REVIEW ARTICLE

INFLUENCE OF NANOTECHNOLOGY IN OPERATIVE DENTISTRY AND ENDODONTICS – THINK "BIG", ACT "SMALL"

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ABSTRACT:
Today the revolutionary development of nanotechnology has become the most demanding discipline in the field of science and technology. It forms the basis of novel methods for disease diagnosis and prevention. The evolution of nanotechnology will help dentists with oral health care services less stressful and more acceptable to the patients. However, patient awareness and education are important to make them understand the developments in this field and the options available in the treatment. This review article provides an insight about the role of nanotechnology and its applications in Operative Dentistry and Endodontics.
Key words: Nanotechnology, Nanodentistry, Nanorobots, Nanomaterials

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INTRODUCTION:

Nanotechnology is an emerging field of applied science and technology that has tremendous potential to bring about significant health benefits to the society. It opens up new avenues for vast, abundant research. It is the science that deals with manipulation of matter at the atomic or molecular level.[1] The basic idea of nanotechnology is to employ individual atoms and molecules to construct functional structures. The growing interest in the dental applications of nanotechnology is leading to the emergence of a new field called nanodentistry which will make possible the maintenance of oral health using nanomaterials, biotechnology and dental nanarobotics.[2] Nanodentistry gives a new dimension to comprehensive dental care as the present trend is focusing more on preventive intervention than curative and restorative treatments.

Nanodentistry is defined as "the science and technology of diagnosing, treating and preventing oral and dental disease, relieving pain and of preserving and improving dental health, suing nanoscaled structures".[3]

The mechanism on which nanodentistry works is by constructing microsized dental nanorobots which use specific motility mechanisms to crawl or swim through human tissue with navigational precision, acquire energy, sense and manipulate their surroundings, achieve safe cytopenetration and use any of the multitude techniques to monitor , interrupt, or alter nerve impulse traffic in individual nerve cells in real time. These nanorobots function may be controlled by an on board nanocomputer that executes pre programmed instructions in response to local sensor stimuli.[4]

CONCEPT OF NANOROBOTS:

A nanorobot is a tiny machine designed to perform a specific task or tasks repeatedly and with precision at nanoscale dimensions, that is, dimensions of a few nanometers (nm) or less, where 1 nm = 10-9 meter. Nanorobots have potential applications in the assembly and maintenance of sophisticated systems. Nanorobots might function at the atomic or molecular level to build devices, machines, or circuits, a process known as molecular manufacturing.

The powering of nanorobots can be done by metabolizing local glucose, oxygen and externally supplied acoustic energy. They can be controlled on-board computers. Nanorobots are able to distinguish between different cell types by checking their surface antigens.When the task of the nanorobot is completed, they can be retrieved by allowing them to exfuse themselves via the usual human excretory channels. They can also be removed by active scavenger systems.[5]

APPROACHES IN NANOTECHNOLOGY:

1. Bottom-up approach: This approach arranges smaller components into more complex assemblies.[6]
2. Top- down approach: This approach creates smaller devices by using larger ones to direct their assembly.[6]
3. Functional approach: This approach develops components of the desired functionality without much importance to their assembly or structure.[6]
4. The Biomimetic Approaches: Seeks to apply biomolecules for applications in nanotechnology6.
5. Speculative approach: This approach often takes a big picture view of nanotechnology, with more emphasis on its societal implications than the details of how such inventions could actually be created.[7]

APPLICATIONS OF NANOTECHNOLOGY IN OPERATIVE DENTISTRY AND ENDODONTICS:

I.OPERATIVE DENTISTRY

1. Nanocomposites: Nanotechnology has great impact on restorative dentistry by offering refinements to already clinically proven resin - based composite technology. Nanocomposites consist of nanofiller particles that are two types: Nanomeric (NM) and Nanoclusters (NCs). NM particles are monodisperse, nonaggregated and nonagglomerated silica nanoparticles. Advantages of nanocomposites: They have excellent mechanical properties such as hardness, strength and superior esthetic properties with high polish retention and lower polymerization shrinkage. These have very good handling properties that allow for optimal placement and contouring. Regardless of the finishing and polishing technique, the nanofilled composites exhibited the lowest pretesting surface roughness and wear.[8]

