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RESEARCH ARTICLE

NANODENTISTRY- EXPLORING THE BEAUTY OF MINIATURE

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ABSTRACT

Nanotechnology is considered to be an upcoming technology. In the field of dentistry, it helps in diagnosis, prevention and treatment. Nanotechnology incorporates the usage of nanoparticles less than 100 nm. It has delivered its impact on almost every facet of science and development. It is but natural that medicine and dentistry too are being influenced by this recent entrant which has immense potential. A new revolution in the field of dentistry by the use of nanotechnology has got remarkable potential that can bring considerable improvements to human health in the form of nanomaterials, nano diagnostics and nano robotics. The usage of nanoparticles in restorative materials has increased the quality and life of dental restorations resulting in better oral care and hygiene. The technology helps in modifying the existing restorative material in terms of physical, chemical and biological aspects to improve their quality. The restorative materials with nanoparticles currently used are nanocomposites, nano glass ionomers, nano adhesives. In endodontics these nanoparticles can be incorporated in endodontic sealer, obturating material, intracanal medicament and irrigating solutions to provide the desired results. Nanotechnology possesses tremendous potential but social issues of public acceptance, ethics, regulation, and human safety must be addressed before it can be looked upon as the hope for the future.

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INTRODUCTION

Man's quest to create new technology and materials which are better and more efficient led to the introduction of 'Nanotechnology', a technology that deals with structures ranging in the size of 100 nanometers or smaller in at least one dimension and developing materials or devices within that size. Nano' is derived from nan (n) os, the Greek word for 'dwarf, little old man'. The prefix "nano" is defined as a unit of measurement in which the characteristic dimension is one-billionth of a unit. Today's nanotechnology harnesses current progress in chemistry, physics, materials science, and biotechnology to create novel materials that have unique properties because their structures are determined on the nanometer scale (Mobasser amd Firoozi 2016). Nanotechnology has delivered its impact on almost every facet of science and development. It is but natural that medicine and dentistry too are being influenced by this recent entrant which has immense potential (Bhushan and Maini 2019).

With the help of nanotechnology, it is possible to decrease the size of devices and increase the strength of materials, which makes tools more appropriate for utilization in medical devices. Various studies have been conducted on the application of nanotechnology in dentistry as well.Applications of nanotechnology in dentistry are multi-fold, some of which include- nanorobotic, carbon nanotube or nano-needle based drug delivery; nanofillers in composite resins and vinylpolysiloxane impression materials; nanorobotic administration of local anaesthesia; nanosolution based bonding agents for composite resin; dentinal hypersensitivity cure; nanorobotic dentrifice; tooth repair and repositioning with orthodontic nanorobots and nano- hydroxyapatite; nanodiagnosis with stem cell imaging & tracking for the treatment of oral cancer (Mithra 2017). The restorative materials with nanoparticles currently used are nanocomposites, nano glass ionomers, nano adhesives and endodontic sealers. Nano filled composites show better hardness, superior flexural strength, modulus of elasticity and translucency, superior handling properties, and display a 50% decrease in filling shrinkage (Arora and Kapoor 2014).

Nano-modification of conventional GICs and resin modified GICs (RMGICs) can be achieved by incorporation of nano-sized fillers to RMGICs, reducing the size of the glass particles, and introducing nano-sized bioceramics to the glass powder (Najeeb *et al* 2016). Nanofillers are incorporated in vinylpolysiloxanes, creating an exclusive addition of siloxane impression materials. The material has improved flow, enhanced hydrophilic properties and better feature accuracy (Arora and Kapoor 2014). The combination of nanotechnology, which allows the creation of sophisticated materials with exquisite fine structural detail, and stem cell biology turns out to be increasingly useful in regenerative medicine and is expected to increase the regenerative impact of dental pathological tissues (Mitsiadis *et al.,* 2012). Nanotechnology possesses tremendous potential but social issues of public acceptance, ethics, regulation, and human safety must be addressed before nanotechnology can be looked upon as the hope for the future (Arora and Kapoor 2014). The aim of this article is to have a brief overview into the present status, ongoing progress, and potential implications of NPs along with the challenges faced by nanotechnology in dentistry more so in reference to conservative dentistry and endodontics.

