NANOPARTICLES IN PREVENTIVE DENTISTRY

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***ABSTRACT*: Nano technology is the engineering of functional systems at the molecular scale, by the centre for responsible nanotechnology. Nanotechnology deals with the physical, chemical, and biological properties of structures and their components at nano scale 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. New potential treatment opportunities in dentistry may include, local anesthesia, dentition re-naturalization, and permanent hypersensitivity cure, and continuous oral health maintenance using mechanical dentifrobots. Nanotechnology is being beneficial in health care senses including dentistry by improving the diagnostic predictability, drug delivery and tissue engineering. The prevention of tooth decay and the treatment of lesions and cavities are ongoing challenges in dentistry. In recent years, biomimetic approaches have been used to develop nano materials for inclusion in a variety of oral health-care products. Examples include liquids and pastes that contain nano-apatites for biofilm management at the tooth surface, and products that contain nano materials for the remineralization of early sub micrometre-sized enamel lesions.**

Keywords: dentistry, nano particles, nanotechnology, biofilm

INTRODUCTION:

Nanomaterials are cornerstones of nanoscience and nanotechnology. Nanoscale materials are defined as a set of substances where at least one dimension is less than approximately 100 nanometers. Nanomaterials are of interest because at this scale unique optical, magnetic, electrical, and other properties emerge. These emergent properties have the potential for great impacts in electronics, medicine, and other fields.[(1)]

Nanotechnologyis the engineering of functional systems at the molecular scale, by the centre for responsible nanotechnology. In general, nanotechnology is translated as “the science of the small.”[(1)]

Nanoscience is the study of atoms, molecules, and objects whose size is on the nanometer scale (1 -100 nanometers).[(1)]

The aims of nanotechnology are to enable the analysis of structures at the nanoscale, to understand the physical properties of structures at the nanoscale dimension, to manufacture nanoscale structures, to develop devices with nano-precision, and to establish a link between nanoscopic and macroscopic universes by inventing adequate methods.

BRIEF HISTORY OF NANOTECHNOLOGY:

The term nanotechnology was first suggested in 1974 by N. Taniguchi. The first report about creation of these new materials was published in 1985 (Kroto et al. 1985). In this report was announced the discovery of a new type of carbon compound in nature—the fullerenes (C60). In 1996 the Nobel Prize was awarded for this discovery. The first carbon nanotubes were created in 1991 (Iijima 1991). The first National Nanotechnology Initiative was announced in the United States in 2000 . Thus, one can see that we are at the beginning of a new era in materials science. Among other important discoveries in nanotechnology development, one can also note the invention of the scanning tunnel microscope (STM) in 1982 (Bennig and Rohrer 1982) and the scanning atomic power microscope in 1986 (Bennig et al. 1986; Noble Prize in 1992). Tese new microscopes allowed observation of the atomic-molecular structure of monocrystal surfaces in the nanometer size range.[(2)]

NANAOTECHNOLOGY IN DIAGNOSIS:

Nanoelectricalmechanicalsystem(NEMS): Convert chemical to electrical signal.

Cantilever array sensors:Ultrasensitive mass detection technology:

Picogram-bacterium

Femiogram-virus

Attogram-DNA

MULTIPLEXING MODALITY: Sensing of large number of biomolecules simultaneously.

APPLICATIONS:

Diagnosis of diabetes mellitus and cancer and detection of various bacteria, fungi and virus.[3]

Nanomaterials for periodontal drug delivery:

Researchers have developed nanoparticles impregnated with triclosan for the treatment of periodontal diseases. The best example of future use of this technology is a procedure called Arestin, in which microspheres containing tetracycline are placed into periodontal pockets and tetracycline is administered locally.[4]

An in-vitro study was performed by Lee SY(08) with a toothpaste containing nanosized carbonate apatite showed that dentin tubules were effectively sealed, which is important for sustained treatment of dentin sensitivity.[5]

