Nanotechnology in Conservative Dentistry & Endodontics

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Introduction

Nanotechnology the science of atoms and molecules within the nanometer scale has expanded to all the areas of science . It is defined as the creation of functional material , device or symptoms through the control of matter on the nanometer scale. According to european commission , nanomaterials are those natural , incidental or manufactured materials which contain particles in non-binding states , which agglomerates or aggregates in which 50% or more of the particles are in range of 1 and 100 nm[1]. Dental materials have evolved with the advent of nano-technological research focusing on the production and application of nanoparticle with high quality and structural characteristics. It is a much needed change in the scenario of dental materials which significantly improvise the materials for enhanced oral health care. The incorporation of nanoparticle like silver , silica , titanium dioxide etc represents an innovation by manufacturers to improve the chemical and physical properties of these materials along with the drastic improvement in the biological properties[2]. The main advantage of nanoparticles are its smaller size , higher surface area ,reduced side effects , low dosage, increased number of atoms on the surface, controlled ,targeted and uniform delivery[3].

History

The idea of nanotechnology first came from the physicist Richard Feynman in 1959. The term "nanotechnology" was coined by Norio taguchi at the tokyo science university in 1974[2]. Gerd Binning and Henrich Rohrer at IBM research lab zurich , developed scanning tunneling microscopy in 1980 which paved the path for further research . In 1984 Eric Drexler gave the concept of constructing molecular assemblers which are machines which could robotically assemble molecular materials and devices by manipulating individual atoms or molecules.

Production

Nanomaterials in dentistry are produced by two approaches

1) The Top Down approach- It is the creation of smaller structures by using bigger particles with the help of molecular assemblers[2].

Materials fabricated by this approach are:

a) Nanolightcuring GI restorative materials
b) Nano impression materials
c) Nanocomposite denture teeth
d) Nano needles
e) Nanocomposite

2) The Bottom Up approach- It is the technique in which smaller particles are agglom-eratedinto compound structures[2].

Materials fabricated by this approach are :

a) Anesthesia
b) Major tooth repair
c) Hypersensitivity cure
d) Dental durability and cosmetics
e) Nanorobotic dentrifice
f) Nano diagnostics

Application

1. Application of nanomaterials in treatment procedures

The use of nanoparticles with antimicrobial properties prevent the chance of drug resistance [3]. Evidencesalso have shown that the reactions occur between positively charged metal particles and negatively charged membranes of microorganism [4]. Metal nanoparticles which mostly used in oxidized form have higher surface area and unconventional shape making numerous highly reactive corners[5]. The affinity of metal nanoparticle to different microorganism varies, for example silver nanoparticles have high affinity for gram negative anaerobic microorganism[6], Chitosan is a positively charged polysaccharide from chitin family having high affinity for gram positive anaerobic microorganism[7]. Carbon nanotubes are allotropes of carbon with a cylindrical nanostructure used for water filtration and surface coating[8]. Nano quarternary ammonium disintegrate cellmembrane and kill microorganism thus preventing the biofilm formation.

2. Application of Nanomaterials in Delivery Systems

Nanoparticles can be used for the delivery of drugs , proteins, growth factors , genes and cells to the target sites. Different forms of delivery systems are :

a) Nano-Capsules

Encapsulation of drugs into nanoparticle shells is one method of protecting the drug during delivery and also protecting the body against very toxic drugs. Sustained release of drugs occur during a specific time period through the nanoparticles capsule at specific target location preventing the burst release of drug[9]. Nano capsules are mainly used in the delivery of protein and apoptein into the cancer cells, as a neutraceutical [13]and as a self healing material[14].

b) Nano Scaffolds

Nano scaffolds were used for drug and hormone delivery purpose , but later researchers found that these materials were capable of preserving and delivery of cells to human body. PIHCA (poly isohexyl cyanoacrylate) and PAA (polyacrylate) nanoparticles are used in drug delivery, RGDS and peptide amphiphilis are used in cell delivery.[f] They have many application in dentistry for regeneration of oral and dental tissue like the alveolar bone , PDL , dental pulp , even mineralizd tissue like enamel.

C) Nano coatings

Nano coatings are used for delivery of antibacterial agents like triclosan ,also in corporation of nitricoxide into the nano-silver coat enhances its diffusion into oral biofilm and subsequent elimination of bacteria.

