



Recent Advances of Nanotechnology in Endodontics, Conservative and Preventive Dentistry-A Review

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Abstract

Nanotechnology has revolutionized all aspects of health including the dentistry. It is the science of producing functional materials and structures in range of 0.1 nm to 100 nm. The most important contribution of nanotechnology to conservative dentistry is the more enhanced restoration of tooth structure with nanocomposites. The field of nanotechnology has tremendous potential, which if harnessed efficiently, can bring out significant benefits to the human society such as improved health, better use of natural resources. The future beholds an era of dentistry in which every procedure will be performed using equipments and devices based on nanotechnology. This article reviews the applications of nanotechnology in Endodontics, Conservative and Preventive dentistry.

Keywords: Nanotechnology; Nanodentistry; Nanocomposites; Dentifrobots; Nanosolution

Introduction

Nanotechnology has revolutionized all aspects of health including the dentistry. It is the science of producing functional materials and structures in range of 0.1 nm to 100 nm [1]. The term was coined by Prof. Kerie E. Drexler, in 1980's derived from Greek word which means 'dwarf' [2]. The purpose of Nanodentistry is to maintain the near-perfect oral health through the use of nanomaterials including tissue engineering and nanorobotics [3]. The structures are fabricated by 2 approaches either "top-down" and "bottom-up" [4,5]. The purpose of this article is to review current status of nanotechnology in restorative dentistry.

The Approaches from Bottom-Up Are

1. Local anaesthesia: In order to reduce anxiety and to provide patient comfort, research is going to induce local anesthesia in the era of nanodentistry so as to provide greater selectivity, controllability of the analgesic effect and to avoid various complications.
2. A colloidal suspension containing millions of active analgesic micron size dental robot will be instilled on patient's gingivae. These nanorobots, after contacting the surface of the crown or mucosa, reach the dentin by migrating into the gingival sulcus and pass painlessly to the target site. On reaching the dentin, the nanorobots enter dentinal tubule holes that are 1 Am to 4 Am in diameter (10-12) 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. Once installed in the pulp, the analgesic dental robots may be commanded by the 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 exit from tooth by similar pathways used to enter [2,6].
3. Hypersensitivity cure: Dentine hypersensitivity is a pathological condition mainly caused by changes in pressure transmitted hydrodynamically to pulp. The hypersensitive teeth have dentinal tubules with surface densities that are eight times higher than those of non-sensitive teeth. Dental nanorobots could selectively and precisely occlude selected tubule in a minute thus offering patients a quick and permanent cure [6,7]. Nanorobotic dentifrices: The nanorobotic dentifrices delivered by mouthwash or toothpaste on subocclusal surfaces could act on supragingival and subgingival area by metabolizing trapped organic matter into harmless and odorless vapors thereby leading to continuous calculus debridement.
4. Dental durability and cosmetics: Tooth durability and appearance may be improved by replacing upper enamel layers with pure sapphire and diamond which can be made more fracture resistance as nanostructure composites, possibly including embedded carbon nanotubes.

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5. Orthodontic treatment.
6. Orthodontic nanorobots could directly manipulate the periodontal tissues, thus leading to rapid and painless tooth rotation, straightening and repositioning within minutes to hours. Sliding a tooth along an archwire involves a frictional type of force that resists this movement. Use of excessive orthodontic force might cause loss of anchorage and root resorption, but coating orthodontic wire with inorganic fullerene like tungsten disulfide nanoparticles, reduction in friction has been reported.
7. Photosensitizers and carriers: Quantum dots can be used as photosensitizers and carriers. They can bind to the antibody present on surface of target cell and when stimulated by UV light, give rise to reactive oxygen species which will be lethal to target cell.

Approaches from Top-Down Include

1. Nanocomposites: Nonagglomerated discrete nanoparticles are homogeneously distributed in resins or coatings to produce nanocomposites [8]. The nanofiller used includes an alumino silicate powder having a mean particle size of 80 nm, 1:4 ratio of alumina to silica and a refractive index of 1.508. These nanocomposites offer superior hardness, flexural strength, modulus of elasticity and 50% reduction in polymerization shrinkage. Commercially they are available as Filtek O Supreme Universal Restorative Pure Nano O.

2. Nanosolutions: It produces unique and dispersible nanoparticles which can be used in bonding agents. This insures homogeneity and adhesive is perfectly mixed every time. Trade name Adper O single bond plus Adhesive single bond.

3. Impression materials: Nanofillers are integrated in vinylpolysiloxanes, producing unique additions of siloxane impression materials, having better flow, improved hydrophilic properties and enhanced details. Commercially available as Nanotech Elite H-D.

