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Application of Nanoparticles in Endodontics

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Nanoscience is a planned blend of nanotechnologies/nanoparticles used in healthcare to discover novel treatment strategies for human infections. N anotechnology is used in many aspects of our daily lives, including medical science. Nanostructures are employed in dental advances, diagnosis and treatment [2]. When compared to traditional materials, Nanoparticles was shown to have significantly superior adhesive plus surface properties. Nanotechnology's practical implementation in endodontics has allows for new study in this domain.

Keywords: Nanoparticles; nanotechnology; endodontics.

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1. INTRODUCTION

Professor Kerie E. Drexler, a nanotechnology educator and researcher, is credited with coining the term "nanotechnology." [1-4]. Nanoparticles are a new discipline of science that deals with the creation and evolution of nanoparticles. The name 'Nano' comes from the Greek word 'vacos,' which signifies dwarf in English [5]. In the department of endodontics, nanoparticles are being developed with the objective of strengthening antibacterial efficacy in root canals. Nature provides nanoparticles with different diameters between 1 to 100 nm, which are routinely used in a variety of common products. Nanoparticles can always be observed in soil which are used in a multitude of scenarios. Ultraviolet light filters, mouthwashes, multivitamins, various aerosols for sealing, scrubbing, and procreation contain titanium oxide (TiO2) but rather zinc oxide (ZnO) particles [6]. Nanoparticles have a number of characteristics that make them beneficial in today's dentistry. Regenerative therapies are more effective as a result of their use. Nanoparticles can be exploited as a nanocarriers for active substances that increase stem neurogenesis, emigration, including transformation, or even as a scaffold that allows stem cells develop & differentiate. Another advantage of nanoparticles appears to be their key to achieve the retention of obturation as well as restorative materials to root canal margins.

2. METHODOLOGY

Search strategy:

I searched google scholar database for article on application of nanoparticals in endodontics. using key words and their alternatives, search strategy developed.

- Google scholar N=148
- Excluded studies N=92

-application of nanoparticles in periodontology and other branches N=25
-nanoparticles for drug therapy N=45
-metal nanoparticles synthesis N=15
-nanoparticles toxicities N=7

- Included studies N=56

3. HISTORY

In modern physics, nanomaterials get a long and illustrious history Around 1959, Dr. Richard Feynman invented the term "nanotechnology." [7]. Dr. Sumio Lijima first proposed the concept of nanotubes in 1991. Dr. Freitas Jr. invented the phrase "nano-dentistry" a year 2000. He created nanomaterials as well as nanorobots, assisted in dentition regeneration, and invented dentirobots or dental robots. All of these concepts were once thought to be unachievable and labelled "science fiction," but in today's world, clinicians are finally acknowledging them [8].

Despite nanoparticles are supposed to be a recent scientific discovery, they have a long history. Nano particles are used by previous humans. However, no one can say for definite when they initially started using strengths of nanoparticles in a number of fields. Nanomaterials have been featured in painting since the fourth century AD because due to their optical characteristics. The Lycurgus cup is the most well-known example. The British Museum in London houses this cup. This beautiful cup is a great historical illustration. It's constructed of dichroic glass, which really is a unique sort of glass. When light falls on it, it can change colours. When light hits the cup at a 90° angle, the cup's opaque green colour converts into a luminous translucent.

A small amount of gold as well as silver crystals together in 1:14 molar ratio are used to make beautiful cup.It has uncommon optical properties because to the metal crystals. The presence of these nanostructures gives this Lycurgus Cup a unique tint [9].

4. CLASSIFICATION OF NANO-PARTICALS

The Nanoparticles are classified under following categories [10]

1. Depending on source:

- Natural
- Artificial

2. Depending upon measurement:

- Zero-dimensional or nanostructures
- One-dimensional or nanorods
- Two-dimensional or thin films

3. Based on structural configuration:

- Carbon-based Nanoparticles

- Metal nanoparticles
- Dendrimers
- Composite

5. PROPERTIES OF NANOPARTICALS [11]

The size of the crystallite is significant. The size is between 10 and 100 nanometres.

- Particles with dimensions less than 10 nm but also greater exceeding 100 nm still had no medicinal qualities.
- Polymers encapsulated with nanoparticles, such as polyethylene glycol, prevent proteins from adsorbing and hence extend the split.
- The smaller nanoparticles, the greater the absorption efficiency.