D) Nanoshells

Nanoshells are nanoparticle with a dielectric core and a thin metal coating of gold nanoparticles. Infrared light stimulate the nanoshell and generates heat and thus can be used for thermal distribution of bacteria, cancer cells , ligature of vessels,wound healing and decreased angiogenesis. Nano shells loaded with antibodies , proteins or other cell-targetting agents can be used for targeted drug delivery[10].

E) Quantum Dots

Quantum dotsare a group of semiconductive nanoparticles like lead sulphide , zinc sulphide and indium sulphide that can radiate light based on the amount and wavelength of light radiated to them . They can also be used for treatment of head and neck disease via drug delivery , correction of genetic defects and also in prevention of cancer.

Application of Nanomaterials in General Dentistry

Because of the growing interest in the future of dental application of nanotechnology, a new field called nanodentistry is emerging. The development of nanodentistry will allow nearly perfect oral health by the use of nanomaterials and biotechnologies including tissue engin-eering and nanorobots.[38]

The new treatment opportunities in dentistry include local anesthesia, dentition reminer-alization, permanent cure of hypersensitivity, complete orthodontic realignment during a single office visit, covalently bonded diamon-dized enamel and continuous oral health maintenance with the help of mechanical dentifrobots (nanorobotic dentifrice) that destroy caries-causing bacteria and even repair blemishes on the teeth where decay has set in.[21]

Application In Conservative Dentistry And Endodontics

Silver Nanoparticles

Silver nanoparticles with already proven extensive antimicrobial activities have a scope of enormous applicability in conservative dentistry and endodontics. The antimicrobial properties can be attributed to its ability to

attack multiple site within the cells at a very low concetration (0.5-1.0%)[17] [18]. Agnps bind to the proteoglycans and bacterial cell membrane ,they interacts with sulfydryl group during protein synthesis and finally interfere with replication of bacterial DNA[19]. Agnps in aqueous composition comprising ethylene-diamine tetraacetic acid, chlorhexidine and N,N,N - trimethyl ammonium bromide can be used in root canal irrigation and found very effective against E. Faecalis[20].It can be conjugated in adhesives containing calcium phosphate [21], polyvinyl pyrrolidone,poly-acrylic acid, glycerol, antiseptic cetrimide and sodium alginate[22]. In a study to develop an acrylic resin containing silver nanoparticles as an antifungal agentconducted by acosta et al the result showed that PMMA silver nanoparticle significatly reduced the adherence c. Albicans to the surface without causing any genotoxic damage to the indegenous cells [38].In a study by samie et al using cross-linked poly (N-is opropylacry lamide-methacrylic acid-vinyl pyrrolidone) hydrogel containing silver nps [(silver cross-linked hydrogel nanocomposites (SCHNC)] the evaluation of antibacterial properties of SCHNC at a concentration of 30 ppm in root canals with E.Faecalis was done, the results, showed that SCHNC decreased E. Faecalis counts to below 10 CFU.It also have been found to be used in some commercialy available root canal sealers (Guttaflow bioseal by coltene whaledent)

Zincoxide Nanoparticles

The use of zinc oxide in dentistry has begun before many decades as a major filler component in many dental materials. Zinc oxide exhibit effective antibacterila activity and this effect is higher when zinc oxide is present as nanoparticle . Zno nps interact with cell membrane ,binds strongly with lipids and proteins altering the osmotic balance inside the cell and finally leads the increased cellular perme ability[23]. Calcium phosphate cements when incorporated with zincoxide nanoparticles have exhibited improved remineralization of depleted dentin and also changes within the hybrid layer which includes substantial gain in hardness and modulus of elasticity [24]. In a study to evaluate the antibacterial properties of composite resins containing 1% silver and zinc-oxide nanoparticles on Streptococcus mutans and Lactobacillus conducted by kasraei et al it was proved that Composites containing nano zinc-oxide particles or silver nanoparticles exhibited higher antibacterial activity against Streptococcus mutans and Lactobacillus [24].when incorporated into resin composite adhesives a potent antibacterial effect was observed which was more than the composites doped with agnp nanoparticle[25] in a study conducted by kishesn et al where the examination of the antibacterial and antibiofilm efficacy of different cationic nanoparticles for root canal disinfection was done , the results showed that the cationic nanoparticles like zno-NP, CS/zno-NP, or CS-layer-zno-NP when used in treating root canal surfaces significantly inhibited the bacterial adhesion to dentin and thus prevented the bacterial recolonization and biofilm formation [41].