NANOTECHNOLOGY IN DENTISTRY

The usage of nanotechnology in the field of dentistry promotes the material stability and possesses antimicrobial properties according to the concentrations given. The future nanoparticle and the advance are to produce and enhance the application of the nanoparticles in the field of dentistry

Two main approaches in order to explain nanotechnology in dentistry have been given. These involve

- Top-down approach
- Bottom-up approach

Top-down approach: In simpler terms, it means to create smaller nano-sized particles from complex structures with improved functional properties. As size of the particles in a system decreases, there is an increase in surface area resulting in pronounced increase in physical phenomena or properties due statistical as well as quantum mechanical effects.

Bottom-up approach: This approach simply means to aggregate smaller Nano-sized particles to form complex assemblies with improved functional properties. This aims at designing custom-made Nano-sized particles which demonstrate the ability of self-assembling or self-organizing into complex high order mesoscale/macroscale particles or structures. For example, synthetic DNA fabrication and replication by pairing nucleic acids of nanosize dimensions.

Applications in Dentistry: Currently, there is a wide range of nanomaterial's applications in different subspecialties of dentistry. As a result of active research for developing new nano-products, the variety of available products for various dental applications is expected to increase remarkably in the near future.

Nanomaterials for Restorative Dentistry: There has been a drastic evolution in recent years in the field of restorative materials, particularly in tooth-coloured materials. Nanotechnologies have been applied for the manufacturing of dental composites (nanocomposites), glass-ionomers cements (nano-ionomers), endodontic sealers and tooth regeneration (Khurshid *et al* 2015)

Nanocomposites: The last decade has witnessed rapid advances in dental restorative materials including the resin-based composites. The introduction of nanotechnology led to the discovery of nano-filler particles. All efforts were and are being made to achieve considerable advances in physical properties and tackle issues like polymerization shrinkage, wear resistance, micro hardness and achieve patient satisfaction in terms of the aesthetic appearance. At present, there are two distinct types of dental nanocomposites available which are nanofills and nanohybrids,

- Nanofills—these contain nanometer-sized particles (1–100nm) throughout the resin matrix, with no other large primary particles being included.
- Nanohybrids—these consist of large particles (0.4–5μm) with added nanometer sized particles.

One of the key purposes of using nanomeric particles is to reduce the particle size than the wavelength of visible light (400 nm to 800 nm). This helps in obtaining highly translucent materials, high surface area to volume ratio and molecular interactions as the polymer size range is usually in the same dimensions. Highly filled composites if made using nanomers of the same size have a poor effect on rheological properties. In order to overcome this drawback nanoclusters were synthesized by lightly sintering nanomeric oxides resulting in controlled particle size distribution. Nanoclusters act as a bunch of grapes with an average size range of 0.6 μm. These nanoclusters are also surface treated with silane to improve chemical bonding and adhesion with the organic resin matrix (Khurshid *et al* 2015)

Advantage of Nanocomposites

- The polymerization shrinkage innanocomposites is reported to be 1.4% to 1.6% which is less than the polymerization shrinkage of conventional composite (2.1%-2.5%). The low shrinkage value of Nanocomposites is due to the low shrinkage epoxy resin and strong interfacial interactions between resin and nanoparticle.
- Nanocomposites show less water sorption than microfill composites (Bociong et al. 2017)
- The flexural strength of Nanocomposites was found to be statistically equivalent or higher than those of the hybrid or microhybrid composites and significantly higher than those of the microfill composites.
- The nano-sized primary particles in the nanoclusters wear by breaking off individual primary particles rather than plucking out the larger secondary particles from the resin. Thus, resulting wear surfaces have smaller defects and better gloss retention.
- Due to their small particle sizes, nanofillers can increase the overall filler level. More filler can be accommodated if smaller particles are used for particle packing.
- A higher filler fraction helps in increasing the fracture toughness because fillers decrease the volume of the weak polymer matrix and act as toughening sources.

NANOTECHNOLOGY IN RESIN MODIFIED GIC (Nano-Ionomers): Unlike conventional GICs that consist of a glass powder and a polyacid solution, resin modified GICs also have a polymer resin component which usually sets by a self-activated (chemically cured) or light-activated polymerization reaction. These "hybrid" materials have been developed to combine the mechanical properties of a resin composite with the anti-carious potential of GICs. RMGICs have a decreased fluoride release and higher creep relative to conventional powder-based ionomers. To overcome these drawbacks, there have been attempts to incorporate nano-sized fillers and bioceramics particles to RMGICs that has resulted in improvement of mechanical properties like higher flexural strength, tensile strength, and resistance to solubility compared to conventional GICs.