2. Nanobond: It is a nano particulate reinforced adhesive system.These new bonding agents are prepared from nano solutions which contain homogenous nanoparticles dispersed in the solution. Silica nanofillers are stable and do not cluster in the solution so provide the superior bond strength values. Nano interaction zone (NIZ - <300 nm) with minimal decalcification and almost no exposure to collagen fibers producing an insoluble calcium compound for a better bond less likely to deteriorate from enzymes contained in the mouth.[9]

3. Nanosolutions: These solutions are self etching, one step materials which provide unique and dispersible nanoparticle, which can be used in bonding agents. The new generation of bonding agents is one-step application. The homogeneously dispersed nanofillers provide the maximum bond strength and prevent particle settling.Homogenous coat of bonding agent can be applied.[10]

4. Coating Agents: These agents have light activated nanosized fillers which can be used as coating over the composite, glass inomer cements, jacket crowns and veneers. Incorporation of nanofillers provide superb polish on the restorations which prevents staining, increases abrasion and wear resistance. Recently, a nanotechnology liquid polish system was designed to overcome the limitations of liquid polishers. The addition of nanofillers provides excellent results such as a glossy surface for direct or indirect resin composite restorations.[11]

5. Ultrafine Polishing: Polishing the teeth results in roughness, this provides medium for biofilm formation. Ultra-fine polishing of teeth leads to nanoscale roughness which is few in nanometers. It protects the teeth from cariogenic bacteria, which can be easily removed from these ultrafine polished surfaces, therefore prevent staining and lead to superior esthetics of the restorations.[9]

6. Nano Ionomer: Nano Ionomer is glass ionomer cement whose formulation is based on bonded nanofiller technology. Mechanical properties of nano-ionomer are improved by the combination of fluoroaluminosilicate glass, nanofillers, and nanofiller clusters. The nanofiller components also improve some physical properties of the hardened restorative. It also shows high fluoride release that is rechargeable after being exposed to a topical fluoride source. Additionally, in vitro tests showed that the nano ionomer (Ketac N100) has the ability to create a caries inhibition zone after acid exposure. This product meets a wide range of clinical indications ranging from Class I, III,

V,Sandwich restorations and core build-ups. Advantages of this material: superb polish, excellent esthetics, improved wear resistance.[12]

7. Nano - ceramic technology: The Organically Modified Ceramic nano-particles comprise a polysiloxane backbone. These nano-ceramic particles can be best described as inorganic-organic hybrid particles where the inorganic part consisting of siloxane and the methacrylic organic part blends all the particles with resin matrix. The good resistance to microcrack propagation might be related to the strengthening effect of the nano-ceramic particles. Propagating cracks are either more often reflected or absorbed by the nanoceramic particles.[13]

8. Nanotechnology for Impression Materials: Here, nanofillers are perfectly blended with vinylpolysiloxanes, resulting in a unique addition siloxane impression material having a better flow, improved hydrophilic properties, tear strength and enhanced detail precision. The presence of the nanostructure increases the fluidity of the material, especially when pressure is applied.[14]

9. Local Anesthesia: Nanotechnology uses millions of active analgesic micrometer sized dental nanorobots in a colloidal suspension for local anaesthesia on reaching the dentin, the nanorobots, within 100 seconds, are said to enter dentinal tubular holes that are 1 to 4 μm in diameter and proceed towards the pulp. Once installed there, analgesic dental robots may be commanded by dentist to shut down all sensitivity in any particular tooth that requires treatment. After oral procedure is completed, dentist orders the nanorobots to restore all sensations to relinquish control of nerve traffic and to egress from tooth by similar pathways used to ingress.[2]

10. Pit & fissure sealants: The nano fissure sealant results in outstanding wear resistance and a reduced shrinkage, feasible sealing ability, hydrophilic material and easy to place. Due to high fluoride release, it may lead to remineralization.[5]