4. Nanoencapsulation: South-west research institute has developed targeted systems that encompass nanocapsules include novel vaccines, antibiotics and drug delivery with reduced side effects [2]. Pinon-Segundo et al. [9] studied Triclosan loaded nanoparticles, 500 nm in size, used in an attempt to obtain a novel drug delivery system adequate for the treatment of periodontal disease. These particles were found to significantly reduce inflammation at the experimental sites. An example of the development of this technology is arrest in which minocycline is incorporated into microsphere for drug delivery by local means to a periodontal pocket. Nanoneedles: Suture needles incorporating nano sized stainless steel crystals have been developed. Nanoneedles like Sandvik Bioline, RK 91 needles are available.

5. Nanotweezers: In 1999, Philip Kim and Charles Lieber at Harvard University created the first general purpose nanotweezer.

6. Bone replacement materials: Hydroxyapatite nanoparticles named Ostium, Vitosso and NanOSS can be used in maxillofacial injuries as bone graft to treat cleft patients and in periodontal surgeries used to treat osseous defects.

Advances of Nanotechnology in Conservative Dentistry Nanocomposite

One of the most significant contributions to dentistry has been the development of resin based composite technology. Adhesively

bonded composites have the advantage of conserving sound tooth structure with the potential for tooth reinforcement, while at same time providing cosmetically acceptable restorations. However, no composite material has been able to meet both functional needs of posterior class I or II restorations and superior esthetics required for anterior restorations. There was a need to develop a composite dental that could excellent mechanical properties suitable for high stress – bearing restoration as well as superior polish retention. Nanoproducts Corporation has successfully manufactured nonagglomerated discrete nanoparticles that are homogeneously distributed in resins or coatings to produce nanocomposites. The nanofiller used include an alumino silicate powder having a mean particle size of 80 nm. Due to small particle sizes nanofillers are capable of increasing the overall filler level as high as 90% to 95% by weight. Since polymerization shrinkage is mainly due to the resin matrix, the increase in filler level results in a lower amount of resin in nanocomposites and will also significantly reduce polymerization shrinkage and dramatically improve the physical properties of nanocomposites. The nanocomposite is composed of three different types of filler components: nonagglomerated discrete silica nanoparticles, barium glass, and prepolymerized fillers.

Ormocers

A new organically modified ceramics based on sol-gel synthesis called Ormocers are widely used in nanocomposite restorative systems [10]. The particles are silicones, organic polymers, and ceramic glasses that are applicable to dental composites and the nanoparticle fillers are ZrO_2 .

Advances of Nanotechnology in Preventive Dentistry

Caries prevention fillers

To increase mineral content to control dental caries, calcium and phosphate ion-releasing fillers have been developed, such as nanoparticles of dicalcium phosphate anhydrous (DCPA) and tetracalcium phosphate [TTCP: $Ca(PO)_4$]-whiskers [11]. Recent studies by Xu et al. [12,13] have evaluated the incorporation of nano-sized $CaPO_4$ particles with resin bonded composites, with a resulting improvement in stress-bearing capacity, as well as ion release that could inhibit caries. Further investigation of this model using dicalcium phosphate anhydrous incorporated with nanosilica-fused whiskers found that it increased the strength of the resin bonded composites by as much as threefold while releasing $CaPO_4$. This release was greater with decreasing $CaPO_4$ particle size. The authors hypothesize that such a system could provide a desirable combination of caries prevention and increased restoration strength.

Nanofilled Resin Modified Glass Ionomer

For the restoration of primary teeth and small cavities in permanent teeth a new nano-filled Resin Modified Glass Ionomer (RMGIC) restorative material has been introduced. It is based on a prior Resin Modified Glass Ionomer (RMGIC) with a simplified dispensing and mixing system (paste/paste) that requires the use of a priming step, but no separate conditioning step. Its primary curing mechanism is by light activation, and no redox or self curing occurs during setting [14]. Apart from the user-friendliness, the major innovation of this material involves the incorporation of nano-technology, which allows a highly packed filler composition (69%), of which approximately two-thirds are nanofillers. Chemistry of nanoionomer is based on the

methacrylate modified polyalkenoic acid, which is capable of both crosslinking via pendent methacrylate groups as well as the acid-base reaction between the Fluoroaluminosilicate Glass (FAS) and the acrylic and itaconic acid copolymer groups. It contains surface treated nanofillers (approx 5 nm to 25 nm) and nanoclusters (approx 1 μ to 1.6 μ). Filler loading is approx. 69% by weight of which the relative proportion of two filler types (FAS and combination of nanofillers) are approx 2/5 and 3/5 respectively. All nanofillers are further surface modified with methacrylate silane coupling agents to provide covalent bond formation into free radically polymerized matrix [15].