Titanium Dioxide Nanoparticles

Titanium dioxide nanoparticle are highly potent and can be used along with various dental materials. It basically interacts with micro-organism in two ways , when exposed to UV rays it undergoes photo catalysis and produces reactive oxygen species which alter the osmotic equilibrium of bacteria. Further more it can also interfere with phosphorylation and causes oxidative cell death[26]. In a study to evaluate shear bond strength and the antibacterial effects of a composite after adding titanium oxide nanoparticles conducted by poosti et al tio_2 np when incorporated with light curable composite showed a reduction in enamel

Demineralization and provide antibacterial properties for dental adhesive systems without effecting its shear bond strength [26].it also has been incorporated into bleaching agents like hydrogen peroxide which helped in reducing the concentration of hydrogen peroxide to 6%[27].

Chitosan Nanoparticle

A long polymer cahin ,"chitosan" composed of randomly arranged N-acetyl - glucosamine and glucosamine residues, have been the new potential antibacterial agent available for dental application [28]. Chitosan nanoparticle acts by effecting the membrane permeability by causing an increase outward flow of ions from microbial cells causing mrna transcription inhibition and alteration of trnaslation of proteins owing to binding of chitosan to several microorganism nuclear material DNA [29].

In a study to evaluate the antimicrobial and cytotoxic activity of a formulation containing silver nanoparticles and chitosan, provisionally called nano silver fluoride (NSF), against Streptococcus mutans in comparison to chlorhexidine and silver diamine fluoride conducted by targino et al chitosan nps when incorpoorated with dental composite displayed high antibacterial activity against S.mutans[30]. In a study by shresta et alto assess the antibacterial effect of a novel photosensitizer (rose bengal functionalized chitosan nano-particles [csrbnp]) to eliminate bacteria in the presence of various root canal constituents that are known to inhibit the antibacterial efficacy of root canal disinfectants the results showed that photoactivation of RB syner-gistically provided csrbnp the potential to achieve significant antibacterial efficacy even in the presence of tissue inhibitors within root canals[].

Quaternary Ammonium Compounds Nano -particles

Nanostructured materials containing low concentrations (1%) of QAC have been recently tried in dentistry in view of their antibacterial effects against several species including S.mutans and lactobacillus casei[31]. QAC nanoparticles which are highly cationic cause adsorption of positively charged polymer on bacterial cell membrane and increases membrane permeability which leads to the lysis of cell membrane[32]. Gong et al conjugated quaternary ammonium compounds with organosilanes and silica nanoparticles which further when incorporated into resin composite adhesives have exhibited high antibacterial properties against S .mutans , actinomyces naeslundi , candida albicans , E faecalis[33].

ACP Nanoparticles

ACP have been incorporated into dental composites to release calcium and phosphate increasing the mineral content in the carious lesions. In a study to synthesize novel nanoparticles of amorphous calcium phosphate (NACP), develop NACP nanocomposite with calcium (Ca) and phosphate (PO4) ion release to combat caries, and investigate the effects of NACP filler level and glass co-filler rein forcement on composite properties conducted by Hockin et al At higher concentration ACP nanoparticles released calcium and phosphate ions stimulating the precipitation and deposition of these ions into the tooth structure which in turn resulted in remineralization[34].

Silica Nanoparticles

Silica nanopraticles which have antimicrobial properties within the oral cavity have recieved much attention in the recent years. It has been used in many tooth pastes to carry and deliver antimicrobials such as triclosan[35. Dental composites with silica nanoparticle s have proved an enhanced fracture toughness and adhesion to tooth tissue eg Filtek Z 350 by 3M ESPE [36]. Bioactive glasses of sio2 - Na2O-cao-P2O5 system have been shown to posses antimicrobial activity through the release of ionic alkaline species over time and are under consideration as dentine disinfectants to offer an alternative to calcium hydroxide .In a test by waltimo et al to access the Antimicrobial Effect of Nanometric Bioactive Glass 45S5 the results showed that nanoparticulate 45S5 substantially decreased the viability of the enterococci[43].It has been incorporated to rootcanal sealers due to its antimicrobial activity activity against E.faecalis eg MTA fillapex.

Conclusion

Various studies are been carried out in areas evaluating the production charecterization and application of nanoparticles in dentistry but still it is required to explore the behaviour of these structures exhibited in the oral cavity ,more number of studies are also needed for testing the existing nanoparticles for a clear understanding of their mechanism of action.

References

References are available on request at editor@healtalkht.com