

Review Article**Role of Nanotechnology in Dentistry****Dr Suhail Majid Jan¹, Dr Reyaz Ahmad Mir*², Dr Roobal Behal³, Dr Munaza Shafi⁴, Dr Mehraj Kirmani⁵, Dr Muzafar Ahmad Bhat⁶**¹Professor and Head, Department of Periodontics, Government Dental College Srinagar, India^{2,4,6}P.G Student, Department of Periodontics, Government Dental College Srinagar, India³Consultant, Department of Periodontics, Government Dental College Srinagar, India⁵Registrar, Department of Periodontics, Government Dental College Srinagar, India***Corresponding author**

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Abstract: The human characteristics of curiosity, wonder, and ingenuity are as old as mankind. People around the world have been harnessing their curiosity into inquiry and the process of scientific methodology. There is increasing optimism that nanotechnology applied to dentistry will bring significant advances in the diagnosis, treatment, and prevention of disease. Recently nanotechnology has emerged as a new science exploiting specific phenomena and direct manipulation of materials on nanoscale. 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.**Keywords:** Nanotechnology, Nanodentistry, Nanocomposite, Nanorobots, Nanomaterials

INTRODUCTION

The concept of nanotechnology introduced in 1959 by late Nobel Physicist Richard P Feynman in dinner talk said, "There is plenty of room at the bottom," [1] proposed employing machine tools to make smaller machine tools, these are to be used in turn to make still smaller machine tools, and so on all the way down to the atomic level, noting that this is "a development which I think cannot be avoided". He suggested nanomachines, nanorobots, and nanodevices ultimately could be used to develop a wide range of automatically precise microscopic instrumentation and manufacturing tools, could be applied to produce vast quantities of ultrasmall computers and various nanoscale microscale robots. Feynman's idea remained largely undiscussed until the mid-1980s, when the MIT educated engineer K Eric Drexler published "Engines of Creation", a book to popularize the potential of molecular nanotechnology [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 [3]. One nanometer (nm) is a unit of length that equals 1 billionth of a meter [4]. Given that a single hair strand has a thickness of 100,000 nm, it becomes easier to

visualize what is meant by "nano" and to understand its significance [5].

According to the definition of the National Nanotechnology Initiative, nanotechnology is the direct manipulation of materials at the nanoscale [6]. 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 [7, 8].

Nanotechnology is based on the idea of creating functional structures by controlling atoms and molecules on a one-by-one basis. What makes nanoparticles interesting and bestows unique features upon them is the fact that their size is smaller than the critical lengths defining many physical events. In general, nanotechnology is translated as "the science of the small"[9]. However, in addition to creating small structures, nano-technology involves inventing materials, devices, and systems with physical, chemical, and biologic properties that differ from those of large-scale structures.

TECHNIQUES IN NANOTECHNOLOGY

Top-down Technique

In this technique smaller devices are created by using larger ones to direct their assembly. So, small features are made by starting with larger materials patterning and carving down to make nanoscale structures in precise patterns. Complex structures containing hundreds of millions of precisely positioned nanostructures can be fabricated. Materials are reduced to the nanoscale and can suddenly show very different properties, enabling unique applications. As the size of system decreases there is increase in ratio of surface area to volume and number of physical phenomena becomes noticeably pronounced

Bottom-up Technique

In this technique smaller components are arranged into more complex assembly. This begins by designing and synthesizing custom made molecules that have the ability to self-assemble or self-organize into higher order mesoscale or macroscale structures. Modern synthetic chemistry has reached the point where it is possible to prepare small molecules to almost any structure. These methods are used today to manufacture a wide variety of useful chemicals such as pharmaceuticals or commercial polymers. Such bottom-up approaches are much cheaper than top-down methods, but could potentially be overwhelmed as the size and complexity of the desired assembly increases.