11. Tooth repair: Nanodentistry for major tooth repair may consist of growing the whole new teeth in vitro using genetic and tissue engineering and embedding them into the socket. Dental enamel, the hardest tissue in the human body was recreated by using highly organized microarchitectural units of nanorods.[15]

12. Dental durability and cosmetics: Covalently bonded artificial materials such as, sapphire or diamond which have hardness and strength 20-100 times more than that of natural enamel and ceramic incorporated in a fracture resistant nanostructured composite material that possibly include carbon nanotubes are used for replacing upper enamel layers for aesthetic purposes.[7]

13. Hypersensitivity cure: Biological materials manufactured from nanotechnology can selectively occlude the dentinal tubules and provide fast and permanent cure to the patient. These can allay the anxiety and associated pain within minutes of application. Reconstructive dental nanorobots selectively and precisely occlude selected tubules in minutes, using native biological materials, offering patients a quick and permanent cure for hypersensitivity caused by the changes in pressure transmitted hydrodynamically to the pulp.[2]

14. Nanorobotic dentifrice (dentifrobots): Nanorobotic dentifrices, which may be available in mouthwash or toothpaste form, on contact with the tooth surface they scroll over the supragingival and subgingival surfaces, once in a day, removing the attached organic matter and debris on the tooth surface. These could detect the cariogenic bacteria in the biofilm with maintaining normal ecosystem of the oral cavity.[2]

15. Nanoparticles of gold and silver: Silver and gold nanoparticles are being used as an alternative to dental filling agents. The unique advantages of these nanoparticles are the anti wear; antibacterial and antifungal properties enable their use in restorative dentistry. They also act on dental biofilms in root canals when used during endodontic therapy.[16]

16. Nano reminerializing agent: Calcium Nanophosphate paste (Desensibilize Nano-P, FGM Produtos Odontologicos) for bleached enamel. The calcium nanophosphate crystals may have penetrated more deeply into the defects of the enamel, forming a “reservoir-like” deposit of the eroded calcium and phosphate ions. The reservoir-like deposit help maintain a state of supersaturation with enamel minerals.[17]

17. Nanozone: Nano technology based ozone therapy. It provides strongly oxidizing ozone. When given in adequate doses allowa removal of 99.9% of bacteria which are responsible for the development of dental caries.[18]

18.Nanotechnology microscope: Nanotechnology is emerging to underpin a new generation of deep‐probe detectors; a new area of the electromagnetic spectrum is becoming available

for probing the human body as well as revealing hidden matter. This is known as Terahertz radiation, the area is in between light and radio waves in the spectrum. It can be used to spot cavities in teeth.[19]

II.ENDODONTICS

1. Nano bone replacement materials: Nanotechnology is used to create "smart" material that will assist in the repair and regeneration of cellular tissue in the bone. Calcium phosphate enriched biomaterials have better handling properties, increased flow and blend well with host bone.These nanobone graft materials are osteo inductive, completely synthetic, non – sintered, extremely porous with bone targeting nanocarriers. Hydroxyapatite nanoparticles used to treat bone defects are Ostim® (Osartis GmbH, Germany) nano HA,VITOSSO (Orthovita, Inc, USA) HA +TCP, NanOSSTM (Angstrom Medica, USA) HA. These can be used in maxillofacial injuries requiring bone graft, cleft patient, endodontic surgeries and osseous defect in periodontal surgeries.[7]

2. Nanoparticles as antimicrobial agents: Nano particulates exhibit higher antibacterial activity as a result of their poly cationic or poly anionic in nature with higher surface area and charge density, resulting in a greater degree of interaction with the bacterial cell. These disinfect the canal by removing the residual microbes in the canal and enhance the antibacterial action of the intra canal medicaments. Nano particles have been applied in the treatment of bacterial bio films as well as wound healing primarily because of their antimicrobial properties and biocompatibility. These have been shown to provide a significant improvement in the root canal disinfection by effectively eliminating the residual adherent and non adherent bacteria as well as increasing the diffusion of antibacterial components from the root canal sealers. There is significant antibacterial efficacy against Enterococcus faecalis. Nano care plus is used for final rinsing of root canal treatment. It has Bacteriostatic effect. Due to its low surface tension, the nanoparticles penetrate into the smallest fissures and dental ducts of the system. As a result, even bacteria residing in the fissures in spore form after treatment have no chances for growth and development.[20]

