Nanotechnology in prosthodontics: A game changer

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Abstract: Nanotechnology refers to the branch of science and engineering involved in designing and producing, structures and devices by manipulating atoms and molecules at nanoscale dimensions i.e. of the order of 100 nanometres or less. Due to a very high surface area to volume ratio of nanoparticles, new materials with superior properties and effects can be produced compared to their larger counterparts. The tremendously growing scientific and innovative research, has led to the development of nanomaterials with advanced bioapplications. Inorganic nanoparticles, exhibit significantly novel and improved physical, chemical and biological properties, phenomena and functionality due to their Nano scale size. The use of nano phasic and nanostructured materials is increasing manifold due to their potential for achieving specific processes and selectivity, especially in biological and pharmaceutical application. Specifically formulated nanomaterials have become very popular in the design and development of many dental materials so as to improve their chemical, physical and mechanical properties. Their unique phenomena enable the dentists to execute curative and reconstructive procedures at the cellular and molecular levels enabling the maintenance of near-perfect oral health and uplift the standard of medicine. This article tries to give an insight of the applications and recent developments of nano products with superior quality in the field of prosthodontics, Implant materials, Bone replacement materials and Maxillofacial prosthesis. The evolution of nanotechnology will help dentists with more precision made materials, prosthesis and equipments and to illustrate their potentially far-reaching impact on clinical dental practice. In this article, we have made an attempt to have a glimpse on impact of nanotechnology in the field of prosthodontics.

Index Terms: Nanotechnology, Nanodentistry, Nanomaterials, Implant surface modifications, Prosthodontics.

I. INTRODUCTION

"Nano" is derived from the greek word for dwarf[1],[2],[3]. Nanotechnology is the science and engineering involved within the design, synthesis, characterization and application of materials and devices whose smallest functional organization in a minimum of one dimension is on the nanometer scale[4]. The term 'nanotechnology' was coined by Prof. Kerie E Drexler in 1977[2]. As the human body is comprised of molecules, the availability of molecular nanotechnology will permit dramatic progress in human medical services to improve human health at the molecular scale[5].

II. WHAT IS NANOTECHNOLOGY ?

Nanotechnology has been defined as 'the creation of functional materials, systems and devices through the control of matter on the nanometer scale (1-100nm) and exploitation of novel phenomena and properties (physical, chemical and biological) at that length scale'[6].

III. APPROACHES TO NANOTECHNOLOGY

Current research is directed towards the production of a wide array of different nanoscale structures. The fabrication techniques of these structures can be divided into two approaches:

1. Top down approach **Fig. 1**
2. Bottom down approach[2]. **Fig. 1**

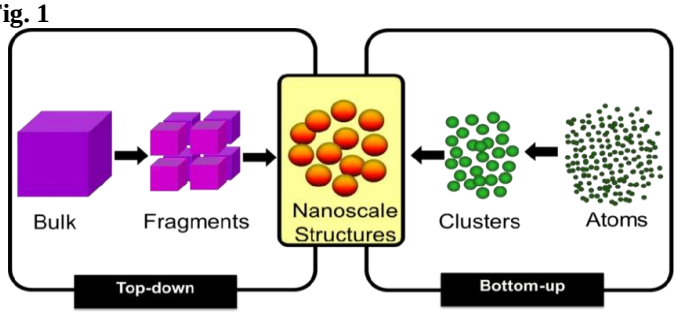

Figure 1 "Top-down" and "bottom-up" synthesis of nanofabrication.

Top-down synthesis

Destructive or Top -down technique refers to the decrease in bulk materials to the Nano-meter scale particles.

Bottom-up synthesis

Generating materials from atoms to clusters to Nano-materials is called bottom-up or constructive technique with widespread applications for producing Nano-materials[6].