NANOMATERIALS

Siegel has classified nanomaterials as zero dimensional, one dimensional, two dimensional and three dimensional nanostructures [10]. Various nanostructures include: Nanoparticles, Nanopores, Nanotubes, Nanorods, Nanospheres, Nanofibers, Nanoshells, Dendrimers & dendritic copolymers. Inorganic nanoparticles either currently in use or under development include (Semiconductor nanoparticles, Metal nanoparticles, Metal oxide nanoparticles, Silica nanoparticles, Polyoxometalates, Gold nanocrystals)

NANODENTISTRY AND ITS APPLICATIONS

Nanodentistry will make possible the maintenance of comprehensive oral health by employing nanomaterials, biotechnology, including tissue engineering, and ultimately, dental nanorobotics. Nanodentistry includes:

- Nanorobotics
- Nanodiagnosics
- Nanomaterials

NANOROBOTICS

Local Anaesthesia

One of the most common procedure in dental practice, to make oral anesthesia, dental professionals will instill a colloidal suspension containing millions of active analgesic micron-sized dental nanorobot 'particles' on the patient's gingivae. After contacting the surface of the crown or mucosa, the ambulating

nanorobots reach the dentin by migrating into the gingival sulcus and passing painlessly through the lamina propria or the 1-3-micron thick layer of loose tissue at the cementodentinal junction. On reaching dentin, the nanorobots enter dentinal tubules holes that are 1-4 microns in diameter and proceed toward the pulp, guided by a combination of chemical gradients, temperature differentials, and even positional navigation, all under the control of the onboard nanocomputer as directed by the dentist [11]. Once installed in the pulp and having established control over nerve impulse traffic, the analgesic dental nanorobots may be commanded by the dentist to shut down all sensitivity in any particular tooth that requires treatment. When on the hand-held controller display, the selected tooth immediately becomes numb. After the oral procedures completed, the dentist orders the nanorobots to restore all sensation, to relinquish control of nerve traffic and to egress, followed by aspiration. Nanorobotic analgesics offer greater patient comfort and reduced anxiety, no needles, greater selectivity, and controllability of the analgesic effect, fast and completely reversible switchable action and avoidance of most side effects and complications.

Hypersensitivity Cure

Dentin hypersensitivity may be caused by changes in pressure transmitted hydrodynamically to the pulp. teeth. Natural hypersensitive teeth have eight times higher surface density of dentinal tubules and diameter with twice as large than nonsensitive teeth. Reconstructive dental nanorobots, using native biological materials, could selectively and precisely occlude specific tubules within minutes, offering patients a quick and permanent cure.

Dental Biomimetics

The most interesting venue for speculation on the nanorestoration of tooth structures is that of nanotechnology mimicking processes that occur in nature (biomimetics), such as the formation of dental enamel. Through an affordable desktop manufacturing facility, fabrication of a new tooth in the dentist's office within the time & economic constraints of a typical dental office visit, complete dentition replacement therapy will become feasible soon.

Chen *et al* utilizing nanotechnology simulated the natural biomineralization process to create the dental enamel, using highly organized microarchitectural units of nanorod-like calcium hydroxyapatite crystals arranged roughly parallel to each other [12].

Dental Durability and Cosmetics

Artificial materials such as sapphire or diamond, which have 20 to 100 times the hardness and failure strength of natural enamel or contemporary ceramic veneers, as well as good biocompatibility, are nowadays used to improve the durability & appearance of tooth. Though sapphire is susceptible to acid corrosion, it can

be manufactured in virtually any color, offering interesting cosmetic alternatives to standard whitening and sealant procedures. Pure sapphire and diamond are brittle and are prone to fracture if sufficient shear forces are imposed, but they can be made more fracture-resistant as part of a nano-structured composite material that possibly includes embedded carbon nanotubes.

Orthodontic Treatment

Orthodontic nanorobots could directly manipulate the periodontal tissues, including gingivae, periodontal ligament, cementum and alveolar bone, allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours. This is in contrast to current molar-uprighting techniques, which require weeks or months to complete.

