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NANOTECHNOLOGY IN ENDODONTICS: ADVANCING AND EFFICACY IN ROOT CANAL TERAPY

Feyza OZDEMIR KISACIK[1*]

[1] *Burdur Mehmet Akif Ersoy University, Faculty of Dentistry, Department of Endodontics, Burdur, Turkey*

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ABSTRACT

Nanotechnology is a rapidly developing field with a wide range of applications in various industries, including medicine, electronics, and materials science. Nanomaterials produced with nanotechnology have also started to be used in dentistry applications. The use of nanotechnology in dentistry has revolutionized various aspects of oral healthcare, from diagnostics to treatments.
This article reviews the current status of nanotechnology in the field of endodontics with its possible applications.

1. INTRODUCTION

Nano technology involves nanoscale dimensions, corresponding to a range of 1−100 nm, and has a diverse application range in almost every field of science [1]. Also in dentistry, it is a groundbreaking field with promising innovations in diagnosis and treatment methods [2].
One of the most significant benefits was the enhanced precision and accuracy in dental procedures. Nanomaterials and nanodevices allow dentists to target specific areas with unparalleled accuracy, reducing the invasiveness of treatments and minimizing damage to surrounding healthy tissues [3].
Another aspect was the efficiency and speed of dental treatments. Nano dentistry has enabled faster healing and recovery times due to its ability to stimulate tissue regeneration and accelerate the body's natural healing processes [4]. This means less time spent in the dentist's chair and quicker return to normal activities, which is undoubtedly a huge plus for any dental patient.
Endodontics is a specialized field of dentistry that focuses on treating the innermost part of the tooth, known as the pulp or root canal. Root canal therapy is crucial for saving teeth from extraction, and advancements in nanotechnology have introduced a new era of precision and efficacy in this essential dental procedure. This article explores the role of nanotechnology in endodontics, discussing its potential applications, benefits, and future prospects.

2. NANOTECHNOLOGY FOR GENERAL DENTISTRY

The term nano-dentistry started with the development of nanorobots and nanomaterials in the 2000s [5].
Nano robot technology is used for local anesthesia by being controlled by dentist-controlled nanocomputers. Deposited nanorobots in gingival tissue reach the pulp through the dentinal tubules and anesthesia is provided by controlling their movements with temperature difference and chemical signaling with the nanocomputer [6]. Then, when the procedure is finished, it is possible to remove anesthesia with the command to end anesthesia.
Reconstructive dental nanorobots using natural biological materials can selectively and sensitively occlude relevant dentinal tubules within minutes and provide permanent and rapid solutions to patients' dentin sensitvity [5]
By adding nanoparticles to bonding agents, higher dentin and enamel bond strength achieved. It has longer shelf life, high stress absorption, and better marginal sealing with less marginal leakage and prevent secondary caries [7,8].
By adding nanoparticles to the composite fillings, superior hardness and bending strength, flexibility modulus, transparency and comfortable use properties are gained. The shrinkage of the filler is reduced [9].

* Corresponding Author: feyzaozdemir@gmail.com

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Nanorobots are added to mouthwash or toothpaste can circulate on all supragingival and subgingival surfaces at least once a day, metabolizing trapped organic matter into harmless and odorless vapors, thus preventing the formation of calculus permanently [9].
Nano-fillers are added to vinyl polysiloxanes to produce a unique siloxane impression material with better flow, improved hydrophilic properties and improved precision detail [9].
Nanotechnology is used in orthodontics as brackets, archives, elastomeric ligatures, orthodontic adhesives [10].
This technology also used in implantology for a modification of the implant surface, in the diagnosis of oral cancers and for periodontal diseases [11].

3. ENDODONTIC NANOTECHNOLOGY

Successful endodontic treatment includes some important procedures such as biomechenical preperation, disinfection, appropirate sealing and filling of the root canal system [12]. Failure in root canal treatment may be due to inadequacy of root canal treatment steps. Microleakage, irrigant activation and cleaning play an important role in the success of endodontic treatment. Synthesis of new materials having better quality sealing and biomechanical properties will ensure the success of endodontic treatment [13]. There are many studies that will significantly affect success when improved in clinical practice, such as files and filling materials.
Some nanoparticles added to irrigation solutions and intracanal medicaments, can increase the antimicrobial effectiveness of the materials with their small size and their ability to spread over complex anatomical areas in root canal systems [14].
Much of the nanotechnology studies has focused on creating "nanomodified" materials. These nanoparticles can strengthen the sealing of obturation and filling materials used in both root repair and root tip filling materials [15,16].

4. DENTIN HYPERSENSITIVITY

Dentin hypersensitivity can be caused by changes in hydrodynamic pressure in the pulp. Using local biological materials, dental nanorobots can quickly and precisely occlude selected tubules, providing quick and lasting relief to patients [17].

5. ENDODONTIC ISTRUMENTS

Nickel-titanium (NiTi) endodontic rotary files are one of the most commonly used instruments in endodontic practice. It has many positive properties such as high corrosion resistance and superelastic modulus. Cobalt coating these types of rotary files with fullerene-like tungsten disulfide (WS2) nanoparticles results in a significant improvement in fatigue resistance and breakage time [18].

