Recent Advances In Endodontic Materials Through Nanotechnology – *A Review*

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Abstract: When compared to conventional materials nanoparticle based materials have superior physical , chemical and biological properties. As a result , nanoparticles are being added to dental materials in order to improve their varied properties for a predictable clinical outcome. Studies have shown that dental materials based on nanotechnology for endodontic applications are positively correlated with the alteration of the surface of NiTi rotary instruments , improvement of root canal system disinfection, 3D obturation, dentinal / pulp tissue repair and regeneration with the ultimate goal of predictable outcome each time. However , long term clinical information of these nanomaterials is limited in literature limiting their application. Thus this brief review attempts to illustrate some of the prospective endodontic applications of nanotechnology.

Index Terms— Nanoparticles , Nanotechnology , Silver nanoparticles , Nano- biotechnology . *(key words)*

I. INTRODUCTION

Nano is derived from the Greek phrase nanos, which means dwarf. Nanotechnology is commonly defined because the study and creation of materials, technology, and structures with physical, chemical, and biological homes that fluctuate from those found at larger scales. The primary goal of incorporating nanotechnology into dental substances is to boom mechanical traits, abrasion resistance, much less shrinkage, and optical and aesthetic residences. Within the realm of endodontics, research are being carried out with the intention to improve every step of the process, from the documents to the filling substances. Nanoparticles may additionally improve the treatment of endodontic infections due to their nanoscale dimensions, which encompass better antibacterial homes, accelerated reactivity, and the potential to be functionalized with other reactive compounds, amongst other traits. The hallmarks of appropriate endodontic remedy are powerful disinfection and root canal device sealing. The lifestyles of bacterial biofilms and resistance to endodontic disinfectants, but, make this intention tough to obtain. This has induced researchers to investigate antibacterial nanoparticle-primarily based irrigants and intra-canal medicaments that would help cast off endodontic infection. These nanoparticles engage with micro organism in a ramification of approaches. Many in vitro studies have appeared into the bactericidal impact of nanoparticles. Nanomaterials are getting used inside the discipline of endodontics to improve antibacterial efficiency, mechanical integrity of formerly broken dentinal matrix, tissue regeneration, and many different problems. Many greater novel technologies are being tried in the area lately, with the aim of solving the microbiological challenges.

II. MECHANISM OF ACTION

The mechanism of action was shown to be their capacity to: 1. Release ions when in contact with a hydrous media. 2. Improve the environment's pH. 3. Increase the absorptive force surrounding the microbial cell to inhibit bacterial growth. 4. To induce the bacterial cell membrane to rupture by precipitating calcium and phosphate ions.

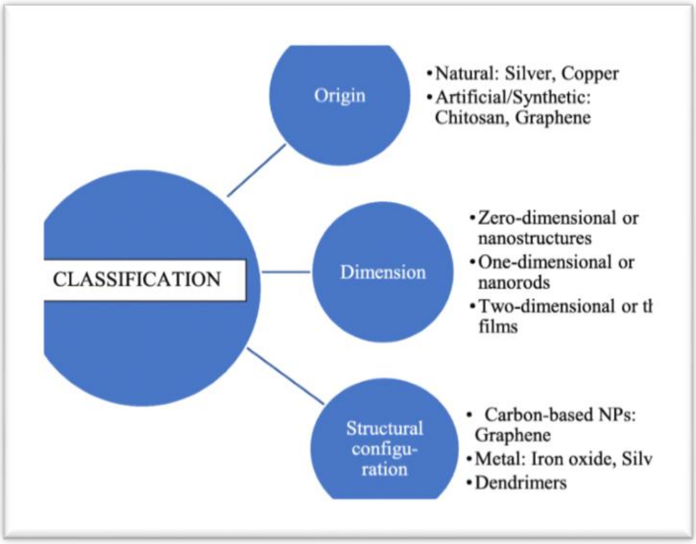

Fig 1.0 CLASSIFICATION OF NANOPARTICLES

Raura N, Garg A, Arora A, Roma M. Nanoparticle technology and its implications in endodontics: a review. Biomaterials Research.2020 Dec;24(1).