Nanoparticles promote better therapeutic outcome by providing controlled release of bioactive molecules, such as growth factors or anticancer drugs. Nanoparticles when adequately tuned allow temporally controlled, sustained drug delivery.[6] Clinical application of nanoparticle in cancer treatment was demonstrated by loading particles with the drug paclitaxe.[7]
Shah DA(11) reported that nanoparticles can be used as an effective protein or drug delivery system to support bone tissue regeneration. For this purpose, several nondegradable particles, such as silica, lipid, dendrimer, hydroxyapatite, or gold nanoparticles, as well as degradable particles made of poly(L-lactide) or poly(L-lactide-co-glycolide) (PLGA)were used.[8]

NANOTECHNOLOGY IN BIOMATERIALS:

Nanoparticles usually forms the core of nano-biomaterial.

Local anesthesia:

Saravnakumar(06) has reported thatwhen a colloidal suspension containing millions of active analgesic micro-size dental robots will be instilled on the patient's gingival, after contacting the surface of crown or mucosa, thenanorobots reach the pulp via the gingival sulcus, lamina propria and dentinal tubules.[3]Once installed in the pulp, the analgesic dental robots may be commanded by the dentist to shut down all sensitivity in any tooth that requires treatment. After oral procedures are completed, the dentist orders the nanorobots to restore all sensation and to egress from the tooth by a similar pathway used for ingress.[3]

Hypersensitivity care:

Saravanakumar(2006) also reported that dentin hypersensitivity maybe caused by changes in pressure transmitted hydrodynamically to the pulp. This is based on the fact that hypersensitive tooth have8times higher surface density of dentinal tubules and tubules with diameter twice as larger than nanosensitive tooth. Dental robots could selectively occlude selective tubules in minutes, using native biological materials, offering a patientwith quick and permanent cure.[3]

Nanoroboticdentrifice:

Nanoroboticdentrifice delivered by mouthwash or toothpaste could protect all supragingival and subgingival surfaces, atleast once a day metabolizing trapped organic matter and performing continuous calculus debridement.[3]

Prajapati E.R et al (2012) reported that 'complete dentition replacement therapy' by the use of nanorobottsshould become feasible within the time and economic constraints of a typical office visit through the use of an affordable desktop manufacturing facility, that could fabricate the new tooth in the dentist's office.[9]

Cell labeling:

Nanoparticles offer great potential for cell labeling during regenerative therapies. Depending on the therapeutic approach, labeling agents are applied in vivo or the cells are labeled ex vivo and are subsequently applied locally or systemically. Thereby, cell labeling allows for the practicable detection of transplanted cells, eg, via magnetic resonance imaging (MRI).[10] Thus, cell labeling provides the opportunity to visualize and track cell transport to the area of the defect . This is essential for a reliable evaluation of cell therapy outcome.

To monitor bone regeneration, MSCs have been labeled with diverse nanoparticles, such as quantum dots, which are small semiconductor nanocrystals[11],fluorescence-labeled mesoporous silica nanoparticles,gold nanoparticles, or superparamagnetic iron oxide (SPIO) nanoparticles.[12]

For application as cell-labeling agents, nanoparticles need to fulfill certain criteria. On the one hand, the number of nanoparticles per cell has to be high enough to be detectable. On the other hand, this number should be low enough to avoid any interference with cellular functions. With respect to bone cells, and particularly MSCs, the particles ideally should not compromise the differentiation potential.[12]

Ongoing research will further improve and widen the application of nanoparticles for cell labeling, seeking the best possible way to image and track cells in musculoskeletal therapy[13].