6. NANOPARTICLES IN DISINFECTION AND ANTIBACTERIAL PROPERTIES

Clinically, longer contact times of irrigants and medicaments within the canal walls are required for sterilization and disinfection of root canals that cannot be adequately cleaned with canal instruments. Nanoparticles have been added to increase the effectiveness of irrigation solutions and intracanal medicaments [14,19,20,21].
Studies have evaluated tissue responses to the use of nanoparticle type irrigants. One of these particles, silver nanoparticles, has been used as an antibacterial and antifungal agent in different applications and as a component of biotechnology and bioengineering in dental care [20,22].
Studies have found that the nanoparticle component generally causes a significant reduction by acting on the cell walls of the microorganism. They found the use of polyacticcoglycolic acid (PLGA) nanoparticles encapsulated with protective drugs beneficial in terms of antimicrobial activity. It has been shown to be effective on microbial biofilms such as E. Faecalis [23].

7. INTRACANAL MEDICAMENTS

Calcium hydroxide paste is the most commonly used intermediate session material. When silver nanoparticles (20 nm in size) are mixed with calcium hydroxide, it causes an increase in antibacterial effect compared to calcium hydroxide alone or in combination with chlorhexidine [24]. A commercially available product, NanocarePlus Silver and Gold (NanoCare Dental, Nanotechnology, Katowice, Poland), has shown promising antimicrobial properties as an intracanal medicament.

8. ROOT CANAL FILLING

It has been shown that bacterial penetration into the root canal is reduced by adding chitosan and zinc oxide nanoparticles to the canal sealers. It was thought that adding nanoparticles to sealers would give successful results [25]. Some researhs concluded that chitosan-loaded endodontic pastes retain their antibacterial activity for a longer period of time [26].
Embedded nano-diamond gutta-percha (NDGP) composite showed superior mechanical properties (such as strength and elastic modulus) compared to routinely used gutta-percha [27].

9. NANOPARTICLES USED IN ENDODONTICS

There are many nanoparticles used in medicine and dentistry. The nanomaterials used in endodontics are summarized in Table 1.

Table 1. Nanoparticles used in endodontics

Nano Particle	Origin	Field of Use	Form of Use	Benefit
Graphene	organic	diagnosis detection formation anti-bacterial surfaces [25]	incorporating graphene into silver nanoparticles	antibacterial property same with sodium hypochlorite cytotoxic effects to bone and soft tissues reduced [28]
Chitosan	organic	Antimicrobial antifungal antiviral	along with CHX	remove *Enterococcus faecalis* from the canals. formation of membrane barriers at the peri-radicular area [29]
Poly (lactic) co-glycolic acid	organic	eradication of microorganisms	incorporated with photoactive drugs in endodontic canals.	reduce microbial counts adhered to the root dentin and canals [30]
Bioactive glass nanoparticles	Non-organic	disinfection of root canals	SiO2, Na2O, and P2O5	Osmotic effects: effective for many microorganisms. Calcium-Phosphate precipitation: Results in mineralization of the demineralized enamel surface [31]
Mesoporous calcium silicate	Non-organic	filling of apical third of the root canals		Drug delivery Antibacterial efficiencies Injectability Apatite mineralization Osteo-stimulation [32]
Hydroxyapatite nanoparticles	Non-organic	decreasing dentin hypersensitivity. periapical healing agent	dentrifices and mouthrinsing solutions	remineralize the demineralized enamel surface [33].
Silver nanoparticles (AgNP's)	Metal nanoparticles	İrrigation penetrate the bacterial cell membrane cause bactericidal action.	Combination with 2.5% sodium hypochlorite, or Poly vinyl coated particles	low bacterial resistance, low toxicity [34], and longstanding antibacterial activity [35]. Effective against *Enterococcus faecalis*.
Iron compound (FeOx)	Metal oxide nanoparticles	elimination of endodontic biofilms		complete elimination of microorganisms [36]
Zirconia	Metal oxide nanoparticles	eradicate bacterial colonization [37,38]	Anti microbial agent Also radiopacifier in Portland cement	Effective against *Enterococcus faecalis* [30] improved radiopacity [39]
Tio2 nanoparticles	Metal oxide nanoparticles	effective antifungal for fluconazole-resistant strains		cell membrane disruption [40,41,42]
MgO and CaO nanoparticles	Metal oxide nanoparticles	Antibacterial activity on Gram-positive and Gram-negative microorganisms [43,44]		MgO has comparable or superior results to the gold standard 5.25% sodium hypochlorite irrigant [25]
CuO nanoparticles	Metal oxide nanoparticles	Anti fungal and Antibacterial activity		damage the vital enzymes of the bacteria [45,46]

10. CONCLUSIONS

Nanoparticles have an important place among the diagnosis and treatment options in dentistry and especially in the field of endodontics, as in all health fields. Nanomaterials may lead to promising developments in endodontics with their antimicrobial activities, effects on the biofilm layer, reducing demineralization and their use in preventive treatments.
Due to the superior properties of nanomaterials recent technological developments and studies are rise. While nanotechnology offers numerous potential benefits, it is also important to be aware of the potential side effects and concerns associated with its use. Therefore, detailed and comprehensive studies are needed to reach widespread usage.

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