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NANOTECHNOLOGY - A NEW DIMENSION IN PROSTHODONTICS

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Abstract

Scientific changes have made our perception, our way of thinking and attitude about today and tomorrow. Keeping this in mind the increasing number of beneficiary fields, we can establish the fact that even the field of dentistry is not spared. In recent years, lots of researches have been launched on nanomaterials for biomedical applications and shown that the performances of many biomaterials used in prosthodontics have been significantly enhanced after their scales were reduced by nanotechnology, from micron-size into nano size. This is an attempt to give an overview about the nanotechnology, nanomaterials and its applications in the field of Prosthodontics.

Keywords: Nanoworld, Nanodentistry, Prosthodontics

Introduction

"You have to be able to fabricate things, you have to be able to analyze things, and you have to be able to handle things smaller than ever imagined in ways not done before" - Cloude Levi Strauss and Winfred Phillips. At present the science is undergoing a great evolution, taking humanity to a new era, "The Era of Nanotechnology". Nanotechnology is the scientific ability to control and restructure the matter at the atomic and molecular levels within the nanoscale. Also, nanotechnology refers to using minute machinery that is capable of manipulating matter on an extremely small scale at dimensions between approximately 1-100 nm where unique phenomenon enables novel applications. In other terms Nano technology means science of small[1]. 1nm is 1 billionth a meter (10^{-9}).

Nanotechnology improves existing processes, materials and applications by scaling them down to the nanoscale in order to ultimately fully exploit the unique quantum and surface phenomena that matter exhibit at nano scale. Also, nanotechnology establishes link between nanoscopic and macroscopic universe by inventing adequate methods and enables to arrange atoms as we desire and subsequently to achieve effective, complete control of the structure of matter[2,3].

Metals were used in powder form used as medicine

in Ayurveda (600-10000 BC). They were converted into very fine and absorbable powders which were therapeutically most effective and least toxic[4, 5]. In Modern Era the vision of Nanotechnology was born by Richard P Feynman (1959) who predicted the potential of nanoparticles in his historic lecture 'there is plenty of room at the bottom'. Norio Taniguchi in 1974 defined Nanotechnology as process of separation, consolidation and deformation of material by one atom or one molecule. In 1981 Gerd Binnig and Heinrich Rohrer introduced scanning tunneling microscope which could image non-conducting organic molecules[6]. Nanotechnology enables analysis of structures at Nanoscale and understand the physical structures at nano level dimension. Nanotechnology helps in manufacture Nano level structures and to develop devices with Nanoprecision

There are mainly three approaches in nanotechnology.[7,8] Bottom-up approach is to arrange smaller molecules into complex assemblies using chemical or physical forces operating at the nanoscale to assemble basic units into large structures. Top-Down Approach is to create smaller equipment/ materials by using larger ones to direct their assembly. The most common top-down approach involves lithographic patterning techniques using short wavelength optical sources. In functional approach, components of a desired functionality are developed without regard to how they might be assembled.

Nanomaterials can be one dimensional, two dimensional or three dimensional. One dimensional nanomaterial has only one parameter, either length, or breadth, or height (E.g - Sheets or thin coatings).Two dimensional material has its length and breadth (E.g - Nano wires & nano tubes). 3D material has all parameters; length, breadth and height (E.g – Nanoring).

Nanotechnology in Prosthodontics

Prosthodontics is the dental specialty pertaining to the diagnosis, treatment planning, rehabilitation, and maintenance of the oral function, comfort, appearance, and health of patients with clinical conditions associated with missing or deficient teeth and/or maxillofacial tissues by using biocompatible substitutes, fixed prosthodontics, implant prosthodontics, maxillofacial prosthetics, removable prosthodontics.[9] Materials reduced to the nanoscale can suddenly show a very different properties enabling unique applications: opaque substances can become transparent(Copper), inert materials may become catalyst(Platinum), stable materials become combustible(Aluminium), solids turns into liquid at room temperature(Gold) and insulators can become conductors(Silicone).

