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Nanotechnology era in Dentistry ; A comprehensive Review

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Abstract:
Nanotechnology is the art and science of material engineering at the Nano scale size (1-100 nm). Nanotechnology consists of the process of separation, consolidation and deformation of materials by one atom or one molecule. It's one often most popular areas of current research and has developed in multiple disciplines. Nanotechnology has been used in the development of restorative materials with significant success. This comprehensive review article highlights the importance of Nanotechnology in dentistry
Keywords: Nanotechnology, Nanomer, Nanocluster and Nanocomposite.

INTRODUCTION

'Nano' is derived from the Greek word which means Dwarf. [1]

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FIGURE 1: NANOTECHNOLOGY

In 1959, famous American physicist, Dr. Richard Feynman seeded the concept of nanotechnology. Bionanorobots can utilize properties of biological materials and their

designs.[2] Nanotechnology is based on the idea of creating functional structures by controlling atoms and molecules on a one-by-one basis.[3] Nanotechnology arranges atoms to achieve effective, complete control of the structure of matter.[4,5] Two principal factors cause the properties of nanomaterials to differ significantly from other materials: Nanoparticles have much greater surface area per unit mass compared with larger particles. Quantum effects can affect the optical, electrical, and magnetic behavior of materials, particularly as the structure or particle size approaches the smaller end of the nanoscale. Newer technology in the medical implementations of nanotechnology have resulted in the formation of a nanomedicine.[6] Nanomedicine includes various applications ranging from drug release with nanospheres to tissue scaffolds [7]

Why there is need of Nanotechnology

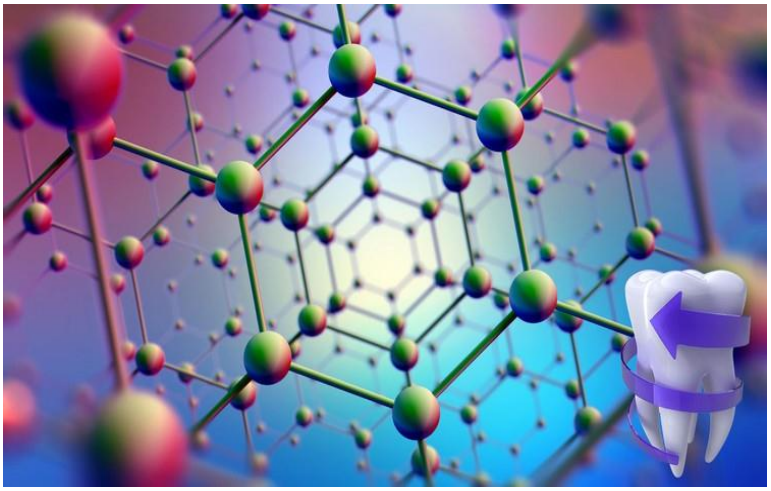

FIGURE 2: NEED FOR NANOTECHNOLOGY

Options for the production of smart materials for dental applications.

- Material Synthesis Producing synthetic materials matching morphology and properties similar to natural dental tissues.
- Biomimetic Approaches to replace lost dental tissues follow the nature's principles and producing biomaterials resembling their properties very closely to the replacing tissues.
- Tissue Engineering Use of regenerative medicine and tissue engineering approaches for replacing the lost dental tissues by regenerations.
- All these approaches are not possible without the intervention of nanotechnology
- Dental hard tissues (enamel, dentin and cementum) are composed of nanoscale structural units.

Approaches in nanotechnology

Top-down approach, To create smaller devices by using larger ones to direct their assembly
Bottom up approach, To arrange smaller components into more complex assemblies
Functional approach, The functional objective is to produce a nanoparticle with a specific functionality.

- Nanotubes
- Quantumdots
- Nanoshells

- Dendrimers
- Nanospheres
- Nanowires
- Nanobelts
- Nanorings
- Fullerene

NANOMATERIALS IN PROSTHODONTIC APPLICATIONS

In prosthodontics, nanoparticles are added to ceramics, acrylic resins ,composites, metals, dental adhesives, dental cements, implants and maxillo-facial prosthesis

Since modulating these materials to nanosize has given greater efficacy and durability.

FIGURE 3: NANOTECHNOLOGY IN IMPLANTS

IMPLANTS

Nanotechnology has been widely used for surface modifications of dental implants as it has altered the implant surface at an atomic level thus changing the chemical composition of the surface. This change in the chemistry and the roughness has aided in good osseointegration. Titanium dioxide nanotubes on Titanium improved the production of alkaline phosphatase activity by osteoblastic cells. The addition of nanoscale deposits of calcium phosphate and hydroxyapatite, creates a complex .Implant surface for osteoblast formation[8,9]

Immobilization of therapeutic agents that induce osteogenesis, eg, bisphosphonates and simvastatin, or prevent bacterial infection, eg. silver and zinc oxide nanoparticles into the bio functionalized implant surface has also been attempted.

