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Nanomodified Materials in Endodontics – A Game Changer!!!

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***Abstract*:**
Nanodentistry aims towards the application of nanotechnology for the maintanence of oral health. Research in nanotechnology has gained significant momentum over the years and has it's implications in the field of endodontics. From modifications in the rotary file systems to pulp regeneration nanotechnology has come a long way. A better understanding of the nanomodified materials and the ongoing research in this emerging field would help to appreciate how these materials can be used in daily practice. It would be safe to say that nanotechnology would definitely be a game changer in improving the quality of endodontic treatment.
***Key Word*:**

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I. INTRODUCTION

The primary goal of endodontic therapy is to create an environment within the root canal system which allows the healing and continued maintenance of the health of the periradicular tissue. Current materials possess certain limitations such as shrinkage, solubility in the oral environment and moisture intolerance.[1] Therefore, the success of treatment depends on the development of proper materials for cleaning and shaping and sealing of the root canal system.

The current focus of research is in the field of nanotechnology. Nanotechnology is defined as the creation of functional materials with structures of 100nm or more[2]. Currently, research directed towards developing 'Nanomodified materials' by dispersion of nanoparticles to current and novel materials to improve their properties have gained significant momentum.

II. HISTORY

Molecular nanotechnology was first introduced by Richard Feynman in 1959[3]. It involves the tailoring of materials at atomic level (one nm is one billionth (10^{-9}) of a meter) to attain unique properties, which can be suitably manipulated for the desired applications[4].. In 1991, Dr.Sumio Lijima introduced the concept of nanotubes. The term 'nano-dentistry' was coined by Dr. Freitas Jr. in the year 2000. He developed nanomaterials and nanorobots, helped in regeneration of dentition, and developed dentifrobots– robots in dentrifices[5]. Even though these were considered to be near impossible in the past, these are slowly becoming a fruitful reality.

III. CLASSIFICATION OF NANOPARTICLES[5]

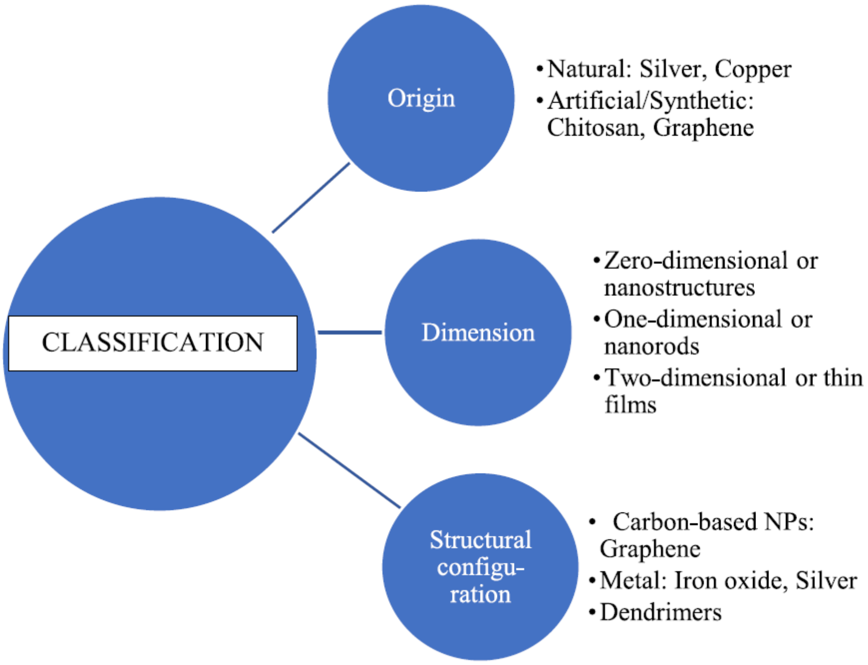

Fig 1: Classification of nanoparticles[5]