Remineralization of submicrometre-sized tooth defects:

Fluoride is an effective remineralizing agent and has therefore been widely applied for the prevention of mineral loss. CPP–ACP has also been shown to promote remineralization of initial enamel lesions and to prevent demineralization in laboratory, animal and human experiments.[14]

In particular, CPP–ACP released by chewing gum has been tested successfully in situ for remineralization of enamel subsurface lesions and for the prevention of demineralization.[15]

The use of a toothpaste containing nanosized calcium carbonate enabled remineralization of early enamel lesions.Furthermore, a study that investigated the bacteriostatic effects of silver, zinc oxide, and gold nanoparticles on Streptococcus mutans, which causes dental caries, reported that compared to the other nanoparticles, silver nanoparticles had an antimicrobial effect in lower concentrations and with lower toxicity.[16]

Dental nanorobots:

Dental nanorobots are able to move through teeth and surrounding tissues by using specific movement mechanisms[17]. Nanocomputers that have been previously programmed via acoustic signals used for ultrasonography can control nanorobotic functions.

Nanorobots (dentifrobots) left by mouthwash or toothpaste on the occlusal surfaces of teeth can clean organic residues by moving throughout the supragingival and subgingival surfaces, continuously preventing the accumulation of calculus. These nanorobots, which can move as fast as 1 to 10 micron/second, are safely deactivated when they are swallowed.[3]

Cancer therapy:

Photodynamic cancer therapy is based on the destruction of the cancer cells by laser generated atomic oxygen, which is cytotoxic. A greater of special dye that is used to generate atomic oxygen is taken in by the cancer cells when compared with a healthy tissue. Hence, only the cancer cells are destroyed then exposed to a laser radiation. Unfortunately, the remaining dye molecules migrate to the skin and to the eyes and makes the patient very sensitive to daylight exposure. This effect can last upto six weeks.[18]

To avoid this side effect hydrophobic version of dye molecule was enclosed inside a porous nanoparticle. The dye stayed trapped inside the ormosil nanoparticle and did not spread to the other parts of the body. At the same time this oxygen generating ability has not been affected and at the same time pore size of about 1nm freely allow oxygen to diffuse out.

Tissue engineering and dentistry:

Potential applications of tissue engineering and stem cell research in dentistry include the treatment of orofacial fractures, bone augmentation, cartilage regeneration of the temporomandibular joint, pulp repair, periodontal ligament regeneration, and implant osseointegration. Tissue engineering enables the placement of implants that eliminate a prolonged recovery period, are biologically and physiologically more stable than previously used implants, and can safely support early loading.[19]

Nanoscale fibers are similar in shape to the arrangement between collagen fibrils and hydroxyapatite crystals in bone. The biodegradable polymers or ceramic materials that are often preferred in bone tissue engineering may not have sufficient mechanical endurance despite their osteoconductive and biocompatible properties despite their osteoconductive and biocompatible properties. Studies performed in recent years indicate that nanoparticles can be used to enhance the mechanical properties of these materials. The main reason for preferring nanoparticles is that the range of dimension of these structures is the same as that of cellular and molecular components. Bone replacement materials developed via nanotechnology are commercially available.[20]

Bone grafts with better characteristics can be developed with the use of nanocrystalline hydroxyapatite. Furthermore, it was shown that nanocrystalline hydroxyapatite stimulated the cell proliferation required for periodontal tissue regeneration.[21]

Titanium is a well-known bone repairing material widely used in dentistry and orthopaedics. It has high fracture resistance, ductility and weight to strength ratio. Unfortunately it suffers from lack of bioactivity, as it does not support cell adhesion and growth well. Apatite coatings are said to be bioactive and bond to the bone. Hence several techniques were used in the past to produce apatite coatings on titanium. Those coatings suffer from thickness non-uniformity, poor adhesion and low mechanical strength. In addition, stable porous structure is required to support the nutrients transport through the cell growth.

It was shown that using a biomimetic approach- a slow growth of nanostructured apatite film simulated body fluid- resulted in the formation of a strongly adherent, uniform nanoporous layer. The layer was found to be built of 60nm crystallites and posseses a stable nanoporous structure and bioactivity.[22]

Jensen T(11) reported that when the extracellular matrix molecule osteopontin was incorporated in hydroxyapatite nanoparticles located in a degradable matrix and was analyzed for its osteoinductive potential in a canine endosseous gap implant model, other than new bone formation within the matrix, no positive effects were observed.[23]

Nanotechnology in infection control:

Dental caries is caused by bacterial biofilms on the tooth surface, and the process of caries formation is modulated by complex interactions between acid-producing bacteria and host factors including teeth and saliva. The number of streptococci and lactobacilli bacteria that cause caries can increase, especially in the presence of dietary sugars. These bacterial species produce acids as by-products from the metabolism of fermentable carbohydrates, and cause demineralization below the surface of the tooth.