Dentirobots

Subocclusal dwelling nanorobotics dentifrice delivered by mouthwash or toothpaste could patrol all supragingival and subgingival surfaces at least once a day, metabolizing trapped organic matter into harmless and odorless vapors and performing continuous calculus debridement. These invisibly small dentifrobots [1-10 micron], crawling at 1-10 microns/sec, would be inexpensive, purely mechanical devices, that would safely deactivate themselves if swallowed, and would be programmed with strict occlusal avoidance protocol. Properly configured dentifrobots could identify and destroy pathogenic bacteria residing in the plaque and elsewhere, while allowing the ~500 species of harmless oral microflora to flourish in a healthy ecosystem. Dentifrobots also would provide a continuous barrier to halitosis, since bacterial petrification is the central metabolic process involved in oral malodor.

Renaturalization Procedures

Dentition renaturalization procedures may become a popular addition to the future dental practice, made possible through esthetic dentistry. This can be mainly used in patients who desire to have their old dental amalgams excavated and their teeth remanufactured with native biological materials. Full coronal renaturalization procedures in which all fillings and crowns are removed, and the affected teeth are remanufactured to become indistinguishable from the original teeth.

NANODIAGNOSTICS

Nanoscale Cantilevers

These are flexible beams resembling a row of diving boards that can be engineered to bind to molecules associated with cancer.

Nanopores

These are tiny holes that allow DNA to pass through one strand at a time. They will make DNA sequencing more efficient.

Nanotubes

These are carbon rods about half the diameter of a molecule of DNA that not only can detect the presence of altered genes but also may help researchers pinpoint the exact location of those changes.

Quantum Dots

These are nanomaterials that glow very brightly when illuminated by ultraviolet light. They can be coated with a material that makes the dots attach specifically to the molecules to be tracked. Quantum dots bind themselves to proteins unique to cancer cells, literally bringing tumours to light.

Nano Electromechanical Systems (NEMS)

Nanotechnology based NEMS biosensors that exhibit exquisite sensitivity and specificity for analyte detection, down to single molecule level are being developed. They convert (bio) chemical to electrical signal [13].

Lab-on-a-chip methods

Lab-on-a-chip (LOC) is a device which integrates several laboratory functions on a single chip. LOCs deal with the handling of extremely small fluid volumes down to less than pico liters.

Assays are performed on chemically sensitized beads populated into etched silicon wafers with embedded fluid handling and optical detection capabilities. Complex assays can be performed with small sample volumes, short analysis times, and markedly reduced reagent costs. LOC methodologies have been used to assess the levels of interleukin-1beta (IL-1beta), C-reactive protein (CRP), and matrix metalloproteinase-8 (MMP-8) in whole saliva, which are potential use of these biomarkers for diagnosing and categorizing the severity and extent of periodontitis [14,15].

NANOMATERIALS IN DENTISTRY

Nanocomposites

Non agglomerated discrete nanoparticles are homogeneously distributed in resins or coatings to produce nanocomposites. The nanofiller used includes an aluminosilicate powder having a mean particle size of 80 nm and a 1:4 M ratio of alumina to silica and a refractive index of 1.508.

Advantages: Superior hardness, flexible strength, modulus of elasticity, translucency, esthetic appeal, excellent colour density, high polish & polish retention & excellent handling properties.

Nanosolution

Nanosolutions produce unique and dispersible nanoparticles, which can be added to various solvents, paints & polymers in which they are dispersed homogeneously. Nano technology in bonding agents ensures homogeneity and that the adhesive is perfectly mixed everytime [16].

Esthetic Materials

With the combination of finishing and polishing procedures, a nanotechnology liquid polish application might provide a glossier surface for resin composite restorations.

Nano-optimised Mouldable Ceramics

- Nanofillers - Enhances polishing ability and reduces wear.
- Nanopigments - Adjust the shade of the restoration to the surrounding teeth (chameleon effect).
- Nanomodifiers - Increases the stability of the material and prevent sticking to instruments.

Impression Materials

Nanofillers are integrated in vinylpolysiloxanes, producing a unique addition of siloxane impression materials. The material has better flow, improved hydrophilic properties and enhanced detail precision [17].