IV. NANOPARTICLES IN ENDODONTICS

Nanoparticles possess many properties that benefit endodontic treatment. The most commonly used nanoparticles in endodontics are metal nanoparticles as they are found to have antibacterial effect and hence helps in the disruption of biofilms.With their seemingly immiscible size (10^{-9} meters) these nanoparticles have the potential to lessen antibacterial resistance through specially formulated metal oxides such as silver and copper. To prevent the formation of biofilms, the positive charge on nanoparticles acts as an antimicrobial agent via disrupting bacterial electron transport chain and causing cell lysis. Such interaction have made headway in fighting methicillin resistant *Staphylococcus aureus* (MRSA), an incredibly virulent bacterium[6]

1. *NiTi INSTRUMENTS*

The introduction of nickel–titanium (NiTi) alloys and the subsequent automation of mechanical preparation were the first steps towards a new era in endodontics[7]**.** It was definitely a game changer in terms of the quality of endodontic treatment, dentist as well as patient comfort. NiTi instruments have undergone significant changes in terms of machining and manufacturing since it's introduction. Despite the innumerable advantage of NiTi instrumentation over conventional hand files, the unpredictable breakage of rotary files owing to poor resistance to cyclic fatigue could neither be predicted nor avoided. Adini et al examined the effects of cobalt coatings with impregnated fullerene-like WS2 nanoparticles on file fatigue and failure. A significant improvement in the fatigue resistance and time to breakage of the coated files were observed stemming from reduced friction between the file and the surrounding tissue[8].Thus, future research in this direction could pave the way for a safer and stress free endodontics.

2. *ROOT CANAL IRRIGATION*

Root canal irrigation plays an important role in disinfection of the root canal space. Even after mechanical instrumentation, a large part of the root canal system remains uninstrumented[9]. Although, current irrigants like sodium hypochlorite and chlorhexidine have proven to be effective antimicrobials they do not warranty complete disinfection of the root canal space[10]. A plethora of research have been done to devise an ideal solution as an adjuvant to root canal treatment as each product varies in its physical properties, antimicrobial effects and biocompatibility[11].

None of the existing technology guarantee complete removal of endodontic biofilms. Incorporation of antimicrobial nanoparticles have been considered as a novel strategy to improve the efficacy of root canal irrigants. Nano based formulations are found to have better penetration and slow and controlled release of active ingredients at target sites[12-13].The antimicrobial property of metal nanoparticles are well established and they are of great importance in strategies devised to eradicate chronic infections[14].The most popular among the metal nanoparticles are the silver nanoparticles. Gomes Filho et al evaluated the tissue response to implanted polyethylene tubes filled with fibrin sponge embedded with silver nanoparticles dispersion[15]. It was observed that silver nanoparticles were biocompatible especially in lower concentration. Bukhari s et al tested a new disinfection technology using biomimetic iron oxide nanoparticles with peroxidase like activity to enhance antibacterial activity on root canal surfaces and in dentinal tubules. The results revealed that the potential to exploit nanocatalysts with enzyme like activity can be a potent alternative approach for the treatment of endodontic infections[16].

Nanoparticle based antimicrobial photodynamic therapy is another root canal disinfection method being investigated. Pagonis et al concluded that PLGA nanoparticles encapsulated with photoactive drugs may be a promising adjunct in endodontic treatment. Thus, these therapies may be the game changers in the quality of endodontic treatment in the near future[17].

3. INTRACANAL MEDICAMENTS

Intracanal medicaments are considered as an integral part of treatment and important for the success of root canal therapy. Placement of intracanal medicaments is especially important in multi – visit procedure, and forms part of the chemical preparation of the root canal system; eradicating microorganisms prior to permanent restoration. Calcium hydroxide is the most commonly used intracanal medicament, however it has been demonstrated that E.fecalis biofilms are resistant to Calcium hydroxide. Several new formulations of nanoparticles have been investigated as intracanal medicaments.

Chitosan nanoparticles and Zincoxide nanoparticles are established as having antibacterial properties. Jhamb S et al compared the antibacterial effect of silver nanoparticle gel alone and combination of silver nanoparticle gel with various medicaments against E. fecalis. It was observed that the combination of silver nanoparticle gel along with other medicament was more effective than the nanoparticle gel alone[18]. The efficacy of fresh and aged CS-np and ZnO-np in disrupting E. fecalis biofilms was evaluated by Shreshta *et al*.The authors concluded that the rate of bacterial killing by the nanoparticulates depended on the concentration and time of interaction and that aging for 90 days did not affect their antibacterial properties[19].However further animal and in-vivo studies are needed to bring them to a fruitful reality.

