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Review Article

Application of nanotechnology in clinical dentistry type of manuscript: Review article

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ABSTRACT

Over the years, dentistry has undergone multiple phases of revolution, increasing its reliability and patients' comfort. One of these, "NANOTECHNOLOGY," has the potential to fundamentally alter how management and diagnostics are performed. A preliminary vision by Feynma led to the conception of nanotechnology in 1959. Since the dimensions of nanotechnology have been understood, it has been suggested that nanotechnology is the sector with a great potential for development considering its implications in the different fields of medical and dental sciences.

Several nanotechnology advancements have been applied in the field of oral health over the past 10 years, however many of these applications are still in their early years. Just a few of the several dental applications of nanotechnology include dentition renaturalization, treatment for dentin hypersensitivity, full-visit orthodontic realignment, covalent bonding of diamondized enamel, enhanced root canal sealant properties, and currently ongoing oral health maintenance using mechanical dentifrobots.

Numerous artificial nanoparticles, such as hydroxyapatite, bio glass, titanium, zirconia, and silver nanoparticles, are recommended for dental restoration. If executed correctly, the discipline of nanotechnology has the potential to significantly benefit human society by enhancing health, better utilizing natural resources, and reducing environmental pollution. Every procedure in dentistry in the future will be performed with instruments and technologies based on nanotechnology.

1. Introduction

The word "Nano" is a Greek word that means "dwarf." Nanotechnology is the branch of science and engineering that deals with the design, synthesis, characterization, and use of materials and devices whose smallest functional arrangement in at least one dimension is on the nanoscale scale (one billionth of a metre).[1,2]

In comparison to the parent material, nanomaterials have better characteristics. The two main types of change are (1) caused by an increase in surface area and (2) by quantum effects. With the resulting increase in surface area, more of these nanoscale components can be integrated as the material size approaches nanoscale levels.[3] Quantum effects are the changes in the optical, electric, and magnetic properties that occur when a material gets nearer to the nanoscale.[3]

There are several disciplines, such as production technology, information technology and electronics, environment, energy conservation, nano-biosystems, medical appliances, transportation, economy, etc. could benefit from advances in nanotechnology and the science of nanomaterials.[2]

Numerous medical applications of nanotechnology exist, including medication development and imaging. A further efficient and safe method of treating a disease is the targeted delivery of medications to cancerous cells along

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with other unhealthy/diseased cells. There are numerous possible applications of nanotechnology in various fields, but above everything the development of more efficient as well as novel applications would be the development of various efficient medical therapies. [1–3]

In contrast to the use of nanotechnology in fields like medicine, advancements in dentistry have been quite modest. Numerous hypothetical statements based on the potential uses of nanotechnology in dentistry have been made over the past ten years, with varied degrees of certainty. By offering advanced preventive, diagnostic, and therapeutic procedures using nanomaterials, biotechnology, and nanorobots, Nano dentistry has the potential to enhance oral health. [1,2]

Before nanotechnology to flourish in the delivery of high-quality dental treatment, public acceptance, human safety, and legal laws must be effectively addressed. Nanotechnology has an excellent potential to provide newer era materials and methods for dentistry. Additionally, the science of nanotechnology entails a potential of abuse and misuse on a scale never before deemed possible by mankind. [4] Nanoparticles are being employed in resin-based composite (RBC) restorations and preventive dentistry, notably in the management and control of bacterial biofilms, according to current research in dentistry. The numerous uses of nanotechnology in dentistry and their potentially expansive prospects will be highlighted in this article. [2,5,6]

2. History

James Clerk Maxwell first put forth the revolutionary concept of nanotechnology in 1867. Professor Kerie E. Drexler coined the term "nanotechnology." The idea of nanomaterials was introduced by Richard Zsigmondy in the beginning of the 20th century.

The Nobel Prize winner Richard P. Feynman stated in 1959 that his colleague Albert R. Hibbshad had made a captivating suggestion for extraordinarily tiny machines. [7]

In the year 2000, R.A. Freitas Jr. invented the term "Nano dentistry." He explored ideas for utilizing nanorobots in dentifrices-dentifrobots, orthodontics, nanomaterials, and dentition regeneration. Although most of his concepts were and still are science fiction, they are slowly becoming reality. There are now numerous uses for nanoscale technology in the field of dentistry. [1,8,9]

3. Discussion

The fabrication techniques of these structures can be divided into 2 approaches: "top- down" and "bottom up". [10]