Nanomaterials in endodontics: Due to benefits over other conventional materials and mechanism of action, there has been an enormous increase in the application of nanoparticles in various fields of dentistry since their introduction. In endodontics, these nanoparticles can be incorporated in endodontic sealer, obturating material, intracanal medicament and irrigating solutions to provide the desired results.

Irrigant: Ibrahim et al. investigated the effect of using antibacterial nano particles (Chitosan, Silver NP) in endodontics. Obtained results showed that using antibacterial nano particles had significant impact on resistant pathogens, which was attributed to their physiochemical properties. Moreover, it was observed that using nano particles as antibacterial had eliminated bacterial cells by applying multiple mechanisms.

Filler: In another study, Javidi et al. utilized zinc oxide nano powder and compared its leakage with AH26 and micro sized zinc oxide eugenol sealer. Their results indicated that zinc oxide nano powders had the lowest micro-leakage among the investigated sealers; as a consequence, these types of sealerscan be more appropriate for root canal therapy.

Photodynamic therapy: Nanotechnology is applicable to novel endodontics treatment method such as photodynamic therapy. In a study, a type of nano particle (poly lactico-glycolic acid) was loaded on a photosensitizer (methylene blue) and was exposed to the light in order to investigate its efficacy in elimination of E. faecalis. Results indicated that using the nano particles which wereencapsulated with photoactive drugs could be a favourable supplement in antimicrobial endodontic therapy.

Testing Mechanical Properties of Endodontic Instruments: Nanotechnology can be used to evaluate mechanical properties of instruments utilized in endodontic procedures Jamleh et al. applied nano-indentation test to investigate the impact of cyclic fatigue on the nickel-titanium (NiTi) tool which was used in endodontics. The study showed that the mentioned technique (nano-indentation test) was applicable to evaluate failure mechanism of the NiTi instruments. In another study, Zinelis et al. applied nanoindentation technique to assess in-depth hardness of endodontic instruments (Akbarianrad *et al* 2018)

Nanomaterials in preventive and aesthetic dentistry: Xie *et al* in 2016 reported the development of a rechargeable nano amorphous calcium phosphate (nACP) filled composite resin. The nanoparticles were able to not only improve composites' remineralising properties, it also maintained the same level of Ca and P release through recharge and release.

Ionescu *et al* in 2015 introduced nanocomposite coating consisting of lactose-modified chitosan (Chitlac) with silver nanoparticles (nAg) in order to enable restorative materials to actively prevent the initiation and progression of secondary caries.

Shvero *et al* in 2015 Incorporated cross–linked quaternised polyethyleneimine (QPEI) nanoparticles in resin composites which was reported to have antibacterial effects against various oral pathogens, such as Enterococcus faecalis, Streptococcus mutans, Actinomyces viscousus, Lactobacilus casei, and whole saliva. The addition of QPEI nanoparticles was reported to have a long-lasting antibacterial effect, providedstability within the matrix, did not leach out into the surrounding environment and helped in preventing secondary caries. Various metal nanoparticles are used for caries prevention. These include silver NP, zinc and zinc oxide NP, titanium dioxide NP. Nano Anti-Caries Materials used for remineralization purpose include Nano Particulate Hydroxyapatite (NHAP), Nanosized Calcium Fluoride (NCaF2), Nanosized Amorphous Calciumphosphate Particle (NACP), Bioactive Glass Nanoparticle (NBG) **(**Chen *et al* 2020)

NANOTECHNOLOGY BASED IMPRESSION MATERIALS: Nanofillers are incorporated in vinylpolysiloxanes, creating an exclusive kind of siloxane impression materials. This material has improved flow, enhanced hydrophilic properties and better feature accuracy. Commercially available as Nanotech Elite H-D, these offeradditional advantages like high tear resistance, resistance to distortion and heat resistance, instant set that reduces errors caused by micro movements.