4. OBTURATING MATERIALS

4.1 CORE OBTURATING MATERIALS

Although, several materials have been suggested as obturating materials, Gutta percha has stood the test of time and has remained the material of choice. Gutta Percha is biocompatible and satisfies several criteria for an ideal root canal filling material put forth by Grossman. However, several disadvantages has been noted which include lack of rigidity and adhesiveness, ease of displacement under pressure, minimal antimicrobial property and shrinkage if thermoplasticized. Proper adaptation to the prepared root canals and increased antimicrobial property would be imporatant to produce a hermetic seal.

Lee et al developed a nanodiamond – gutta-percha composite (NDGP) embedded with nanodiamond – amoxicillin (ND-AMC) conjugates which can reduce the chance of reinfection[20].An improvement in mechanical properties were also noted upon Nanodiamond incorporation. Bioactive glass 45S5 is another recently introduced nanoparticle used in endodontic therapy. Similar to Calcium hydroxide, it is used in the treatment of traumatized anterior teeth with open apices. Thus, it helps to overcome the potential disadvantage of reduced flexural strength upon placement of calcium hydroxide over a long period of time. Nanosized particles of Bioactive glass were modified with bismuth oxide by Mohn et al to obtain radiopaque properties. Based on Scanning electrom microscope analysis, the authors concluded that bioactive glass modified with bismuth oxide is a radio-opaque bioactive root canal filling material[21].

4.2 SEALERS

Sealer forms an integral part of obturation. They hold gutta percha within the root canal space. Ideal properties sealer includes ease of handling, non – toxic, biocompatibility, absence of shrinkage upon setting, effective working time, hydrophilicity, antibacterial property, ease of retreatment etc.

According to Gutmann and Witherspoon, the future research on sealers should focus on materials that: 1) penetrate patent dentinal tubules, 2) bind intimately to both organic and inorganic phases on dentin 3) Neutralize or destroy microorganisms and their by products 4) predictably induce a cemental layer 5) strengthen the root system. Nanoparticle sbecause of their smaller size can penetrate deep into the dentinal tubules and offer better adaptation to the root canals.

Baras et al in their study observed that incorporation of bioactive additives improved the antibacterial and tooth mineral regeneration capabilities. Antimicrobial properties were improved by addition of Nanosilver paricles. Incorporation of NanoACP helps strengthen the root structure and prevent future tooth fractures[22].Desouky et al evaluated the sealing ability of nano calcium hydroxide sealer and nano bioactive glass against Zinc oxide eugenol sealer and observd thet nanomodified sealers performed better in terms of sealing ability compared to Zinc oxide eugenol sealer[23].

4.3 ROOT END FILLING MATERIALS

Endodontic surgery becomes the treatment of choice if non surgical treatment cannot be perfomed due to complex root canal anatomy, inadequate instrumentation and presence of physical barriers[24]. According to Cartner & Dorn, an ideal root end filling material should prevent leakage of microorgatiisms and their byproducts into the petitadictilar tissues. It should also be non-toxic, non-carcinogenic, and biocompatible with the host tissues. In addition, it sbould be insoluble in tissue fluids and dimensionally stable. The presence of moisture should not affect its sealing ability. For practical purposes it should also be easy to use and be radiopaque to be recognized on the radiographs. Eventhough a number of root end filling materials have been suggested over the years, a single material which satisfies the above mentioned criteria has not yet been developed.

MTA has been considered the material of choice over the past few years. However, the major disadvantage of this material is it's difficult handling and long setting time. Inorder to overcome these shortcomings, Saghiri et al evaluated the properties of nanomodified mineral trioxide aggregate fo enhanced physicochemical properties. The pushout bond strength of nanomodified WMTA was compared with WMTA. The authors concluded that the force needed for the displacement of nano-modified WMTA was significantly higher then for Angelus WMTA[25].