6. MECHANISM OF ACTION OF NANOPARTICLES

A) Collapse of a nuclear envelope due to the electrostatic coupling

Positively charged nanoparticles interact with negatively charged microbial surfaces, allowing nanoparticles to clump. These The positively charged Nanoparticles adhere to the phospholipid bilayer efficiently, leading the cell wall structure to be thrown off and increasing cell permeability, allows an increasing number of Nanostructures to enter the bacteria, due to the release of cell contents. By interacting to mesosomes, these nanoparticles alter respiration, mitosis, and other functions, along with DNA replication [12,13]

B) Generation When nanocrystals cross the cell membrane of a pathogen and release reactive oxygen species (ROS), the cell undergoes peroxidation, that contributes to an attack on the bacterium. As a result of the incident, inhalation and output have been restricted. The cell membrane becomes ruptured when the amount of ATP in the cell falls. Metal oxides create Radicals as a result of active biotransformation and the addition of a pro-oxidant. There is a hydrocarbon on the metal oxide-NP junction of reactive oxygen species (ROS) [14].

C) Reduction of signalling pathways and cytotoxicity

Due to their electrical properties, Particles interact with bacterial DNA and have a negative impact. As a response, chromosomal and recombinant DNA replication is prevented, and signal transduction is constricted [15,16,17].

7. APPLICATION OF NANOMATERIALS AND NANOTECHNOLOGY IN ENDO-DONTICS ARE AS FOLLOWS

7.1 Nano Based Root Canal Sealer

According to Schilder [18] Full obturation of the root canal space, along with three-dimensional imaging (apically, coronally, and laterally) but also apical, coronal, and lateral sealing are now ultimate goals of endodontic procedure. The radicular space is essential for main contributions. Nanoparticles have improved obturating compound adaption to dentinal walls by increasing surface area [19].

Zinc oxide eugenol, calcium hydroxide, glass ionomer, silicone, resin, even bio ceramic-based sealants all examples of endodontic sealants [20].

Endodontic sealers, which are based on nanotechnology, are the most recent advancement. By actively sealing minute spaces, these sealers help to minimise infection. Nanoparticles of titanium dioxide are present in the sealer.40-60nm calcium phosphate hydroxyapatite Dentine tubules are invaded by these rod-shaped particles, that enter the tubules in to canals. It ensures that everything is in running condition [21].

According to Grossman, Ideal features of root canal sealer are:

1) Compatibility of tissue
2) There was no shrinking during setting process.
3) Allow for a considerable amount of setting time
4) capability to adhere
5) Radiopacity
6) stain resistance
7) solubility in water
8) insolubility in saliva and other bodily fluids
9) Bacteriostatic features as well as the power to make a bacteriostatic environment. *But none of the sealers currently available that possesses all of these ideal characteristics [22]

Nanoparticle-based sealers have improved antibacterial effect and, compact size, can penetrate the dentinal tubules, enhancing the

effectiveness to repair [23]. The initial setting process of nanocrystalline bio ceramic sealers has

1) high pH (highly antibacterial)
2) hydrophilic. Biocompatible
3) won't shrink or resorb.
4) They sealed efficiently, cure rapidly, and thus is straightforward to use [24].

Nano-Brush is a brand-new type of applicator brush. The typical scaffolding for entering the root canal. It aids in the evacuation of pulp from the root chamber, the clearing of detritus and the use of anti-restorative compounds against the internal surface of canal. It is advantageous for deeper penetration of sealers into dentine tubules [25].

7.2 Nanomaterials for Tissue Repair and Regeneration

Major goals are to restore, replace, maintain, or improve the function of various types of biological tissues [26 ,27].

Various Nanomaterials that enhance chronic wound healing [28]

A) Metal nanoparticles

(Silver, gold, zinc): - antibacterial action
-reepithelization

B) scaffolds

(Hydrogels, chitosan): - cell growth
-matrix formation

C) polymeric nanostructures
(Silicone, polystyrene, collagen):

- blood vessel formation
- neovascularisation

D) peptides nanostructures:

- liver progenitor cells differentiation
- endothelial cells survival
- dental stem cells growth

7.3 Photodynamic Treatment Based on Nanoscale Particles

Photodynamic therapy is an example of a revolutionary endodontic treatment procedure that can benefit from nanotechnology [29,30]. In photodynamic treatment, a photosensitizing or photosensitizer chemical, as well as a precise wavelength of the light, are being used (PDT). Displaying a specific light wavelength is one way to do this. Photosensitizer release oxygen, which kills the cells around them [31,32].