Nanomaterials for Managing Oral Biofilms

Nanotechnology has been used to study the dynamics of demineralization/remineralization process in dental caries by using tools such as atomic force microscopy (AFM) which detect bacteria induced demineralization at an ultrasensitive level. Using AFM the correlation between genetically modified *Streptococcus mutans* scale morphology has been assessed. The nanoscale cellular ultra structure is a direct representation of genetic modifications as most initiate changes in surface protein and enzyme expression, where host-cell nutrient pathways and immune response protection likely occur. The surface proteins and enzymes, common to *S. mutans* strains are a key contributor to the carcinogenicity of these microbes. New silver nanotechnology chemistry has proven to be effective against biofilms. Silver works in a number of ways to disrupt critical functions in a micro-organism. For example it has a high affinity for negatively charged side groups on biological molecules such as sulphhydryl, carboxyl, phosphate and other charged groups distributed throughout microbial cells. Silver attacks multiple sites within the cell to inactivate critical physiological functions such as cell wall synthesis, membrane transport, nucleic acid (RNA and DNA) synthesis and translation, protein folding and function and electron transport. For certain bacteria as little as one part per billion of silver may be effective in preventing cell growth. Recent studies show that ionic plasma disposition silver antimicrobial nanotechnology is effective against pathogens associated with bio-films including *E. coli*, *S. pneumoniae*, *S. pneumoniae*, *S. aureus* and *A. niger* [16].

Advances of Nanotechnology in Endodontics

Nanoparticulate based disinfection in endodontics

The most efficient disinfection of root canals with nanoparticles has gained popularity in the recent years. This is mainly due to the broad spectrum antibacterial activity [17,18]. The nanoparticles evaluated in endodontics include Chitosan, zinc oxide and silver [19]. The efficacy of chitosan and zinc oxide nanoparticles against *Enterococcus faecalis* has been attributed to their ability to disrupt the cell wall. In addition, these nanoparticles are also able to disintegrate the biofilms within the root canal system [17,20,21]. Silver nanoparticles are being evaluated for use as root canal disinfecting agents. It has been shown that 0.02% silver nanoparticle gel is able to kill and disrupt *Enterococcus faecalis* biofilm [22,23]. Another revolutionary introduction in the field of endodontics, the fundamental basis of which lies in nanotechnology, is bioactive glass ($\text{SiO}_2\text{-Na}_2\text{O-CaO-P}_2\text{O}_5$). The use of $\text{SiO}_2\text{-Na}_2\text{O-CaO-P}_2\text{O}_5$ has been suggested for root canal disinfection [24,25]. The antimicrobial effect of bioactive glass is due its ability to maintain an alkaline environment over a period of time. The efficacy of 45S5 bioactive suspension-nanometric/micrometric hybrid as an antimicrobial agent showed that a ten-fold increase in silica release and 3 units of pH elevation was found with the nanometric bioactive

glass [26].

Materials for endodontic regeneration

Teeth with degenerated and necroses pulps are routinely saved by root canal therapy. Although current treatment modalities offer high levels of success for many conditions, an ideal form of therapy might consist of regenerative approaches, in which diseased or necrotic pulp tissues are removed and replaced with healthy pulp tissues to revitalize teeth. In their study, Fioretti et al. [27] showed that a-MSH (melanocortin peptides) possess anti-inflammatory properties and also promote the proliferation of pulpal fibroblasts. They reported the first use of nanostructured and functionalized multilayered films containing a-MSH as a new active biomaterial for endodontic regeneration.

Challenges faced by nanodentistry

Although nanotechnology appears to introduce ground breaking techniques and devices in the dental field, there are some concerns as well. These include economical nanorobot mass production technique, ethical issues and human safety, biocompatibility issues and the expertise in precise positioning and technique. Nanotechnology is foreseen to change health care in a fundamental way by providing novel methods for disease diagnosis and prevention, therapeutics selection, tailored to the patients profile, drug delivery and gene therapy.

Conclusion

The future of dentistry will be changed with Nanotechnology which will have profound effect on health care and human life. It will give a new vision to comprehensive oral health care which will lead to more changes in the preventive intervention rather the curative one. Nanodentistry is still developing but has a strong potential to revolutionize dentistry by new technique in diagnosis and treatment of dental diseases. It can open new avenues for research work in dentistry. However, there can be increased social issues related to public acceptance, ethics, regulation, and human safety. These issues can be addressed before molecular nanotechnology can enter the modern medical and dentistry.

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