3. Nanotechnology based endodontic sealer: One of the newest developments in Endodontics is the development of the endodontic sealer based on nanotechnology which actively seals the tiny gaps thereby reducing the infection. It is made up of calcium phosphate hydroxyapatite nanoparticles range from 40-60nm. The rod shaped active nanoparticles can penetrate the dentinal tubules and enter accessory canals to ensure that all the spaces are effectively sealed.[21]

4. Nanotechnology based root end sealant: Nanomaterial enhanced retrofill polymers (NERPs), a novel root end filling material, provides superior bond strength and adaptability to the tooth structure as compared to conventional retrofill materials. NERP materials were also found to significantly reduce the micro-leakage,demonstrating their ability to seal effectively and penetrate dentinal tubules of diameter 5 -10nm to provide additional 'nano retention'. Bio aggregate (BA), white nanoparticle ceramic cement is new-end filling material composed primarily of calcium silicate, calcium hydroxide, and hydroxyapatite.[22]

5. Denbur Nano-Brush: It is an innovative applicator that follows the natural anatomy to access the root canal. It can be used to remove the pulp from the chamber to clean the debris in the canal, or to apply cleansing and restorative materials onto the internal radicular surfaces in the canal. It promotes deep penetration of sealers into the dentinal tubules and lateral canals.[23]

6. Nanometric bioactive glass for root canal disinfection: Increased anti microbial efficacy by decreasing the size of glass particle size and increasing the surface area. It can be used as dentin disinfectant.[24]

7. Nanotech Endo: Nano technology based endodontic irrigation system used to rinse the root canals during RCT. It eliminates the disadvantages of traditional syringe and ensures maximum safety. No dental assistant required while operating this equipment. Also helps in preventing the accidental leakage of the liquids into patient's mouth and beyond root apex.[18]

8. Nano Needles and Nano tweezers: Suture needles with nano sized stainless steel crystals have been developed. Nano tweezers are also under development which will make cell surgery possible in the near future. The characteristics in general can be said to be a combination of properties of ordinary austenitic stainless and low alloyed ferritic steels.[25]

OBSTACLES TO OVERCOME:

There is no doubt that nanotechnology has great potential to bring benefits to society over a wide

range of applications, but nanodentistry still faces many significant challenges in realizing its tremendous potential.

1. Engineering challenges
   - Feasibility of mass production technique
   - Manipulating and coordinating activities of large numbers of independent microscale robots simultaneously
   - Precise positioning and assembly of molecular scale part
   - Economical nanorobot mass production technique.
2. Biological challenges
   - developing biofriendly nanomaterial
   - Biocompatibility
3. Social challenges
   - Ethics
   - Public Acceptance
   - Regulation and Human Safety

There are larger social issues of public acceptance, ethics, regulation and human safety that must be addressed before molecular nanotechnology can enter the modern medical armamentarium. Due to large surface area volume ratio of nanoparticles, there is always a chance of increased rate of absorption through the skin, lungs, or digestive tract. This could cause unwanted effects in the lungs and other organs throughout the body, as non-degradable nanoparticles could accumulate.[25]

CONCLUSION:

The far reaching potential of nanotechnology is now making it one of the most important and exciting areas of science .the future holds in store an era of dentistry in which dental procedures will be performed using equipment and devices based on nanotechnology. It encourages the concept of minimally invasive dentistry, creating a more dentist friendly atmosphere. Optimal utilization of the advantages and opportunities offered by nanotechnology in clinical dental practice will facilitate improvements in oral health. It is recognised that care has to be taken to ensure these advances come about in as safe a manner as possible.

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