THE ROLE OF NANOPARTICLES IN ENDODONTICS

i. ENDODONTIC IRRIGANTS

Different irrigants and techniques both manual and machine-asssisted are being used to disinfect the root canal system. In modern times, the use of nanoparticles has attracted the attention of many clinicians . Silver nanoparticles are of the materials that are being used for this purpose. Another example is the use of antimicrobial photodynamic therapy based on nanoparticles . Nanoparticles exhibit antibacterial activity as a result of their polycationic/ polyanionic nature with higher surface area and charge density, resulting in greater degree of interaction with bacterial cell. Thus these therapies may provide a new alternative to conventional irrigants used in the endodontic treatment.[1]

ii. IN INTRACANAL MEDICAMENTS

Calcium hydroxide (CH) is a commonly used intracanal medicament. [2,3] Despite the fact that CH is the most commonly utilized intracanal medicament in endodontic therapy, it cannot be used to treat all organisms found in root canals. By assessing the minimum inhibitory concentration (MIC) and agar diffusion test (ADT) in dentin models from different depths, Omid Diana et al. compared the antibacterial efficacy of NCH (nano-sized CH) against E. faecalis to that of CH. When compared to ordinary CH, nano-sized CH particles have stronger antibacterial activity. Chitosan is a positively charged polysaccharide from the chitin family that has antibacterial characteristics, making it a good alternative for use in infection-prone locations. [4]

iii. IN OBTURATING MATERIALS

Over the previous 150 years, a variety of materials have been recommended for root canal obturation, but gutta-percha has remained the material of choice. Nanoparticles in obturating materials would increase the surface area between the dentin and the obturating material, resulting in improved adaptation. Narayan Nair et al evaluated the antimicrobial efficacy of Chitosan nanoparticle and Zinc oxide nanoparticle incorporated Calcium Hydroxide based sealers and found that the incorporation of nanoparticles (ZnO and CS) into calcium hydroxide based sealers significantly enhances the antibiofilm efficiency against *E. faecalis* strain ATCC 29212.[5]

III. VARIOUS NANOPARTICLES USED IN ENDODONTICS

i. GRAPHENE

Graphene is a two-dimensional carbon allotrope with sp2-bonded carbon atoms arranged in a honeycomb pattern in a single sheetlike arrangement with extraordinarily high mechanical strength and modulus of elasticity. Its amazing structural, chemical, thermal, and biological qualities have been proven and can be used in dentistry. Furthermore, graphene offers unparalleled electrical characteristics and a huge surface area for chemical functionalization. Graphene has antibacterial characteristics because the rough edges of GNP flakes pierce the bacteria's fragile cell wall, trapping and shrinking them [6]. When compared to 3 percent sodium hypochlorite, graphene in conjunction with silver nanoparticles showed excellent antibacterial characteristics with a lesser cytotoxic effect on soft tissues and bones [7]. As a result, graphene is a potential irrigant for infected canals in the future. It could also be added to Biodentine to help minimise the setting time by speeding up the hydration process and lowering induction[8] Furthermore, because of its unique qualities, graphene development should be actively pursued in the future.

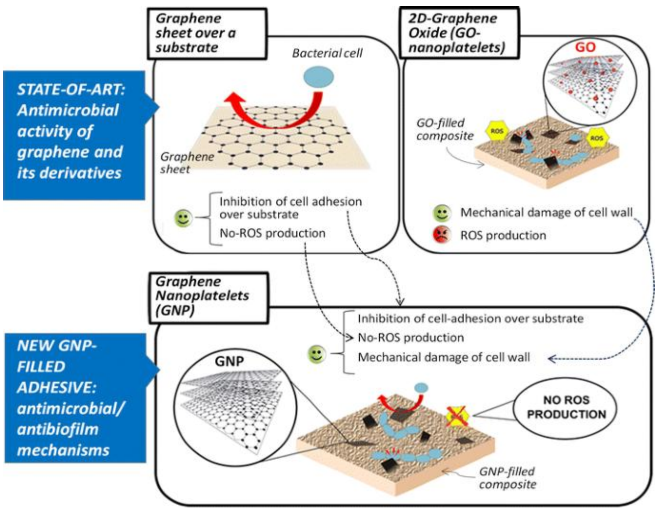

Fig 2.0 A GNP-filled polymer composite that enables to combine the anti-adhesion properties of graphene towards *S. mutans* biofilm, with the antimicrobial activity of GNPs, without producing a surplus of reactive oxygen species (ROS), which are correlated to higher cytotoxicity.

