Nano-Prosthodontics

Abstract

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, bio-technology, electronic and computer technology, aviation, and space exploration. 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.

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Introduction

Science is presently undergoing a great evolution, taking humanity to a new era: the era of Nano-technology[1]. The opportunity to witness the beginning of a pioneering development in technology is encountered rarely.

The application of Nanotechnology to Dentistry and the time that will be required to implement the results of research into practice are the first questions that arise regarding Nanotechnology in Dentistry.[2]

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.[1]

The term 'Nanotechnology' was coined by Prof. Kerie E. Drexler, a lecturer, researcher, and writer of nanotechnology.[1]

According to the definition of the National Nanotechnology Initiative, nanotechnology is the direct manipulation of materials at the nanoscale4.

This term defines a technology that enables almost complete control of the structure of matter at nanoscale dimensions. Nanotechnology will give us the ability to arrange atoms as we desire and subsequently to achieve effective, complete control of the structure of matter.[5,6]

Nanotechnology In Prosthodontics

The development of Nanodentistry will allow nearly perfect oral health by the use of Nanomaterials and Biotechnologies, including Tissue engineering and Nanorobots.[7]

Tissue engineering and dentistry: Potential applications of Tissue engineering and stem cell research in Dentistry include the treatment of orofacial fractures, bone augmentation, cartilage regeneration of the temporo-mandibular joint, pulp repair, periodontal ligament regeneration, and implant osseointegration. Tissue engineering enables the placement of implants that eliminate a prolonged recovery period, are biologically and physiologically more stable than previously used implants, and can safely support early loading.[8,9]

Studies related to the regeneration of bone tissue constitute a major part of the studies in the Tissue-engineering field. Nanoscale fibers are similar in shape to the arrangement between collagen fibrils and hydroxyapatite crystals in bone. The biodegradable polymers or ceramic materials that are often preferred in bone tissue engineering may not have sufficient mechanical endurance despite their osteocon-ductive 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.[4,18]

Bone replacement materials developed via nano-technology are commercially available.[1,19,20] Bone grafts with better characteristics can be developed with the use of nanocrystalline hydroxyapatite. Furthermore, it was shown that nanocrystalline hydroxy-apatite stimulated the cell proliferation required for periodontal tissue regeneration.[21]

Bio-nano surface technology and dental implants

The natural bone surface has a roughness of approximately 100 nm, and such nano details are therefore important on the surfaces of implants. Osteoblast proliferation has been induced through the creation of nano-size particles on the implant surface.[4,22]

Roughing the implant surface at the nanoscale level is important for the cellular response that occurs in the tissue.

Titanium implants treated with a nanostruc-tured calcium surface coat were inserted into rabbit tibias, and their effect on osteogenesis was investigated; the nanostructured calcium coat increased the responsiveness of the bone around the implant.[25]

Many in-vitro studies have shown that the nanotopography of the implant surface considerably affects osteogenic cells and that the nanoscale surface morphology enhances osteoblast adhesion. Moreover, the nanoscale surface morphology augments the surface area and thus provides an increased implant surface area that can react to the biologic environment.[25-28]

Dental nanorobots

Although medical robots are not anticipated to have an effect on Dentistry in the near future, it is not too early to consider their potential effects.[2]

Dental nanorobots are able to move through teeth and surrounding tissues by using specific movement mechanisms. Nanocomputers that have been previously programmed via acoustic signals used for ultrasonography can control nanorobotic functions.[11]

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.[1]

Nanocomposites

The increasing interest in esthetic restorations in recent years has led to further development of materials that have the same color as that of teeth.[29]

The latest advance in composite resins is the implementation of nanoparticle technology into restorative materials.[16,30]

Nanotechnology has enabled the production of nano-dimensional filler particles,which are added either singly or as nanoclusters into composite resins. Nanofillers are different from traditional fillers.[32,33]

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.[31,33]

Nanotechnology allows the production of nano-sized filler particles that are compatible with dental composites; therefore, a greater amount of filler can be added into the composite resin matrix.[31]

Nanoparticles allow the production of composites with a smooth surface after the polishing process and confer superior esthetic features to the material. Composite resins containing such particles are easy to shape and have a high degree of strength and resistance to abrasion. Therefore, the area of use of resins containing nanoparticles is wider than that of composites containing hybrid and microfill fillers.[29,34]

In contrast to hybrid composites in which large particles can be separated from the matrix, only poorly attached nanoclusters are separated during abrasion in nanocomposites; thus, a well-polished restoration surface can retain its smoothness for a long time.[29]

The particles that are separated from the surface of the nanocomposites and form defects on the surface during abrasion are nano in size, which is smaller than the wavelength of light.[33]

Since particles in the wavelength of visible light (0.4 to 0.8 µm) do not reflect light, the material has superior optic character.[29]

The fillers in nano-composites have higher translucence since they are smaller than the wavelength of light, allowing the generation of more esthetic restorations with a vast range of color options.[33]

Future Fields Of Application Of Nano-technology In Dentistry

In Nanodentistry, millions of active analgesic nanoparticles in a colloidal suspension are placed into the patient's gingiva, and the anesthesia effectiveness is controlled by the Dentist via nanorobots moving into the gingival sulcus. Nanorobotic analgesics are an excellent modality to provide comfort to the patient and alleviate anxiety. Many of the adverse effects and complications associated with the use of typical local analgesic solutions are absent.

Nanodental techniques for major dental repair have been advanced by technologic developments such as Genetic engineering, Tissue engineering, and Tissue regeneration. At some time in the future, it will be possible to form a new tooth in-vitro. Preparing an autologous tooth that has both mineral and cellular dental components will be made possible by advances in research, and this process will eventually be achievable in the dentist's office.

Nanotechnology will offer perfect therapeutic methods for esthetic dentistry. All teeth that undergo treatment such as fillings or crowns will be restored with natural biologic materials in a manner that is indistinguishable from natural dentition.

Dentin sensitivity is another pathology that is suitable for nanodental treatment. Many therapeutic agents provide only a temporary effect for this common, painful condition. However, dental nanorobots can seal specific tubules by using natural biomaterials within a few minutes and provide a quick and permanent recovery from this condition.

Orthodontic nanorobots can directly manipulate all of the periodontal tissues, including gingival, periodontal ligament, cement, and alveolar bone. They can correct, rotate, or vertically reposition the teeth within a few hours in a pain-free manner.

The durability and appearance of teeth can be improved by inserting artificial materials such as sapphire or diamond into the outer layers of the enamel with covalent bonds. Although pure sapphires and diamonds are fragile, their ultimate strength can be augmented by the addition of materials such as carbon nanotubes. Sapphire can be produced in almost all colors from the color scale. This feature provides a cosmetic alternative to standard whitening techniques.

The once-a-day application of a mouthwash or toothpaste that delivers nanorobotic structures will result in the metabolism of organic compounds into harmless and odorless structures and the continuous cleaning of calculus. These dentifrobots, which are nearly invisible (1 to 10 µm), will have the mobility of an amoeba with a velocity of 1–10 µm/second. Their production is inexpensive, and they are fully mechanic devices. Furthermore, their activity can be stopped harmlessly in case they are swallowed. Distinctively manufactured dentifrobots recognize and destroy pathogenic bacteria in plaque and other regions, but they do not affect approximately 500 harmless species in normal flora and thus contribute to the formation of a healthy ecosystem. Dentifrobots constitute a continuous barrier to halitosis by eliminating bacterial putrefaction products, a major cause of oral malodor. Thus, tooth loss and gingival diseases will be eliminated by providing these daily dental practices from a young age.

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