To prevent the pathogenic consequences of tenacious intraoral biofilm formation over a longer interval, wear-resistant nanocomposite surface coatings was developed for the modification of the tooth surface in vivo10. Easy-to-clean surface properties are achieved by integrating nanometre-sized inorganic particles into a fluoropolymer matrix10. These biocompatible surface coatings have a surface free-energy of 20–25 mJ m^{-2} — known as theta surfaces[24] — and therefore can facilitate the detachment of adsorbed salivary proteins and adherent bacteria under the influence of physiological shearing forces in the mouth

Biofilm management are oral health-care products that contain bioinspired apatite nanoparticles, either alone or in combination with proteinaceous additives such as casein phosphopeptides[25]. These bioinspired strategies for biofilm management are based on size-specific effects of the apatite nanoparticles, and are thought to be more effective than traditional approaches that use micro- metre-sized hydroxyl apatite in toothpastes. Hydroxyl apatite has been adopted for years in preventive dentistry; however, effective interaction of the biomineral with the bacteria is only possible if nano-sized particles that are smaller than the microorganisms are used.

Nanotextured surfaces that can reduce microbial adhesion, proliferation, and biofilm growth through emergent antimicrobial properties, as have been found in materials such as ZnO, titanium dioxide (TiO_2), polymers, and carbon nanotubes, are being studied.

RECENT ADVANCEMENTS:

Co-polymer poly(lactic-co-glycolic acid) (PLGA) nanotechnology has been developed for many years and has been approved by the US FDA for the use of drug delivery, diagnostics and other applications of clinical and basic science research, including cardiovascular disease, cancer, vaccine and tissue highlyengineering. Employing constructs such as dendrimers, liposomes, nanoshells, nanotubes, emulsions and quantum dots, these advances lead toward the concept of personalized medicine and the potential for very early, even pre-symptomatic, diagnoses coupled with -effective targeted therapy. Most recent advances in nanomaterials fabrication have given access to complex materials such as SiO_2-Na_2O-CaO-P_2O_5 bioactive glasses in the form of amorphous nanoparticles of 20- to 60-nm size. The clinically interesting antimicrobial properties of commercially available, micron-sized bioactive glass 45S5 have been attributed to the continuous liberation of alkaline species during application.

DISADVANTAGES OF NANOTECHNOLOGY:

- Nanotechnology has increased risk to the health, nanoparticles due to there their small size can cause inhalation problem and many other fatal diseases. by just inhaling for 60 seconds in the air contain nanoparticles can damage lungs easily. Some ethical issues which include the poisoning of mass material which has been processed at nanoscale .This may leave negative impacts on the health and industry. Mass poisoning could happen only if the coatings on the products that nanotechnology has to produce include poisonous micro particles that can penetrate into the brain.
- At present nanotechnology is on the most expensive technologies and its cost is increasing day by day. The main reason for very high cost is the molecular structure and processing of the product. It quite difficult of the manufacturers to randomly produce dynamic products with the nanotechnology. Huge pricing of nanotech machines make it unaffordable for the common people.

CONCLUSION:

Nanotechnology is being beneficial in health care senses including dentistry by improving the diagnostic predictability, drug delivery and tissue engineering. There are certain formidable, ethical and questionable hazards of nanomaterials and nanotechnology owing to their size. The cost of structuring the materials and processing in the technology is also currently beyond the reach of the patients. Thus, the advantages of nanotechnology and nanomaterials can be fully utilized by bringing down the processing, cost and fixing potential hazardous nature.

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