Bregnocchi, A., Zanni, E., Uccelletti, D. et al. Graphene-based dental adhesive with anti-biofilm activity. J Nanobiotechnol 15, 89 (2017).

ii. CHITOSAN

Chitosan is an organic chemical compound from the group of polysaccharides. This non-toxic biodegradable substance is obtained from the deacetylation of chitin in alkaline media. Sources of this homopolysaccharide are the exoskeletons of arthropods, mollusks and insects. Chitosan is a polysaccharide containing deacetylated units and acylated units. These unit are, respectively: D-gucosamine and N-acetyl-D-glucosamine. Due to its availability in many forms such as hydrogels, capsules or scaffoldings, it of interest as a material for biomedicine [9]. In endodontics, chitosan can be used mainly due to its antibacterial properties [10], especially against E.faecalis strain [11,12]. Chitosan combined with 2% Chlorhexidine gel could be used as a root canal sealer[13].

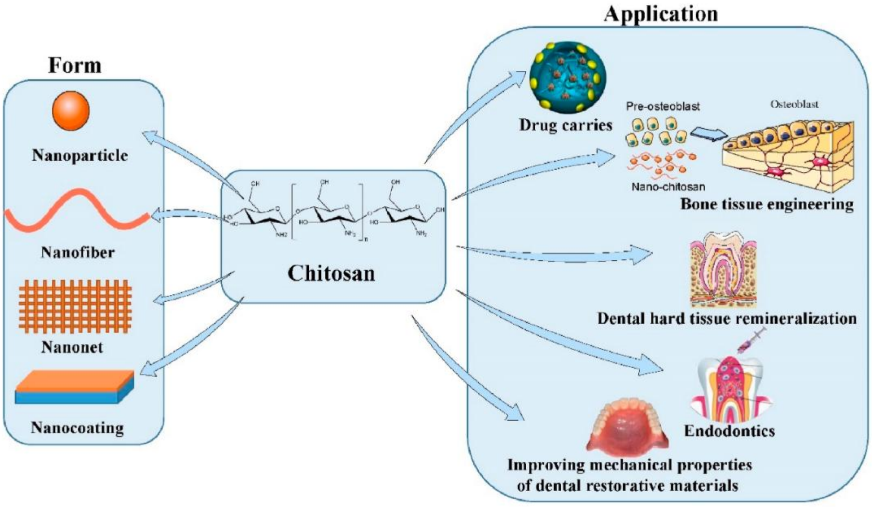

Fig 3.0 Common forms of Chitosan and its applications

Chu S, Wang J, Gao F. The Application of Chitosan Nanostructures in Stomatology. Molecules 2021;26(20):6315.

iii. BIOACTIVE GLASS PARTICLES

The chemistry of BAG is mimicking the natural hard tissues composition, and has a bioactive role in the regeneration. BAGs are usually composed of 40–52% SiO2, 10–50% CaO, 10–35% Na2O, the glass composition may contain 2–8% P2O5, 0–25% CaF2, or 0–10% B2O3. Na-free BAG prevented the disruption of the glass network and showed equal bioactivity. In addition, various elements such as Si, P, Sr, Cu, F, Ag, Zn, and F are added to enhance the bioactivity and antimicrobial properties. The bioactivity is influenced by the structure and composition of the glass, manufacturing techniques, and the rate of ionic dissolution. The FDA has approved Bioglass® 45S5 and S53P4 for clinical applications due to desired antimicrobial properties. BAGs have been implemented in endodontic root filling materials as well. The endodontic obturation thermoplastic polymer commercially known as Resilon™ [14] utilizes BAG as filler particles. Bio-Gutta, a gutta-percha (GP) mixed with Bioglass® 45S5, has emerged [15] Bio-gutta is an obturating material with a high degree of biocompatibility comparable to GP. Additionally, it provides a tight seal, increases the pH, and provides antimicrobial action. Bio-Gutta is based on the premise that the formation of calcium phosphate would precipitate on the material surface under moist conditions and provide self-adhesiveness and a tight seal .

iv. HYDROXYAPAPTITE NANOPARTICLE

The naturally occurring mineral form of calcium apatite is hydroxyapatite (HAp). It is mainly obtained from mineral tissue [16]. Hydroxyapatite is highly biocompatible due to the fact that HAp is one of the main constituents of dentin. In addition, it can also quickly osseointegrate with the supporting connective tissue (bone tissue). HAp is used in a variety of forms, equally as composites, coatings [17] and powders [18] for dental fillings in view of these advantages. Benita Wiatrak et al. [19] showed that nanohydroxyapatite molecules can also induce nerve regeneration. There is an interaction between the time of nerve inflammation and an increase in the activity of mitochondria in neurons affected by hydroxyapatite nanoparticles. In dentistry, nano-hydroxyapatite also plays a significant role due to its remineralizing properties. Remineralization occurs through the precipitation of calcium and phosphate ions, which are provided by hydroxyapatite. This phenomenon is observed with the partial demineralization of the collagen matrix . Rana S. Al-Hamdan et al. [20], as well as Allaker et al. [21], showed that nHAp particles are added to the bond to improve the biomechanical properties of the adhesive resin. Moreover, this mixture strengthens the structure and durability of the tooth.

