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RESEARCH ARTICLE

PROSPECTS OF NANOTECHNOLOGY IN DENTISTRY: A REVIEW

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ABSTRACT

Nanotechnology is manipulating matter at molecular and atomic levels. It holds myriad potentials in the field of medicine and dentistry. The paper tries to provide the reader an insight about nanotechnology in dentistry by addressing its social, health and ethical impacts. Applications of nanotechnology in dental diagnostics, dental materials and preventive dentistry is discussed along with a peep into its future prospects.

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INTRODUCTION

The word nano originates from the Greek word "dwarf" and literally refers to particle size less than 100 nm whereby it works at molecular and atomic levels (Ozak *et al.,* 2013). The shift from microlevel to nanolevel has created a phenomen called nanoscience and its application as nanotechnology. Atoms, usually measured in nanoscale constitute the building blocks in biological tissue. In comparison to macro and micro sized particles, nanoparticles increase overall affinity and efficacy by interaction at a molecular level (Li L *et. al,* 2008).
The nanoparticles have a higher surface to core ratio since there are more nanoparticles at the surface than at the core thereby forming very strong bonds. Nanotechnology will give us the ability to arrange atoms as we desire and subsequently to achieve effective complete control of the structure of matter thereby making them more pliable to be utilized in various applications (Mansoori *et al.,* 2003). The article aims to address the potential application of nanotechnology in dentistry which may create an indelible imprint on future dental practice.

Synthesis of Nanoparticles

- Bottom up approach: These approaches include the miniaturization of material components upto atomic level with further self assembly process leading to formation of nanostructures. During self assembly the physical forces operating at nanoscale area are used to combine basic units into larger stable structures.
- Top-down approach: These approaches use macroscopic initial structures which can be externally controlled in the processing of nanostructures (Moghimi *et al.,* 2005)

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IMPLICATIONS OF NANOTECHNOLOGY

Health Implications: Humans are already exposed to a range of natural and manmade nanoparticles in the air and exposure via food chain, water supply and medical application. Toxicology studies on animals and cells in vitro raise the possibility of adverse effects on the immune system, oxidative stress related disorders, lung diseases and inflammation. However the doses needed to produce these effects are generally high and it remains to be seen if such exposure is possible via environment or work place (Handy RD *et. al.* 2007).

Social Implications: The societal impacts of nanotechnology vision essentially differ from the impacts of software vision because the former is about manipulation of matter whereas the latter is about writing commands for machines. The visionary message of unlimited power to shape the entire world anew atom by atom will likely split those with strong hopes, strong fears and those who feel nauseated by dubious vision. Hostility towards science can occur from all three groups because of frustrations (Shummer, 2005). In an effort to address social concerns, various intiatives were put in place to bridge the gap between society and nanoscience. The advancement of technology will require a new generation of trained workers with advance set of operational and management initiatives (Macnaghten *et al.,* 2005).

Ethical implications

Ethical issues are more pronounced with nanotechnology due to the sharp divide between those who forsee its unlimited potential and those who express great fears over the same. Nanotechnology supporters believe it has the potential to transform lives dramatically while their opponents fear that self replicating mono robots could cause destruction (Florczyk *et al.,* 2007). Human studies with a dose of nanomedicine 500 times less than the recorded toxic limits in animal studies have shown severe adverse reactions. Hence it is imperative that to insure safety and well-being of subjects, monitoring boards should be appointed in every clinical trial and the subjects appraised about the level of risk associated with novel materials (Resnik *et al.,* 2007)

Nanotechnology in dentistry

Dental diagnostics: Nanotechnology used for early disease identification. Saliva or tissue samples can be used to analyze disease at sub cellular levels. Early identification of toxic molecules or tumor cells could be done in vivo by use of nanotechnology. Nanorobots release inhibitors, antagonistics or down regulators for pyrogenic pathway in a targeted fashion whereby they can absorb and modify the pyrogens making them inactive and harmless. Pyrogenic nanorobots are alumina, silica and trace elements like copper and zinc whereas non pyrogenic nanorobots used in vivo are bulk Teflon, Carbon powder and monocrystal Sapphire (Kovvuru *et al.,* 2012). In an effort to improve biorecognition and bioreceptor performances nanobioreceptors were introduced incorporating nanotubes, nanowires and nanodots (Sagadivan *et al. ,* 2014). Nanobiosensors have high sensitivity and is very useful in detecting cancer cell molecules in very early stages and low concentration (Touhami, 2014). Carbon nanotubes were utilized in detecting circulating cancer cells in the body. Carbon nanotubes were arranged by layer to layer assembly technique and then linked chemically to antibodies of specific carcinogenic markers that bind to cancer cells. (Hasanzadeh *et al.,* 2016).

Nanotechnology in Oral Surgery: In local nanoanaestestia, colloidal suspension containing millions of active analgesic microsized dental robots are inserted into patients gingiva which reach the pulp via gingival sulcus, lamina propria and dentinal tubules. These dental robots completely shut down all sensations. Post procedure the dentist orders the nanorobots to relinquish nerve control and restore sensation (Uskokovic *et al.,* 2010). Suture needles incorporating nanosized crystals have been devoleped. (RK91 needles, AB Sandvik, Sweden). Nanotweezers are also in the devolepmental stage. Orofacial pain management by nanotechnology incorporates application of nanorobots that swim through human tissue with precision and monitor, interrupt or alter nerve impulses. Nanorobots can be controlled by preprogrammed nanocomputers. Nanorobots can also be activated by acoustic signals and is useful for treating both trigeminal neuralgia and MPDS (Uskokovic *et al.,* 2010).