Lithography, ionic implantation, anodization,[10] and radio-frequency plasma treatments, have been used to induce controlled nanosurface features (eg, tubes,[11] , dots,[12] and nodule[13] on dental implants

Dual layered Silver hydroxyapatite nanocoating on Titanium alloy implants has created a surface with antibiofilm properties without compromising the biocompatible Hydroxyapatite surface needed for successful osseointegration and accelerated bone healing. Bone morphogenetic protein (BMP) has been also immobilized on the surface of dental implants to enhance bioactivity and hence bone formation.

COMPOSITES

FIGURE 4: NANOCOMPOSITES

The latest advance in composite resins is the application of nanoparticle into restorative materials.[14] Nano Filled Composites Nano fillers of 1-100nm have been incorporated into the resin matrix to produce nanocomposites. Since the dimensions of these filler particles are below that of visible light, it is impossible for them to either scatter or absorb visible light. This phenomenon plays a key role in getting excellent aesthetic properties and can be used for anterior teeth restorations 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.[15,16] Nanotechnology allows the production of nano-sized filler particles that are compatible with dental composites[17]
The two types of nanoparticles that have been used are Nanomers and Nanoclusters

NANOMERS:
They are mono dispersed, non-aggregated and non-agglomerated particles of silica. These helped in chemical bonding of the nanomer filler to the resin while curing.

Advantages:
Good optical properties, Good dispersion rate, High polish and polish retention, Superior hardness, Flexural strength.

Disadvantages:
Poor rheological and handling properties.

Nanoclusters
NANOCLUSTERS: Nanocluster fillers range from 2-20 nm. They have been formed by lightly sintering nanomeric oxides to form clusters of a controlled particle size distribution. Nanoclusters of silica sol exclusively and mixed oxides of silica and zirconia have been synthesize Nanohybrid Composites

- Pre-polymerized organic fillers have been incorporated in nanomers to improve the desirable rheological properties of composites.
  Advantages:
- Improved esthetics
- Increased filler loading

- Improved adaptability
- Disadvantages:
- Decreased polish retention
- Surface gloss.

Nano-Composite Denture Teeth

FIGURE 5: NANOCOMPOSITE DENTURE TEETH

Nanocomposite denture teeth have homogenously distributed nanofillers and polymethyl methacrylate. They have shown high durability and polishability, increased shear strength, superior esthetics and higher abrasion resistance. [18,19,20]

DENTAL ADHESIVES

Bonding of dental composite to tooth structure is obtained through different adhesive resin systems, that creates a transitional zone called hybrid layer or inter-diffusion zone of resin-reinforced collagen. [21]The durability of resin–dentine interface can be jeopardized by:

- Degradation of collagenmatrix;
- Incomplete penetration and polymerization of resin monomer; and Hydrolysis of the resin monomer

TISSUE CONDITIONERS AND SOFT LINERS

Addition of silver Nano-particles in these materials have displayed antimicrobial properties against S.mutans and S.aureus at 0.1% and C.albicans at 0.5% after24 hours incubation period. Solutions of chlorhexidine mixed with sodium triphosphate and Chlorhexidine- HMP coating has been proved to be the most effective antifungal agent thus enhancing the life of the prosthesis

FIGURE 6: TISSUE CONDITIONER WITH SILVER NANOPARTICLE

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MAXILLO-FACIAL PROSTHESIS

Addition of silver nanoparticles to these materials has prevented 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 have been added as opacifiers for silicone elastomers and Titanium dioxide and Cerium dioxide nano particles have exhibited the least colour instability.

Addition of surface treated Silicone dioxide nano particles in 3% concentration have improved the mechanical properties, especially the tear strength.

FIGURE 7: NANOTECHNOLOGY IN MAXILLOFACIAL PROSTHESIS

TISSUE ENGINEERING

Nanotechnology in tissue engineering has allowed significant improvement of the scaffolding materials to provide unique 3D matrix conditions for cells and tissue[22].The nanofibrous scaffolds have been widely developed as the matrices for regeneration of dental tissues, including dentin–pulp complex, enamel, PDL, cementum, alveolar bone, and temporomandibular joint. A key aspect of the nano fibrous structures is their morphological trait largely mimicking the native tissue architecture because most of tissue proteins such as collagen and elastin are nanofibrous
Electrospinning is a common method to generate nanofibers[23,24]

Challenges Faced by Nanotechnology[25]

- Precise positioning and assembly of molecular scale part
- Economical nanorobot mass production technique.
- Simultaneous coordination of activities of large numbers of independent micron scale robots.
- Biocompatibility
- Funding
- Insufficient integration of clinical research.

- Social issues of public acceptance, ethics ,regulation and human safety

CONCLUSION

The future of Nanotechnology is intriguing and is set to revolutionize dental practice. In prosthodontics, it will depend on development of material science thus opening up new avenues for vast and abundant research keeping in the safety, efficacy and applicability of these new technologies.

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