v. SILVER NANOPARTICLES

Silver compounds as NPs are used due to their antibacterial property. Silver in metallic state appears inert. In presence of dampness it appears in ionized form. The particles sequentially interact with sulfhydryl groups of proteins and DNA, altering hydrogen bonding, unwinding of DNA and finally interfere with cell-wall synthesis. Silver nanoparticles (Ag-NPs) disturbs the microbial cell sheet and increase penetrability. This causes outflow of cell contents. n a study by Hiraishi et al. found the effect of silver diamine fluoride against E. faecalis biofilms. 1 Complete eradication of microbial layer after an hour of interaction was seen. In another study, 0.02 % Ag-NP gel was used as intracanal medication for 7 days. It had better result in E. faecalis biofilm destruction, in comparison to calcium hydroxide and syringe irrigation with higher concentration Ag-NP (0.1 %) solution1. Problems with use of silver NPs are the blackening of dentin and toxic effect on mammalian cells.

vi. ZIRCONIA

Zirconia (Zr) is a stabilized regular modification of zirconium oxide. This material is characterized by: high wear resistance, good optical properties and low reactivity. Endodontic treatment causes the reduction of the tooth's mineral tissue (its loss) and consequently, weakening of the tooth. The reduced amount of tooth tissue makes its reconstruction difficult. Core buildups are used to retain core materials that are predictably delivered with state-of-the-art resin composites [22,23]. Based on laboratory tests, it can be observed that reconstructing composites containing Zr nanoparticles showed better c ompressive strength compared to other composites and compared to micro- and macromolecules based on silica and barium.

IV. CONCLUSION

Although the full influence of nanotechnology in the field of endodontics is still unknown, quickly expanding research will ensure that advances that are beneficial to patients are made.
In the future, things that appear impossible today may be possible. Future prospects Nanotechnology's benefits will be put to good use. Endodontics has improved in all aspects, including instrument alteration, irrigation, obturation, and the most important repair and regeneration of pulp tissue is crucial.