Acrylic resin: The main component of PMMA is polymethyl methacrylate, also containing small amounts of ethylene glycol dimethacrylate. It shows poor strength particularly under fatigue failure inside the mouth and has low abrasion resistance. Microbial adhesion onto PMMA is high. Much attention has been given towards the incorporation of inorganic nanoparticles into Polymethyl methacrylate to improve its physical properties. Various nanoparticles such as ZrO2, TiO2, and CNT have been used to improve the performance of PMMA and the results showed that desired mechanical property enhancement can be achieved. TiO2 nanoparticle can reinforce the mechanical behavior of PMMA. Dispersion nano ZrO2 particles can improve the elastic modulus and maintain or even improve ductility. Ag, TiO2 and Fe2O3 particles significantly reduce adherence of C.Albicans to PMMA. Addition of modified ZrO2 nanomaterials in different percentages (2 wt%, 3 wt%, and 5 wt%) to heat-cure acrylic resin materials results in increased abrasive wear resistance, tensile and fatigue strength with 3 wt%

and 5 wt% addition of nanofillers[10].

Denture teeth: Wear resistance is the most desired physical property of denture teeth. Porcelain teeth are more wear resistant but they are brittle, bond mechanically to the denture base and difficult to polish. Acrylic resin denture teeth are easier to manipulate but undergo excessive wear. Nanocomposite denture tooth comprises of polymethylmethacrylate and uniformly dispersed nano sized filler particles[11]. They are highly polishable, stain and impact resistant material. They offer lively surface structure and superior surface hardness and wear resistance (Veracia by Shofu, Japan).

Tissue conditioners: Tissue conditioners have been commonly used to enhance the recovery of denture bearing tissues from trauma, damage or residual ridge resorption usually caused by ill-fitting dentures. Silver nanoparticles, which has antimicrobial properties, are added in tissue conditioners. Modified tissue conditioner combined with silver nanoparticles displayed antimicrobial properties against S. Aureus, S. Mutans at 0.1% and C. Albicans at 0.5% after a 24 hrs and 72 hrs of incubation period[12].

Dental Adhesive: Polymerizable silane is added to dental adhesives in order to increase the cohesive strength. Since the adhesive liquid are not that much viscous, the filler particles tend to settle during storage that leads to inconsistency during their performance. To overcome this discrete silane treated nanoparticles of silica or zirconia, size ranges of 5-7 nm are added to it. According to a study by N. Silikaset al., no decrease in bond strength of dental adhesives after the incorporation of silica or zirconia nanoparticles was obtained[13].

Maxillofacial Silicone: Maxillofacial prostheses are made of artificial substitutes like silicone and used to replace facial parts lost through disease or trauma. They are also used to restore and maintain the health of the tissues and to improve aesthetics for better social acceptance of facial injuries. Current materials used for maxillofacial applications experience some problems like low tear strength and unacceptable color stability. Thus, it is necessary to have a material with satisfactory tear strength, tensile properties, appropriate hardness and color stability. The properties of ideal material should be similar to missing facial tissue to match optimally to patient's articulate features of mastication, speech resonance, and facial gesture. Consequently, there is a need for improved materials with superior physical and mechanical properties which are comparable to those of human tissues and skin. SiO2 nanoparticles are characterized by their small size, large interface area, active function, and strong interfacial interaction with the organic polymer. Therefore, they can improve the physical, mechanical, and optical properties of the organic polymer and provide resistance to environmental stress-caused cracking and aging[14].

Nanocomposite resins[15,16]: Nano fill composites are the dental composites in which the fillers are of 1-100 nm range. Most common materials are nanomeric particles which are essentially monodispersed non-aggregated and non-agglomerated particles of silica. Optical properties of such materials are good with improved dispersion rate. Polish retention and surface gloss are more. Handling and rheological properties are poor. The 2nd type of nanoparticle used for nanofill composite is nanoclusters. This is done in order to overcome the disadvantages of the previously used nanomeric nanoparticle. In nanohybrid Composites, repolymerized organic fillers are incorporated so as to improve the undesirable rheological properties of composites. Titanium Di-Oxide Reinforced Resin Based Composites have been used to improve the microhardness and flexural strength of the

resin-based composites. Inclusion of alumina nanoparticles in nanocomposite increases the hardness of the nanocomposite as compared to other nanocomposites. Calcium phosphate and calcium fluoride nanoparticles-based composites release calcium fluoride or phosphate ions and are shown to provide remineralization to tooth structure. Nano-hydroxyapatites having a particle size of 20 nm, were synthesized to mimic human enamel and were found to provide anticaries effect.