Materials to Induce Bone growth

Bone is a natural nanostructured composite composed of organic compounds (mainly collagen) reinforced with inorganic ions (HA). It is this natural nanostructure that nanotechnology aims to emulate for dental applications. The smaller the particle size, the larger the surface area in volume. Nanobone uses this principle. The nanocrystallites show a loose microstructure, with nanopores situated between the crystallites. This material structure will be completed by pores in the micrometer area. By following this process, a rough surface area is formed on the boundary layer between the biomaterial and cell, which is very important for fast cell growth. All pores are interconnecting. Because the cells are too big for the small pores, blood plasma containing all the important proteins is retained in the interstices [18].

Hydroxyapatite nanoparticles used to treat bone defects are: Ostium (Osartis GmbH, Germany) HA, VITOSSO (Orthovita, Inc, USA) HA + TCP, NanOSS™ (Angstrom Medica, USA) HA.

Nanoneedles

Suture needles incorporating nano-sized stainless steel crystals have been developed. Nanotweezers are also under development which will make cell-surgery possible in the near future.

Nanomaterials for Periodontal Drug Delivery

Nanomaterials widely explored for controlled drug release are hollow spheres, core-shell structure, nanotubes and nanocomposite. Drugs can be incorporated into nanospheres composed of a biodegradable polymer, and this allows for timed release of the drug as the nanospheres degrade facilitating site-specific drug delivery.

Implants

Nanotechnologies are increasingly used for surface modifications of dental implants as surface properties such as chemistry and roughness play a determinant role in achieving and maintaining their long-term stability in bone tissue. Direct bone-to-implant contact is desired for a biomechanical anchoring of implants to bone rather than fibrous tissue encapsulation [19].

SUMMARY AND CONCLUSION

Nanotechnology is part of a predicted future in which dentistry and periodontal practice may become more high-tech and more effective looking to manage individual dental health on a microscopic level by enabling us to battle decay where it begins with bacteria. Construction of a comprehensive research facility is crucial to meet the rigorous requirements for the development of nanotechnologies.

Researchers are looking at ways to use microscopic entities to perform tasks that are now done by hand or with equipment. This concept is known as nanotechnology. Tiny machines, known as nanoassemblers, could be controlled by computer to perform specialized jobs. The nanoassemblers could be smaller than a cell nucleus so that they could fit into places that are hard to reach by hand or with other technology. Used to destroy bacteria in the mouth that cause dental caries or even repair spots on the teeth where decay has set in, by use of computer to direct these tiny workers in their tasks.

Nanotechnology has tremendous potential, but social issues of public acceptance, ethics, regulation, and human safety must be addressed before molecular nanotechnology can be seen as the possibility of providing high quality dental care to the 80% of the world's population that currently receives no significant dental care.

Role of periodontitis will continue to evolve along the lines of currently visible trends. For example, simple self-care neglect will become fewer, while cases involving cosmetic procedures, acute trauma, or rare disease conditions will become relatively more commonplace.

Trends in oral health and disease also may change the focus on specific diagnostic and treatment modalities. Increasingly preventive approaches will reduce the need for cure prevention a viable approach for the most of them.

Diagnosis and treatment will be customized to match the preferences and genetics of each patient. Treatment options will become more numerous and exciting. All this will demand, even more so than today, the best technical abilities, professional skills those are the hallmark of the contemporary dentist and periodontist. Developments are expected to accelerate significantly.

Nanometers and nanotubes, technologies could be used to administer drugs more precisely. Technology should be able to target specific cells in a patient suffering from cancer or other life-threatening conditions. Toxic drugs used to fight these illnesses would become much more direct and consequently less harmful to the body.

CONCLUSION

It is obvious that, recent developments in nanomaterials & nanotechnology will improve dentistry, health care and human life more profoundly than other developments. A successful future for nanotechnology will only be achieved through open sharing of ideas and research finding, through testing and frank discussion. Current work is focused on nanoparticles and nanotubes for periodontal management, the materials developed from such as the hollow nanospheres, core shell structures, nanocomposite, nanoporous materials, and nanomembranes will play a growing role in materials development for the dental industry.

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