IV. NANOMATERIALS

Nanomaterials are defined as materials designed and produced to have structural features with at least one dimension of 100 nanometers or less. These materials typically possess nanostructure-dependent properties (e.g., chemical, mechanical, electrical, optical, magnetic, biological), which make them desirable for commercial or medical applications[7].

V. NANO DENTISTRY

Development of "***Nanodentistry***" will make possible the maintenance of near-perfect oral health through the use of Nanomaterials, biotechnology including tissue engineering and Nanorobotics. Nanotechnology has revolutionized the field of dentistry with tremendous potential to provide a comprehensive oral health care using nano products with superior quality, advanced clinical tools and devices.

Application Of Nanomaterials In Prosthodontics

1. Nanoceramics

Compared with the conventional ceramics, nanoceramics have unique properties like good toughness and ductility. Nanoceramics have superior mechanical properties such as, strength and hardness which is four to five times higher than those of the traditional materials[8].

Ormocers (Organically Modified Ceramics): These nanoparticles consist of a polysiloxane backbone used for glass and ceramics. These nanoceramic particles have shown to prevent the micro crack propagation.

Trade name: Ceram X mono (DENTSPLY) [9]. **Fig. 2**

Figure 2: *Ceram X mono by DENTSPLY*

2. Nano resin based materials

Composites

• **Nano Filled Composites contain** nano fillers of 1-100nm incorporated into the resin matrix. Nanomers and nanoclusters are the two types of nanoparticles that have been used.

Nanomers are mono dispersed particles of silica treated with 3-methacryloxy-propyltrimethoxysilane which has helped in chemical bonding of the nanomeric filler to the resin while curing providing good optical properties, high polish, superior hardness, flexural strength and esthetics.

Nanoclusters are formed by lightly sintering nanomeric oxides to form clusters with the same advantages as nanomers with better rheological properties[9]. **Fig. 3**

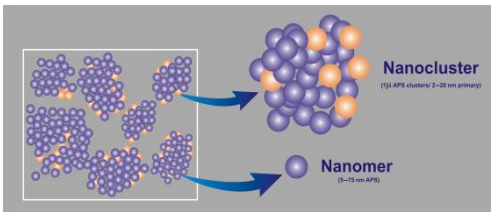

Figure 3: *Nanoclusters and nanomers in composites*

• **Nanohybrid Composites:** Pre-polymerized organic fillers have been incorporated in nanomers to improve the desirable rheological properties of composites[9].

Trade name: Isopast® and Heliomolar® by Ivoclar Vivadent[8]. **Fig. 4**

Figure 4: *Heliomolar hybrid composite by Ivoclar Vivadent*

• **TIO2, Alumina, Calcium Phosphate And Calcium Fluoride Nanoparticles Reinforced Composites** have shown increased hardness, strength, modulus of elasticity and anti-caries repair effect[9].

3. Nano composite denture teeth

They are made of Polymethyl methacrylate (PMMA) and homogeneously distributed nanofillers. Advantages include excellent polishability, stain-resistance, enhanced esthetics, wear resistance and surface hardness.

Trade name: Veracia (Shofu, Kyoto, Japan) [8]. **Fig. 5**

Figure 5: *Nanocomposite denture teeth[12]*

4. Impression materials

Nanofiller integrated vinylpolysiloxanes have better flow, improved hydrophilic properties hence fewer voids at margin and better model pouring[8].

Advantages include increased fluidity, high tear resistance, hydrophilic properties, resistance to distortion, heat resistance and snap set that consequently reduces errors caused by micro movements[6].

Trade name: Nanotech Elite H-D[8]. **Fig. 6**

Figure 6: *Nanotech Elite H-D Plus Addition siloxane impression material with incorporated nanofillers[12]*

5. Nanoparticles in polymethyl methacrylate resin

Nanoparticles are added to PMMA as antimicrobial agents and to increase the viscoelastic property of resins. The addition of metal nanoparticles such as TiO_2, Fe_2O_3 and silver to PMMA materials have shown to increase the surface hydrophobicity to reduce bimolecular adherence[8].