Nanotechnology in Preventive Dentistry: Nanotechnology can have a pivotal role in prevention of dental diseases. The devolepment of nanotooth brush is in the teething stage where colloidal gold or silver is used between brush bristles. It can lead to decline in gingival inflammation and periodontitis. The affinity of silver to negate molecules like phosphates can disrupt cell wall function and removal of microbial biofilm. Nanotechnology in the form of nanotooth pastes is an effective option. The porosity of enamel prisms can cause bacterial agglomerate in hydroxyapatite powder. Nanotooth paste can close porosities leading to improving tooth color shade. (Raval *et al.,* 2016) Tooth paste with nanohydroxyapatite crystals (nHA) significantly increased microhardness values in human enamel following an erosive challenge compared to tooth paste without nHA (Ebadifar *et al.,* 2017).

Nanotechnology in Periodontics: Nanoparticles impregnated with Triclosan has been devoleped as an effective drug delivery system. Biodegradation of nano particles dispersed within the matrix releases drug incrementally improving longer contact duration at diseased site. Clinically stable non ionic vesicles called niosomes can offer enhanced penetration and targeted drug delivery. Fullerenes, which are hollow carbon molecules in different shapes are useful in drug delivery (Alkahtani *et al.,* 2018). Nanotubules can specifically occlude dentinal tubules within minutes and control dentinal hypersensitivity. The movement of nanorobots via dentinal tubules into the pulp guided by combination of chemical and thermal gradients can be controlled by an onboard computer held by the dentist (Chandramouli *et al.,* 2012).

Nanotechnology in Prosthodontics: Addition of 7% weight nanozirconium oxide modified heat cured PMMA increased hardness, flexural strength and fracture toughness of heat cured PMMA. 2% or 5% weight Zirconium oxide also improved transverse strength levels. (Ayad *et al.,* 2008). Titanium dioxide (TiO_2) nanoparticles 0.4% were incorporated into 3D printed PMMA denture base to evaluate its antibacterial and mechanical properties. Measurement by SEM and Fourier Transform Infrared Spectroscopy (FITR) showed significant antibacterial properties against Candida species (Totu *et. al.* 2017).

Nanotechnology in Conservative Dentistry: Incorporation of cross linked quartenary ammonium polyethylenimine(QPEI) nanoparticles in dentin resin composite has a long lasting and wide antimicrobial effect against various pathogens like Streptococcus mutans, Streptococcus sanguis and Actinomycetes israeli. QPEI is reported to have long lasting antibacterial effect and causes disruption of ionic exchange through bacterial membrane (Byth *et al*) Devolepment of rechargeable nano amorphous calcium phosphate (nACP) filled composite resins displayed a strong antibacterial potency inhibiting biofilm viability and lactic acid production and reducing colony forming units by three to four orders of magnitude compared to normal composite (Wu *et al.,* 2015). Composites containing ammoniumdimethylacrylate (QADM), nanoparticles of silver (Nag) and nanoparticles of amorphous calcium phosphate (NACP), NACP-QADM-Nag decreased biofilm viability and lactic acid production while matching load bearing capability of commercial composite. The combination is also useful to combat caries (Chang *et al.,* 2016). Tooth whitening agents nanomodified with calcium peroxide nanoparticles were able to penetrate deep into tooth structures via the micro and nano cracks leading to longer surface contact and deeper penetration into tooth surface thereby increasing whitening efficiency and reducing side effects. (Alkahtani RN *et al.,* 2018)

Nanotechnology in Endodontics: Zincoxide nanoparticles, Chitosan nanoparticles and silver nanoparticles are used for root canal disinfection and showed significant antibacterial properties (Kishen *et al.,* 2008). Use of bioceramic nanoparticles like bioglass, zirconia and glass ceramics in endodontic sealers shows improved dimensional stability, chemical bonding, osseoconductivity and lower tissue solubility compared to normal sealers (Utneja *et al.,* 2015) to inhibit formation of endostains while nanoparticles are used to accelerate the remineralisation process and in increasing bonding stress to dentin (Wang et. al 2017). Nanodiamond particles coated with gutta-percha (NGDP) functionalized with amoxicillin demonstrated superior chemical, mechanical properties and biocompatibility when the obturation was visualized with digital radiography and micro computed tomography (Lee *et al.,* 2015).

Nanotechnology in Impantology: Nanotechnology is increasingly used for surface modifications of dental implants. Bioactive Cacium Phosphate (CaP) nanocrystals deposited on implants are resorbable and stimulate bone apposition and healing. Nanometer controlled surfaces have a great effect on early events such as adsorption of protiens, blood clot formation and cell behavior that occur upto implantation of dental implants. The early events have an effective impact on the migration, adhesion and differentiation of Mesenchymal Stem Cells (Lavenus *et al.,* 2010).

Nanotechnology and Regenerative Dentistry: The combination of nanotechnology which allows the creation of sophisticated materials with exquisite fine structural detail and stem cell biology is useful in regenerative medicine. The administration a triad of dynamic biological agents comprising stem cells, bioactive scaffolds and nanoparticles will increase regenerative capacity of dental tissues (Galler *et al.,* 2010)

Conclusion

Since nanotechnology is a continually evolving science, the scientific community should show great responsibility while embracing this new field. Nanomaterials when compared to conventional materials usually show superior physical and mechanical properties. Nanomaterials are used for new oral drug delivery systems, prevention of common dental conditions like caries and periodontal diseases and even for treatment of oral cancer. However their use should be guided by their efficacy, cost benefit ratio and even ethical considerations. Even though nanotechnology is an intriguing science lot of research needs to done before a paradigm shift can occur from conventional dentistry to nanodentistry.

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