Nanocomposites are a new class of composites that have shown great potential[26]**.** A PNC is a generalized term for polymeric materials that are loaded with minimal amounts of nanoparticles such as clays, carbon nanotubes, etc. dispersed at a nanoscale[27]. Modereszadeh et al evaluated PNC resins such as C-18 Amine montmorillonate (MMT) and vinylbenzyl octadecyldimethyl ammonium chloride (VODAC) MMT, both containing 2% chlorhexidine diacetate salt hydrate, as potential root-end filling material. Cytotoxicity study evaluating these two forms PNC resins found no significant difference between MTA, Geristore and PNC resin C-18 Amine MMT on 24 hours, 1, 2 and 3 weeks samples. Sample elutes of PNC resin VODAC MMT, however, revealed cytotoxic activity during most of these experiments[28].

5 PULP REPAIR AND REGENERATION

Regeneration of dental pulp is a dream for dental clinicians all over the world and will definitely be a game changer in clinical practice[29]. With advancement in technology, it has become a fruitful reality. Theoretically, it is possible to regrow dental pulp inside a pulpless tooth by using Growth factors, scaffolds and stem cells[6].

Use of Nanoscale scaffold materials for tissue regeneration has already been established. Nanoscaffolds comprising nanofibers of biodegradable collagen type I or fibronectin can be used for pulp regeneration. Self-assembling polypeptide hydrogels have been used for pulp tissue regeneration. Poly (l-lactic acid) (PLLA) is a common synthetic polymer that could be applied in nano-form and have the ability to participate in tissue engineering. Wang *et al.* (2010) investigated the odontogenic differentiation of DPSCs on nanofibrous (NF) PLLA scaffolds *in vitro* and *in vivo*. They observed that the NF-PLLA scaffold promoted odontogenic differentiation of human DPSCs and dentin like tissue organization, confirming its ability for dental tissue engineering purposes[30].

Xiangwei Li *et al.* incorporated vascular endothelial growth factor (VEGF) with heparin and then encapsulate it in heparin intermixed gelatin nanospheres, later immobilized in the injectable PLLA NF-MS[31].Another research was conducted to produce a novel injectable cell carrier, nanofibrous spongy microspheres (NF-SMS), for dentin regeneration. Palasuk et al fabricated and discussed in research an antimicrobial scaffold. This investigation aimed to evaluate both the antimicrobial effectiveness and cytocompatibility of bi-mix MET and CIP antibiotic-carrying polydioxanone (PDS)-based polymer scaffolds. The scaffolds were characterized as a micro/nanofibrous arrangement with the attached pores. Antimicrobial efficacy was examined against *Enterococcus faecalis*, *Porphyromonas gingivalis*, and *Fusobacterium nucleatum*, and cytotoxicity was assessed on hDPSCs. The results indicated that the inclusion of multiple antibiotics in a nanofibrous scaffold could be a desirable drug delivery method for regenerative endodontics[32].Shiehzade *et al.* (2014) investigated poly (lactide-co-glycolide)-polyethylene glycol (PLGA-PEG) nanoparticles as an injectable scaffold for SCAP. This study was conducted in cases with large periapical lesions. These three case reports represent the treatment of necrotic or immature teeth with periradicular periodontitis, not treated with routine apexification procedures. Consequently, adverse effects were not observed on the tissues around the injured tooth using the PLGA-PEG scaffold, and periapical bone reconstruction was hastened within 6 months while the tooth continued to function[33].

Li et al evaluated the effectiveness of a Graphene oxide-copper nanocomposite for the regeneration of the dentin – pulp complex. It was observed that when these nanocomposite were transplanted into nude mice, dentin – pulp like structures were formed. The odontogenic and neurovascularization inducing abilities of Graphene oxide – copper nanocomposite suggests its possible application in regenerative endodontics[34]. Thus, based on the various research conducted over the years it is safe to say that nanotechnology has bought significant development in the field of regenerative endodontics, The regeneration of pulp in a pulpless tooth will soon be a reality.

V. CONCLUSION

Endodontics and dentistry in general has made a huge progress over the years. Nanotechnology has definitely contributed to the tremendous improvement in endodontics. The available literature shows that nanotechnology is relevant to root canal therapy in several aspects such as irrigation, root canal disinfection, obturation and pulp regeneration. The on going research on nanomodified materials would definitely lead to the development of smart endodontic therapeutic agents and materials. The future looks promising and nanotechnology is definitely going to be a game changer in improving the quality of dental treatment.

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