Nano Impression Materials[17]: Vinyl polysiloxanes are currently the most popular materials these days. These materials are highly hydrophobic. Physical properties can be improved by the addition of nano sized fumed silica. Better flow, improved hydrophilic properties, fewer voids at margin and enhanced detail precision are the advantages. Nanotech Elite HD+ from the company Zhermack is manufactured with nanotechnology application. Here nanofillers are integrated in the vinyl polysiloxanes, producing a unique addition siloxane impression material having added advantages of better flow and enhanced surface detail reproduction.

Nanoceramics[18]: Ceramics have been used in manufacture of dental prosthesis because of their high strength, suitable color, and low thermal and electrical conductivity. Traditional ceramics are made of clay and other natural occurring materials, while modern high-tech ceramics use zirconia, silicon carbide etc. Nanoceramics has superplasticity and shows good toughness as well as ductility. The arrangement of atoms in nanoceramics is such that they are very easy to migrate under forcede formation. Superior mechanical properties such as strength and hardness are significantly more. The hardness and strength of nanoceramics is 4 to 5 times higher than those of the conventional ceramic materials.

Nano Light cure Glass ionomer cement: Glass ionomers were introduced by Wilson and Kent in the 1970s as dental filling material. Cellulose fibers, hydroxyapatite and fluoroapatite are added to improve their properties. Luting agents based on nanotechnology are being produced for permanent cementing of conventional prosthesis including all ceramic constructions. This material displays high pulpal friendliness and also minimum leakage at the margin. More recently, addition of nanoparticles resulted in the aesthetic improvement of the final restoration and polishablilty. Fluoride release property is not affected by the addition of nanoparticles.

Dental Implant Surface modifications Nanotopographically[19]: Dental implant therapy has been one of the most significant advances in dentistry in the past three decades. Osseointegration is widely accepted in implant dentistry as the basis for implant success. The most frequent cause of failure of implants is insufficient bone formation around the implant. Many research efforts have been directed toward improving the bone-implant interface, with the aim of accelerating bone healing and improving bone anchorage to the implant Surface properties of dental implants play an important role in biological interactions. The nanometer sized roughness and the surface chemistry have a vital role in the interactions of surfaces with proteins and cells. With the introduction of nanotechnology, nanostructured hydroxyapatite and calcium Phosphates coating for dental implants, have attracted much attention. Hydroxyapatite and calcium phosphates coatings promotes bone formation around implant, by increasing osteoblasts function such as adhesion, proliferation and increases mineralization.

Nanotechnology in COVID-19 Scenario: As of now as we are moving towards pre-covid times &

COVID -19 vaccination is playing a crucial role in returning life to normal, we can't neglect the role of nanotechnology in vaccination development. The COVID-19 pandemic has infected millions of people with high prevalence, long incubation period and lack of treatments or vaccines. As of now it is proven that vaccines are the most promising solution to mitigate new viral strains. The genome sequence and protein structure of the novel coronavirus were made available in record time, allowing the development of inactivated or attenuated viral vaccines along with subunit vaccines for prophylaxis. Lipid nanoparticles are a vital component of the mRNA COVID – 19 vaccines, playing a key role in protecting and transporting the mRNA effectively to the right place in cells. They are next generation liposomes that uses nanotechnology and are well suited to stable and efficient delivery of various therapeutics.

Nano technology carries a significant potential for misuse and abuse, if not properly controlled & directed. Nanoparticles have large surface area. The more the surface area, greater the chance to increase the rate of absorption through skin, lungs, digestive tract. This could cause unwanted effects in the body as non-degradable nanoparticles gets accumulated. Decreasing the size of the particle has been identified as main parameter for the increased toxicity of different materials[20]. Accumulation of nano particles is seen in spleen, liver and kidney in animals. Nanoparticles are so small that they can easily cross the blood-brain barrier. Proper care should be taken regarding nano particles and nanotechnology. Safety issues for personal health and safety of the workers involved in the nanomanufacturing and also consumers is a great concern.

Nanotechnology is set to revolutionize clinical dental practice. The future holds in store an era of Prosthodontics in which every procedure will be performed using equipment and devices based on nanotechnology. With a diverse range of applications in all spheres, it has a capacity to change the world we live in. Oral health care services will become less stressful for dental professionals, more acceptable to patients and the outcome will become significantly more favorable. THE BEST IS YET TO COME!!

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