1. Bottom-up approaches: Assembly of small components into compound structures.

3.1. Dental nanorobotics - Bottom-up approach

3.1.1. Local nano-anaesthesia [10,11]

To create local anaesthesia, a colloidal suspension of anaesthetic dental nanorobots would be utilised. The nanorobots would be deposited on the gingival tissue and would migrate from the dentin to the pulp via the dentinal tubules under the direction of a Nano computer that was controlled by the dentist. They would be guided by chemical differentials, temperature gradients, and positional steering. The analgesic robots may stop all tooth sensation once they reach the pulp. Once the procedure is finished, the nanorobots may be programmed to restore all sensation of the tooth. This method is useful since it decreases anxiety and is quick and completely reversible.

3.1.2. Hypersensitivity cure [10–12]

Dental nanorobots for reconstruction could quickly and effectively occlude specific tubules utilising native biological materials, providing patients with a long-lasting treatment.

3.1.3. Tooth repositioning [10]

Orthodontic nanorobots may be used to control all the periodontal tissues, like the gingiva, PDL, cementum, as well as alveolar bone, enabling quick and pain-less corrective movements.

3.1.4. Nanorobotic dentifrice (Dentifrobots): [11,12]

Using toothpaste or mouthwash, sub occlusal-dwelling nanorobotic dentifrice could monitor all supragingival and subgingival surfaces at least once each day.

3.1.5. Dental durability and cosmetics: [12]

Substitute synthetic materials having covalent bonds, such sapphire or diamond, for the higher enamel layers., to increase tooth endurance and esthetics.

3.1.6. Nanodiagnostics (Photosensitizers and carriers): [8,11]

It has already become an attainable potential to study numerous biochemical reactions directly by intracellular imaging using naturally fluorescent proteins. Additionally, quantum dots might function as a transporter and photosensitizer. When stimulated by UV light, they attach the antibody to the target cell and cause the production of reactive oxygen species, which destroy the target cells. Overcoming some limitations of biochip technology may be another use for nanotechnology.

3.1.7. Nanotherapeutics / Drug delivery

The solubility concerns will be resolved through nanotechnology, which will also result in a decrease in drug dosage and a decrease in side effects. This could be

used to treat conditions including Alzheimer's, Parkinson's, and brain diseases, among others.[10,11]

3.1.8. Gene therapy

By repairing or replacing faulty genes that cause disease development, this approach prevents or treats genetic illnesses. In general, there are three different types of gene delivery systems: non-viral vectors, viral vectors, & the direct injection of genes into target tissues (gene guns).

4. Diagnosis of oral cancer[10–12]

1. Nanoscale cantilevers: Elastic beams used to attach with cancer linked molecules.
2. Nanopores: DNA can travel through these tiny holes one strand at a time, which greatly increases the efficiency of DNA sequencing.
3. Nanotubes: Carbon rods that can locate and identify damaged genes.
4. Quantum dots: In UV light, these gleam very brightly. They bind to cancer-related proteins, localizing tumors as a result.

4.1.

4.1.1. Treatment of oral cancer[10,11,13]

1. Nanomaterials for brachy therapy
2. BrachySilTM delivers 32P
3. Nano-vectors for gene therapy
4. Non-viral gene delivery systems

4.1.2. Nano-tissue engineering:[9]

Using highly organised nanorod microarchitectural units, Chan et al. reconstructed dental enamel using the concepts of replacing the entire dentition.

4.2. Dental nanomaterials - as top-down approach

4.2.1. Nanocomposites

To create a commercially available nanocomposite, individual nanoparticles are not agglomerated and are evenly dispersed across resins or coatings. The nanofiller employed is an aluminosilicate powder with a 1: 4 ratios of alumina to silica and a mean particle size of about 80 nm. The refractive index of this nanofiller is 1.508.[12]

Table 1: Advantages:[11,14]

↑ hardness
↑ flexural strength, toughness, and translucency
↓ polymerization shrinkage (almost 50%).
Exceptional handling properties
↑ polish retention
↑ translucency giving it more lifelike appearance.

4.2.2. Nano-solution (Nano adhesives)[11]

Dispersible nanoparticles are being utilised to create nano-solutions, which are then included into bonding agents. They consistently result in an adhesive that is homogeneous and correctly blended.

4.2.3. Nano Light-curing glass ionomer restorative:[12,14]

This combines fluor-alumino silicate technology with nanotechnology that was first developed for Filtek TM Supreme Universal Restorative.