Various Nanomaterials used in PMMA

a. Carbon-Nanotubes - Light cure denture resin reinforced with carbon nanotubes **Fig. 7** showed better impact and flexural strength [10].

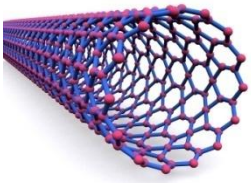

Figure 7: *Carbon nanotube*

b. Silver Nanoparticles- it increases the mean compressive strength, reduces the hydrophobicity of the resin and has a potent antifungal activity[10].

c. TiO_2 and Fe_3O_2 nanoparticles- They lower the *Candida albicans* cell adhesion and porosity of the denture compared to standard PMMA[11].

7. Nanoadhesives in prosthodontics

They contain silica nano filler and when used over esthetic restorations, produces stain and wear resistant surface with smooth luster[12]. "Nano-Interaction Zone"(NIZ- <300nm) with minimal decalcification and almost no exposure to collagen fibres producing an insoluble calcium compound for a better bond and is less likely to deteriorate from enzymes contained in the mouth[8].

Trade name: Adper O Single Bond Plus Adhesive Single Bond[1]. **Fig. 8**

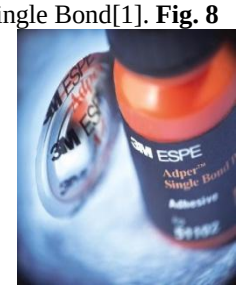

Figure 8: *Adper O Single Bond Plus Adhesive Single Bond Nanoadhesive[3]*

8. Dental cements

Nano light cure Glass ionomer cement contains hydroxyapatite/fluoro-alumino silicate technology and has been used for core build up owing to its significantly high compressive, tensile and biaxial flexural strength[9].

Trade name: Ketac N100 light curing nano-ionomer (3M ESPE). **Fig. 9**

Figure 9: *Ketac N100 light curing nano-ionomer (3M ESPE).*

Silver nano particles in **Resin luting cements** have shown long term inhibitory effect against S. mutans and favourable mechanical properties.TiO_2 nanotube reinforced self adhesive resin cement has exhibited superior physicochemical and biological properties[9].

9. Coating agents in prosthodontics

These light cured agents containing nanosized fillers are used as a final coating over composite restorations, glass ionomer restorations, jacket crowns, veneers and provisionals and have higher wear resistance, preventing abrasion and discolouration[8].

10. Tissue conditioners and soft liners

Addition of silver nano-particles in these materials have displayed anti- microbial properties against S.mutans, S.aureus and C.albicans. Chlorhexidine- Hexametaphosphate incorporated in silicone soft liners is an effective antifungal agent and thus enhances the life of the prosthesis[9].

11. Nanotechnology in implants

The application of nano technology in dental implants can be made by coating of nano particles over the dental implants[9]. Coating implants with nano textured titanium, hydroxyl apatite and pharmacological agents such as bisphosphonates may induce cell differentiation, proliferation and promote greater vascularity in cortical bone thereby offering fast and optimum osseointegration[8].

Trade name: Nanotite[3]. **Fig. 10**

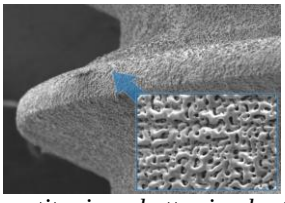

Figure 10: *Nanotitanium- better implant stability[16]*

Coatings Improving Osseointegration include: Fig. 11

a. Nano-hydroxyapatite coating- They immensely increase cell attachment, bioactivity and osteoconductivity of the Ti substrate. Nano-hydroxyapatite could be combined with collagen, bioglass or titanium dioxide in a composite way to simulate the bio-environment of native bones[13].

b. Graphene- Implants coated with graphene oxide effectively enhanced the proliferation, adhesion, osteogenic differentiation and have improved the corrosion resistance of Ti-6Al-4V implants[13].

c. Antibiotic Components of Implant Coating- Titanium dioxide nanotubes loaded with vancomycin and gentamycin showed good antibacterial effect against S. aureus and has enhanced osseointegration and implant longevity[14].