7.3.1 Antimicrobial Photodynamic Therapy (aPDT)

A growing number from in vitro as well as in vivo methods assessing the efficacy as for antimicrobial photodynamic therapy (aPDT) in dentistry have just been described inside the past. Antimicrobial Photodynamic Therapy (aPDT) is an adjuvant technique for improving root canal disinfection and minimizing bacterial resistance evolution [33]. Nanostructures are activated by a laser of a certain wavelength, resulting in the formation of reactive oxygen species (ROS) [34]. As illustrated in below Figure, the aPDT mechanism

Type I: The light-excited PS exchanges electrons or hydrogen atoms with the surrounding molecules. This process causes environmental changes that result in hydroxyl radicals, which are one of ROS's reactive forms [35]. Following the activation of the device by light,PS, the targeted cells are killed by a succession of released oxygen ions and free radicals [36,37]. One of the significant benefits of aPDT is its reliance on enhanced penetration and accessibility of oxygen species [38,39]

Type II: Light activates the PS, which then reacts on molecular oxygen with in ground state so create excited state oxygen. ($^1 O_2$), which seems directly impacted by biofilm-related diseases [40].

Both types of reactions could occur at the same time. The proportion depend on type of PS utilised and the PS molecules' microenvironment influence the processes [35].

Advantages and Disadvantages of Photodynamic Therapy [42]

Advantages:

1) It can be used in outpatient settings -It has a short treatment time
2) Fewer side effects
3) Selectivity on two levels
4) Somewhat intrusive
5) Can be useful in a similar situation
6) After surgery, there is little or no scarring.
7) There are fewer treatments.
8) pricier than other alternatives

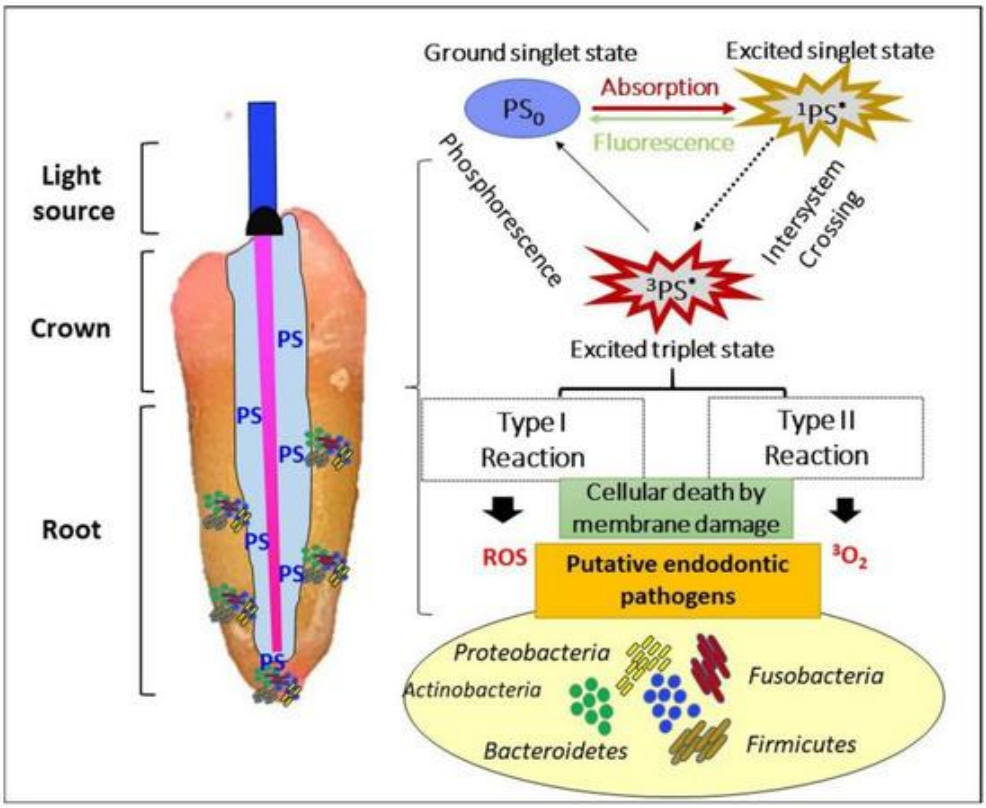

Fig. 1. For antimicrobial photodynamic therapy, any ray of light with such a specified spectrum might activate a photosensitizer to that of an excited singlet state and perhaps a triplet singlet state. Antimicrobial mortality could be caused by the triplet singlet state, wherein produces reactive oxygen species (Type I), singlet oxygen (Type II), maybe both [41]

Disadvantages:

-The photodynamic effect is based on tissue oxygenation
-Photosensitivity after therapy
- The efficiency of treatment is determined by the accurate distribution of light to the affected area.

