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Nanotechnology in dentistry: Present and future perspectives

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ABSTRACT

Breakthroughs in nanotechnology has broadened our views of health issues that are poorly understood and provided innovative means of identification and treatment modalities. Biofilms are considered the root cause of most common dental and periodontal disease affecting the human race. Since ancient times, methods to prevent and tackle them have been devised, discussed, and implemented. However, exploration of improved tools and techniques are in constant need and could be met with ever-increasing scope of Nanotechnology that opens up new opportunities for progress in medical fields. However, the potential application of nanoparticles in existing therapeutic modalities in the field of dentistry has met with moderate success. The key implementations in the field of dentistry include restorative materials, local drug delivery agents, bone graft materials, and implant surface modifications. The placement of dental implants are biologically and physiologically more stable than previously used implants and speed up the recovery period. A lot of improvement in dental care is possible through new diagnostic and therapeutic techniques, pharmacologic approaches and the development of new advanced restorative materials. Tissue engineering and stem cell research in dentistry have potential applications in treating bone augmentation, orofacial fractures, periodontal ligament regeneration, cartilage regeneration of the temporomandibular joint, pulp repair, and implant osseointegration. This paper provides detailed insights about current developments in the field of dentistry, the novel materials and techniques that have been developed for disease diagnosis, prevention, rehabilitation, and pulp/ periodontal regeneration.

KEY WORDS: nanotechnology, dentistry, diagnosis, drug delivery systems, bone grafts, dental implants.

1. INTRODUCTION

Major initiatives in the year 1980s with the invention of scanning tunneling microscope and the discovery of carbon nanotubes and fullerenes have led the twenty first century as an era of nanotechnology. Manipulate matter at the atomic scale has helped to design and use of structures, devices, and systems composed of particles approximately in the length scale of 1-100 nanometer (nm) range. Novel properties of these nano structures are owing to their small size. Creation and development of new 'intelligent' materials or devices are possible through the bottoms-up approach whereas various other processes are utilized to induce nanostructures to self-assemble at a desired scale and then organize into higher macroscale structures like nanorods, nanotubes, quantum dots, fullerenes, liposomes, and nanocapsules. The existing structures of existing materials are miniaturized by rearranging molecules to achieve the desired properties is possible through the top-down approach. The diagnostic discipline emphasizes the manufacture of new sensing devices, and the nanotization of existing devices, to make them more compact and less invasive for mass identification of diseases and their associated markers. The vital tissue receptors are identified by introducing these nanomeric diagnostic devices into the vascular system of human body.

Nanomedicine is the science that prevents, diagnoses, treats, preserves and improves human health, using nanosized particles. They can be generally divided into three effective molecular technologies:

i) Nanoscale materials and devices used in advanced diagnostics and biosensors, targeted drug delivery, and smart drugs

ii) Molecular medicine through genomics, proteomics, artificial biobotics (microbial robots)

iii) Molecular machines and medical nanorobots aid in immediate microbial diagnosis and treatment, and enhancement of physiological functions.

The most common maladies affecting the human race are dental caries and periodontal disease. Though various methods to prevent and combat such diseases have been devised, discussed, and implemented since ancient times, still there is a persistent need for improved tools and techniques. Nanotechnology, with its ever-increasing scope, provides dental research new opportunities for progress. The field of dentistry is supported by diagnostic aids and treatment devices through the novel innovations from the field of biotechnology. Current dental research involves progressive ingress into the preventive, diagnostic, reconstructive, regenerative, restorative, and rehabilitative domains. Near-perfect oral health will be possible through the aid of nanorobotics, nanomaterials and biotechnology.

A colloidal suspension carrying millions of anesthetic dental nanorobots would be able to induce local anesthesia before starting the dental treatment. The nanorobots get deposited on the gingival tissue. The dentist guide

these nanorobots by moving toward the pulp via the dentinal tubules using nanocomputer through the chemical differentials, temperature gradients, and positional steering and assist them to reach the dentin. As soon as they reach the pulp, the analgesic robots close down all sensation in the tooth. After the completion of the treatment procedure, the nanorobots may be ordered to re-establish all sensations and to exit from the tooth. This technique is advantageous as it reduces uneasiness and is fast and totally reversible. Rapid and stable treatment for dentin hypersensitivity is possible by using dental Nanorobots, using local organic materials. Toothpastes or mouthwashes containing the dentifrobots would inspect all gingival surfaces regularly and break down harmful materials and remove them.

Mouthwashes containing nanoparticles loaded with triclosan and silver nanoparticles have demonstrated plaque control potential and have shown high substantitvity due to the use of bioadhesive polymers in the system and provide effective treatment and prevention of periodontal diseases. Mouthwashes containing biomimetic carbonate-hydroxyapatite nanocrystals preserve the implant titanium oxide layer by protecting it against surface oxidative processes. These nanocrystals also reduce implant surface roughness by depositing hydroxyapatite into the streaks present on the titanium surface and prevents plaque accumulation and periimplant pathologies. Orthodontic nanorobots lead to quick and pain free corrective movements to all the periodontal tissues, such as the gingiva, periodontal ligament, cementum and alveolar bone and reposition the tooth. Materials like Sapphire or diamond as part of a nanostructured composite are highly stronger than enamel and so can be used as tooth superficial enamel layer. Quantum dots act as photo senstizer and carrier. They attach the antibody to the target cell. When stimulated by UV light, they form reactive oxygen species which will destroy the target cells.

Gene therapy treats genetic diseases. They correct faulty genes that lead to disease development by repairing or replacing them. Nanocomposite denture teeth made of Polymethylmethacrylate (PMMA) are nanofillers that are homogeneously distributed with excellent polishing ability, stain-resistant, have surface hardness with enhanced wear resistance and are superb aesthetics. Suture needles are manufactured from Nano-structured stainless steel crystals. Cell surgery is made viable using Nanotweezers. Dentition renaturalization technique may revolutionarize cosmetic dentistry. Teeth can be remodeled with natural materials to become identical to natural teeth initially by removing old amalgams restorations. The introduction of dental implants has thus revolutionized the rehabilitative dental procedures.

2. CONCLUSION

The human race is thus always passionate about newer and more progressive technologies. Nanotechnology is one such promising field to bring massive changes into the fields of medicine and dentistry. However, mass manufacturing of cost-effective nanoscale parts, nanorobots, their exact positioning, and synchronization of several independent nanorobots, social issues of public reception, ethics, regulation and human safety are the future challenges. Techniques promising major breakthroughs in medical and dental sectors might also have an obstacle, and hence, must undergo stringent testing before human application. Some areas of concern include the unplanned entry of nanoparticles through the skin via hair follicles, or through the respiratory tract, with the probablity to penetrate vital organs. Therefore, before commencing large-scale production of nanodevices, potential environmental hazards created due to waste generation should be considered. Further research is required to determine the mobility, reactivity, ecotoxicity, and persistence of nanoparticles in the environment. Time alone can tell whether these are biocompatible and environmental friendly or not.

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