanotechnology chemistry has proven to be effective against biofilms. Silver works in a number of ways to disrupt critical functions in a micro-organism.

VII. The Future:

Nanotechnology is part of a predicted future in which dentistry and periodontal practice may become more high-tech and more effective looking to manage individual dental health on a microscopic level by enabling us to battle decay where it begins with bacteria. Construction of a comprehensive research facility is crucial to meet the rigorous requirements for the development of nanotechnologies. Although the effect of nanotechnology on dentistry is limited to the use of currently available materials, rapidly progressing investigations will ensure that developments that seem unbelievable today are possible in the future. The utilization of the advantages of nanotechnology facilitate improvements in oral health. Advanced restorative materials, new diagnostic and therapeutic techniques, and pharmacologic approaches will improve dental care. In future, medical field may furthur advance into even smaller molecular science of *picotechnology* which will change the dimensions of oral health and will bring about a revolution.

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