4.3. Clinical indications

1. Restoration of deciduous teeth
2. Transitional restoration.
3. Class I restoration that are small.
4. Sandwich technique of restoration
5. Class III and V restoration.
6. For Core build-up.

4.3.1. Impression materials:[12]

Nanofillers have been added to conventional vinylpolysiloxanes, creating a novel material that has increased flow, improved hydrophilic characteristics, and better detailed precision.

Trade name: Nano Tech Elite H-D+

4.3.2. Nano-composite denture teeth

Conventional denture teeth have a drawback of their own. Although porcelain is very resistant to wear, it is fragile, incapable of adhering to the base of a denture, and difficult to polish. On the other hand, acrylic is flexible but is subject to excessive wear. Denture teeth comprised of nanocomposite materials are composed of polymethylmethacrylate (PMMA) and evenly dispersed nanofillers.[12]

4.3.3. Nanoencapsulation

SWRI i.e, South-West Research Institute has created specialised targeted release systems. They include nano-capsules that are used to deliver medications with less side effects, antibiotics, and novel vaccines. Japan's Osaka University made it possible to deliver medications and genes specifically to the human liver in 2003. Future research may result in the creation of specific nanoparticles that target oral tissues.

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4.3.5. Laser plasma application for periodontia:[1,11]
When a nanosized titanium particle emulsion is applied to human skin and then exposed to laser light, the titanium particles disintegrate along with other effects such as shock waves, microabrasion of hard tissues, and stimulation of collagen production.

4.3.6. Bone replacement materials:[11,13]
Bone is a naturally occurring nanocomposite comprised of organic substances (mostly collagen) that have been hardened by inorganic substances like hydroxyapatite. Orthopaedic and dentistry applications should imitate this design. Additionally, the surface area multiplies with the reduction in particle size. Nano-Bone® has implemented the utilisation of this regulation. By employing crystals of the highly structured calcium hydroxyapatite that have already been organised in a parallel pattern, Chen et al. have attempted to produce tooth enamel.

4.3.7. Prosthetic implants
Nanotechnology would be beneficial in the production of surfaces with specified structural and chemical properties that enable predictable tissue-integration**.** The type of peri-implant tissues will be precisely identified by tissue differentiation into an identifiable lineage. In addition, while the CaP coating is applied to Ti implants, antibiotics or growth hormones may be added such as the NanotiteTM Nano-Coated Implant.

4.3.8. Radiopacity
Can be inculcated in materials & various instruments to achieve a distinguishable radiopacity

4.3.9. Orthodontic wires
Orthodontic wires can be made from a novel stainless-steel material like, Sandirk Nanoflex.

4.3.10. Nanoneedles
Suture needles have been produced using nanostructured stainless-steel crystals. (AB Sandvik, Sweden's SandvikBioline, RK 91 needles).

4.3.11. Nano-sterilizing solution
Based on nano-emulsion technology, Gandly Enterprises Inc. of Florida has developed a brand-new sterilising solution. Oil droplets with a nanometer in diameter attack and kill the bacteria.

4.4. Regenerative nanotechnology - Biomimicry[11,12,14]

4.4.1. Dentition renaturalization
This method might completely change cosmetic dentistry. The teeth may initially be remodeled with natural materials after the removal of obsolete amalgam restorations. Then, all previous treatments could be left, and all the teeth could possibly be remineralized so that they appear like natural teeth. This is known as complete coronal renaturalization.[11,12]

4.4.2. Dentition replacement therapy (Major tooth repair)
Nanotechnology can first use tissue engineering, genetic engineering, and tissue regeneration before growing and implanting totally new teeth in vitro.

4.5. Challenges faced in nanotechnology[11,12,15]

1. Precise positioning and manufacture of nanoscale parts.
2. Social issues of public acceptance, ethics, regulation and human safety.
3. Inadequate assimilation of clinical research.
4. Synchronization of numerous independent nanorobots.
5. Biocompatibility concern.
6. Financing and tactical concerns
7. Cost-effective nanorobot mass manufacturing methods.

5. Conclusion

Although the impact of nanotechnology in dentistry is currently confined to the usage of materials that are already available in the marketplace, continual advancement in research will assure that future advancements that are currently incomprehensible will be achievable. Future advancements in oral health will be made possible through the utilization of nanotechnology's potential. Dental care as well as oral health will be improved by new pharmaceutical techniques, innovative diagnostic and treatment methods, and advanced restorative materials.

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7. Conflict of Interest

None.

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