CONFLICT OF INTEREST : NIL

FINANCIAL DISCLOSURE : NONE

REFERENCES

1. S. Eckhardt, P. S. Brunetto, J. Gagnon, M. Priebe, B. Giese, and K. M. Fromm, “Nanobio silver: its interactions with peptides and bacteria, and its uses in medicine,” Chemical Reviews 2013; 113(7):4708–4754.
2. Nair PN. On the causes of persistent apical periodontitis: a review. IntEndod J. 2006;39(4):249–81.
3. Love RM, Jenkinson HF. Invasion of dentinal tubules by oral bacteria. Critical Reviews in Oral Biology & Medicine. 2002;13 (2):171–83.
4. Ong
5. SY, Wu J, Moochhala SM, Tan MH, Lu J. Development of a chitosan-based wound dressing with improved hemostatic and antimicrobial properties. Biomaterials 2008; 29: 4323–4332.
6. T. Waltimo, T.J. Brunner, M. Vollenweider, W.J. Stark, M. Zehnder. Antimicrobial effect of nanometric bioactive glass 45S5 J. Dent. Res.2007;86:754–757.
7. . Pranno, N.; La Monaca, G.; Polimeni, A.; Sarto, M.S.; Uccelletti, D.; Bruni, E.; Cristalli, M.P.; Cavallini, D.; Vozza, I. Antibacterial Activity against Staphylococcus Aureus of Titanium Surfaces Coated with Graphene Nanoplatelets to Prevent Peri-Implant Diseases. An In-Vitro Pilot Study. Int. J. Environ. Res. Public Health 2020, 17, 1568.
8. Moradi, F.; Haghgoo, R. Evaluation of antimicrobial efficacy of nanosilver solution, sodium hypochlorite and normal saline in root canal irrigation of primary teeth. Contemp. Clin. Dent. 2018, 9, S227–S232.
9. Dubey, N.; Rajan, S.S.; Bello, Y.D.; Min, K.S.; Rosa, V. Graphene Nanosheets to Improve Physico-Mechanical Properties of Bioactive Calcium Silicate Cements. Materials 2017, 10, 606.
10. Agnihotri, S.A.; Mallikarjuna, N.N.; Aminabhavi, T.M. Recent advances on chitosan-based micro- and nanoparticles in drug delivery. J. Control. Release 2004, 100, 5–28.
11. Del Carpio-Perochena, A.; Kishen, A.; Shrestha, A.; Bramante, C.M. Antibacterial Properties Associated with Chitosan Nanoparticle Treatment on Root Dentin and 2 Types of Endodontic Sealers. J. Endod. 2015, 41, 1353–1358.
12. Ballal, N.V.; Kundabala, M.; Bhat, K.S.; Acharya, S.; Ballal, M.; Kumar, R. Susceptibility of Candida albicans and Enterococcus faecalis to Chitosan, Chlorhexidine gluconate and their combination in vitro. Aust. Endod. J. 2009, 35, 29–33.
13. Wang, N.; Ji, Y.; Zhu, Y.; Wu, X.; Mei, L.; Zhang, H.; Deng, J.; Wang, S. Antibacterial effect of chitosan and its derivative on Enterococcus faecalis associated with endodontic infection. Exp. Ther. Med. 2020, 19, 3805
14. Loyola-Rodríguez, J.P.; Torres-Méndez, F.; Espinosa-Cristobal, L.F.; García-Cortes, J.O.; Loyola-Leyva, A.; González, F.J.; Soto-Barreras, U.; Nieto-Aguilar, R.; Nieto-Aguilar, R. Antimicrobial activity of endodontic sealers and medications containing chitosan and silver nanoparticles against Enterococcus faecalis. J. Appl. Biomater. Funct. Mater. 2019, 17, 2280800019851771.
15. Piotrowski, G.; Hench, L.L.; Allen, W.C.; Miller, G.J. Mechanical studies of the bone bioglass interfacial bond. J. Biomed. Mater. Res. 1975, 9, 47–61.
16. Mohn, D.; Zehnder, M.; Imfeld, T.; Stark, W.J. Radio-opaque nanosized bioactive glass for potential root canal application: Evaluation of radiopacity, bioactivity and alkaline capacity. Int. Endod. J. 2010, 43, 210–217.
17. Sebdani, M.M.; Fathi, M.H. Novel hydroxyapatite-forsterite-bioglass nanocomposite coatings with improved mechanical properties. J. Alloys Compd. 2011, 509, 2273–2276.
18. Sung, Y.M.; Lee, J.C.; Yang, J.W. Crystallization and sintering characteristics of chemically precipitated hydroxyapatite nanopowder. J. Cryst. Growth 2004, 262, 467–472.
19. Fathi, M.H.; Hanifi, A. Evaluation and characterization of nanostructure hydroxyapatite powder prepared by simple sol-gel method. Mater. Lett. 2007, 61, 3978–3983.
20. Wiatrak, B.; Sobierajska, P.; Szandruk-Bender, M.; Jawien, P.; Janeczek, M.; Dobrzynski, M.; Pistor, P.; Szelag, A.; Wiglusz, R.J. Nanohydroxyapatite as a biomaterial for peripheral nerve regeneration after mechanical damage—In vitro study. Int. J. Mol. Sci. 2021, 22, 4454.
21. Al-Hamdan, R.S.; Almutairi, B.; Kattan, H.F.; Alsuwailem, N.A.; Farooq, I.; Vohra, F.; Abduljabbar, T. Influence of hydroxyapatite nanospheres in dentin adhesive on the dentin bond integrity and degree of conversion: A scanning electron microscopy (SEM), raman, fourier transform-infrared (FTIR), and microtensile study. Polymers 2020, 12, 2948.
22. Allaker, R.P.; Ren, G. Potential impact of nanotechnology on the control of infectious diseases. Trans. R. Soc. Trop. Med. Hyg. 2008, 102, 1–2.
23. Renugalakshmi, A.; Sekar Vinothkumar, T.; Kandaswamy, D. Nanodrug Delivery Systems in Dentistry: A Review on Current Status and Future Perspectives. Curr. Drug Deliv. 2011, 8, 586–594.
24. Alenazy, M.S.; Mosadomi, H.A.; Al-Nazhan, S.; Rayyan, M.R. Clinical considerations of nanobiomaterials in endodontics: A systematic review. Saudi Endod. J. 2018, 8, 163–169