The Antimicrobial Properties of Metal Element Components- Silver, zinc, copper and ceria oxide nanopartcles have been applied in implant coatings due to their excellent antibacterial and anti-inflammatory functions[14].

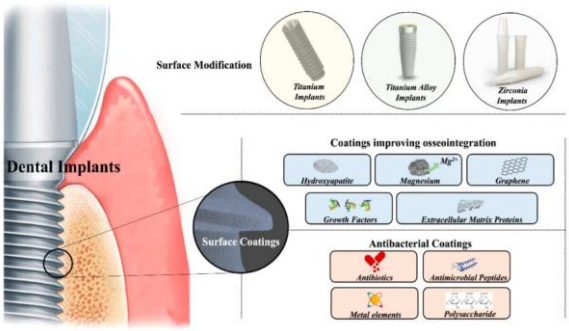

Figure 11: *A schematic illustration of Surface Modifiers and Functional Coating of Dental Implants [13]*

The various surface modification techniques to produce nanostructured implants include:

1. Chemical modification-(a) Anodic oxidation:
(b) Combination of acid and oxidants:

2. Physical modification-(a) Plasma spray-
(b) Blasting[9].

12. Bone replacement materials

Biologically inspired rosette nanotubes and nanocrystalline hydroapatite hydrogel nanocomposites can be used as improved bone. They are osteoinductive, non sintered, highly porous, degraded by osteoclasts and absorb natural proteins into the nanopores[5].

Trade name-OSTIM, NANOSS, VITOSS[3]. **Fig. 12**

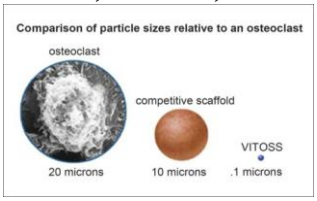

Figure 12: *Vitoss made of β-TCP and composed of nanoparticle (100 nm) [3].*

For bone tissue regeneration, CNTs in composites act by stimulating cell adhesion through good interaction with cell-binding proteins and accelerating stem cell differentiation due to the fact of their preferential affinity for cell binding; thus, osteoblast differentiation and apatite mineralization were induced to promote new bone formation[15].

13. Maxillofacial prosthodontics

The addition of silver nanoparticles has prevented the adherence of *Candida albicans* to the surface of these prostheses with no toxic effect to the human dermal fibroblast cells. Titanium dioxide, Zinc oxide and Cerium dioxide nano particles which are added as opacifiers, exhibit least colour instability. Tear strength has been improved with the addition of surface treated Silicone dioxide nano particles[9].

14.Nano Sterilizing Solution

It is a surface disinfectant that safely kills 100% of HIV and other particles. It has been used to sterilize tools and incisions to prevent postoperative infections[16]. **Fig. 13**

Figure 13: *Nanosterilizing solution developed by Gandly Enterprises Inc., Florida[16].*

Scope

The miracles of nanodentistry envisioned by dentists might sound unlikely, implausible or even heretic. Yet, the theoretical and applied research to turn them into reality is progressing rapidly. Nanotechnology will change dentistry, healthcare and human life more profoundly than many developments of the past. Nanodentistry will lead to efficient and highly effective personalized dental treatments.

Conclusion

Nanotechnology is set to revolutionize clinical dental practice. Recent studies have shown that, properties of materials used in prosthodontics can be significantly improved after their scales were reduced from micron-size to nanosize by nanotechnology[8]. The combination of continual refinements in conventional treatment modalities and advances in the clinical applications of nanotechnology are promising for improving dental care.

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