7.4 Nano Based Root Canal Disinfectant

In endodontic treatment, disinfecting a root canal is a crucial step. The debridement and elimination of the microbial environment associated with the disease process is the goal of endodontic treatment. The need for root canal disinfectants grows, especially in cases where infection is resistant to standard treatment and endodontic therapy outcomes are frequently jeopardised. Antimicrobial properties of silver nanoparticles make them suitable for disinfection. In recent years, it has been proven that Enterococcus faecalis is linked to tooth pulp and periapical illness. One of the most typical bacteria that causes reoccurring or chronic root canal infection, as well as root canal therapy failure, is Enterococcus faecalis. Typical root canal disinfection drugs like sodium hypochlorite, chlorhexidine, as well as calcium hydroxide cannot successfully remove Enterococcus faecalis due to the obvious medication concentration limit or the diversity of an endodontic treatment [43].

Primary and secondary root canal infection are thought to be caused by endodontic biofilms and the intricacy of root canal systems. Unfortunately, these biofilms contain bacteria that are well within dentinal tubules and are therefore inaccessible to standard equipment, irrigates, intracanal medicaments, and sealers. Nano (Nanoparticles) seem to be very tiny molecules with such a diameter from one to one hundred nanometres. The size of nanoparticulate employed in root canal disinfection has been found to play an essential impact in their antibacterial activity by overcoming microbiological hurdles, mechanical integrity of diseased dentin matrix, and other factors [44].

7.4.1 Nanotech endodontic irrigation

This endodontic irrigation system is based on nanotechnology, which is intended to clean root canals in RCT processes. It gives the best protection and eliminates the disadvantage of traditional syringe. There's also no demand of manpower while using this machine. This also eliminates the risk of an accident. Fluids flow out of the oral cavity and beyond the apical area of the root [45].

7.4.2 Nanometric bioactive glass

Glass particle area is smaller, surface area being increased, enhancing antimicrobial efficiency so allowing this to be used for dentin disinfectant [46].

7.5 Modification in Surface Quality of Endodontic Instruments

Root canal shaping, which is done with a variety of endodontic files, is crucial for a successful root canal therapy [47,48,49] mechanical properties of endodontic device can be assessed using nanoscience, Jamleh and his colleagues [50] as an example A nano-indentation method was used to test the impact of periodic wear on nickel-titanium alloys. In endodontics, a piece of equipment known as (NiTi) is employed. The study found that the previously indicated technique (nano-indentation test) may be used to assess Instruments made of NiTi have a failure mechanism. In Zinelis et al. [51] used the nano indentation technique to determine in-depth hardness.

7.5.1 Nano tweezers and nano needles

Nano tweezers will render cell surgery achievable in the near future, while stainless steel nano needles have been invented. They comprise iron alloy and low-alloyed ferritic steel characteristics [52].

8. PROSPECTS OF NANOPARTICLES IN ENDODONTICS

Nanostructures now has a big effect on virtually major field of research and development, so it's no wonder that healthcare and dentistry have prospered from this humankind's incredible potential. With all that being said, there is no hesitation that endodontics' future is bound in the direction of nanoscience, given that a lot of the difficulties faced are all nanoscale. Nano endodontics is opening the way for a brighter tomorrow in dentistry.

9. CONCLUSION

Many previous innovations will have a lesser influence on dentistry, healthcare, and human life than nanoscale. Endodontic therapy methods based on nanoparticles have always had the potential to transform antimicrobial as well as antibiofilm potency. Nanoparticles is used in a number of ways, including root canal sealants, disinfectants & photodynamic therapy.

Endodontic treatment methods based on nanoparticles have the ability to improve antibacterial/antibiofilm efficacy. As a consequence, there is a growing interest in this topic. To underline its relevance of the future, such area demands rigorous study based on scientific & evidence, as well as clinical cooperation. The importance of nanoparticles in clinical endodontics [53].

Nanoparticles have showed incredible potential for reducing biofilm formation, accelerating tissue regeneration, slowing the demineralization of tooth structure, and controlling caries-related and endodontic microorganisms. These observations have attracted the interest of researchers who want to launch more clinical trials to assess the therapeutic efficacy of nanoscale materials [3].

Regarding future growth, a concept of nanoparticles across medical sciences as well as dentistry should be given top priority [54,55,56].

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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