Applications of Nanorobotics in Dentistry: Nanorobots might use specific motility mechanisms to travel through human tissues with navigational precision. They will acquire energy and sense and manipulate their surroundings. These nanorobotic functions may be controlled by an on-board nano computer that executes pre-programmed instructions in response to local nanorobots via acoustic signals or other means. Nanorobots can be used for major tooth repair, Nano anaesthesia, Nano solutions, Nano impression materials, Dentine tubule blocking to alleviate hypersensitivity, Nanorobotic dentifrices (dentifrobots) and Bone replacement materials (Shetty 2013)

ADVANTAGES OF NANOPARTICLES

- The nanoparticles like silver, copper and zinc produce antibacterial properties in bulk form but metals like iron are not antibacterial in 'macro' form but they possess antibacterial activity in nanoform.
- 2 Nanotubes are a type of nanotechnology typically used to mimic the natural biomineralization process to create the hardest tissue in the human body (dental enamel).
- Nanotechnology has also enabled the production of nanofill composites which brings together the aesthetic features of microfill composites and the mechanical features of hybrid composites.

Table Application of Nanotechnology in dentistry with available products

Discipline	Available Materials
Restorative Dentistry	Ketac™ (3M ESPE, St. Paul, MN, USA), Ketac N100; Nano-ionomers (3M ESPE), Filtek Supreme XT (3M ESPE), Fuji IX GP (GC, Leuven, Belgium), Nano-primer, Premise™ (Kerr/Sybron, Orange, CA, USA), Adper™ Single bond plus Adhesive (3M ESPE), Ceram X™ (DENTSPLY International, Milford, CT, USA).
Periodontics	Arestin® (Valeant, Bridgewater, MA, USA), Nanogen® (Orthogen, Springfield, IL, USA).
Preventive Dentistry	NanoCare® Gold (Nano-Care, Saarwellingen, Germany).
Orthodontics	Ketac™ N100 Light Curing Nano-Ionomers (3M ESPE), Filtek Supreme Plus Universal (3M ESPE).
Prosthodontics	Nanotech elite H-D plus (Zhermack, Badia Polesine, Italy), GC OPTIGLAZE color® (GC).
Oral Implantology	Nanotite™ Nano-coated implant (BIOMET 3i, Palm Beach Gardens, FL, USA).
Endodontic	AH plus™ (DENTSPLY International), Epiphany (Pentron Clinical Technologies, Wallingford, CT, USA), Guttaflow® (Coltène, Altstätten, Switzerland).

- Nanofillers also offer advantages in optical properties that enables the clinician to construct a wide range of shades and opacities thus providing highly aesthetic restorations
- The smaller size of the nanoparticles shows advantages like improved bioavailability, high optical clarity, gravitational separation and stability to aggregate.
- Nanotechnology holds great promise in the development in the imaging of the cancer without any potential for heavy metal toxicity.
- Nanocrystalline hydroxyapatite is an invention that has impacted the lives of patients because of its remarkable capabilities of bone grafting and ability to stimulate cell generation (Ellis 2017)

CHALLENGES FACED BY NANODENTISTRY

Though nanotechnology offers several promises in the field of dentistry, it still faces many significant challenges in realizing its tremendous potential.

Engineering issues

- Difficulty in manufacturing nano based dental materials on a mass scale.
- Accurate positioning and assembly of molecular scale parts of dental nanorobots.
- Manipulating and co-ordinating activities of large numbers of independent microscale nanorobots simultaneously inside the oral cavity.

Biological issues

- Developing biocompatible dental nanomaterials.
- Ensuring compatibility with all intricate parts of the oral cavity.

Social challenges

- Ethical issues
- Public awareness, cost factor of manufacture & nanotechnology based dental treatment.
- Bio-regulation and human safety.

CONCLUSION

Nanotechnology plays an important role in the field of dentistry. The nanoparticles possess antimicrobial, anti-inflammatory and anticancer activity. The nanoparticles have a wide range of usage in implants, adhesive, nano-composites and primer-adhesives. Improved properties and higher strength of nanocomposites as compared to the conventional composites make them more suitable for a wide range of applications in restorative dentistry. The demand and preparation of nano based dental materials has increased owing to its potential applications and benefits. The usage of nanorobots is a new evolution which helps in fighting against bacteria and other pathogenic microorganisms. The discussed review article states nanotechnology in dentistry as an emerging field. The upgrading of the nanomaterials will be occurring in the future and new nano based restorative materials can decisively replace the existing conventional materials.

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