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Nanodentistry:
Latest Advancements and Applications of Nanomedicine in Dentistry

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1. Background-Aim

Background

Nanotechnology has gained significant attention in dentistry due to its ability to manipulate materials at the nanoscale, providing superior properties such as enhanced durability, biocompatibility, and antibacterial action. The application of nanotechnology in dental materials, implants, and diagnostics has been a major area of research over the last two decades, aiming to improve patient outcomes, reduce treatment times, and increase the longevity of dental interventions.

Aim

The objective of this bibliographic research is to present the current state of nanotechnology in dentistry, focusing on the latest applications and innovations on the following subjects

Current State: The existing use of nanomaterials in dentistry

Current Research: Ongoing research efforts aimed at enhancing dental materials and improving diagnostic accuracy through safer imaging techniques using nanosensors and quantum dots

Innovations Under Research: Explore innovative developments currently under investigation, such as the use of nanobiosensors for non-invasive detection of oral diseases, and the potential for nanorobots to facilitate targeted drug delivery and tissue regeneration

Future Perspectives: Discuss future perspectives, including the development of nanomaterials that promote both soft and hard tissue regeneration, advancements in non-invasive dental

2. Materials & Methods

Materials

1.Databases:

1. The research utilized various academic databases, including PubMed, Google Scholar, and ScienceDirect,
2. **Keywords**: The search strategy involved terms like "nanotechnology in dentistry," "nanocomposites," "nanobiosensors," "dental implants nanotechnology," and "nanomedicine for oral health."

2.Inclusion Criteria:

1. Articles published between **2010 and 2024** were selected.
2. Focused on clinical trials, systematic reviews, and meta-analyses related to nanomaterials and nanomedicine applications in dentistry.

Methods

1.Research Strategy:

1. A bibliographic research methodology was employed, systematically reviewing scientific papers and journals on nanotechnology applications in dentistry.
2. **Data Extraction**: Each selected article was critically analyzed, and key data were extracted based on:
    1. Type of nanomaterials used (e.g., nanocomposites, nanobiosensors,).
    2. Application areas (e.g., restorative dentistry, implantology, diagnostics).
    3. Outcomes related to the efficacy of nanotechnology in clinical dental applications.

2.Data Synthesis:

1. Findings were synthesized to evaluate the overall impact of nanotechnology in enhancing dental treatments, improving biocompatibility, and facilitating early diagnostics in dentistry. The review highlighted advancements in both materials and methods.

3. Results

What is Nano – Dentistry?

Nanodentistry refers to the application of **nanotechnology** in the field of dentistry, encompassing the use of nanoscale materials (1–100 nm) for diagnostics, therapeutic treatments, and restorative procedures. Nanodentistry aims to improve patient care by enhancing dental materials, promoting tissue regeneration, and enabling more precise diagnostic tools.

Hamissi et al. (2016) define nanodentistry as "the use of nanomaterials, including nanoparticles and nanostructures, to improve dental care in areas such as diagnosis, disease prevention, and tissue regeneration“ **(1)**

Why is Nanotechnology Important in Dentistry?

Nanotechnology introduces groundbreaking advancements that address significant challenges in modern dentistry.

- **Enhanced Dental Materials:** Nanocomposites improve the longevity of restorations
- **Targeted Drug Delivery: Nano-drug delivery systems (nano-DDS)** enable precise delivery of drugs to specific sites, minimizing side effects and improving the treatment of diseases like oral cancer
- **Improved Diagnostics**: Nanoparticles enhance **early detection** of oral diseases by non-invasive diagnostic tools

Tissue Regeneration: Nanomaterials like **nano-hydroxyapatite** are used to promote the regeneration of enamel, dentin, and bone, improving treatment for periodontal disease and trauma

Infection Control: Antibacterial nanoparticles (e.g., **silver, zinc oxide**) help prevent infections in dental implants and periodontics **(2)**

3. Results

Nanodentistry Applications currently in use

Restorative Dentistry: Nanocomposites like 3M Filtek One Bulk Fill or Nanofilled Dental Adhesives Products like Prime & Bond Active by Dentsply Sirona are widely available and used in dental practices today to improve the durability, aesthetics, and wear resistance of restorative materials.

Preventive Care: Nano-hydroxyapatite is currently used in commercial dental products, such as toothpaste and mouthwashes, to aid in enamel remineralization and prevent cavities.

Nanoparticles in Bleaching Agents: Nanotechnology is already being applied in commercially available teeth whitening products. Nanoparticles enhance the penetration of active agents, such as hydrogen peroxide, into the enamel for more effective whitening.

Nanoparticle-Based Coatings for Orthodontic Brackets: Some nanoparticle coatings are already used in orthodontics to reduce bacterial adhesion

Dental Implants: While some nanostructured implants with bioactive coatings are commercially available and used in practice, many advanced versions with nanostructured surfaces (like titanium nanotubes) are still under clinical testing. **(3)**

3. Results

Nanodentistry Applications under Research for Future Use

Several research teams are currently engaged in exploring the potential of nanotechnology in dentistry, aiming to develop more efficient and effective treatments. The following examples highlight prominent research efforts across various domains of dental science.

Nanorobots for Dental Applications: There is a research for the development of dental nanorobots. These tiny robots are conceptualized to perform tasks such as precise enamel repair, plaque removal, and targeted drug delivery for localized dental treatments. These nanorobots could revolutionize non-invasive dental procedures and periodontal care in the future. **(4)**

Nanoparticle-Based Drug Delivery Systems : This research focuses on the development of nanoparticles that can be used for targeted drug delivery within the oral cavity. These nanoparticles, such as those made from silver and zinc oxide, are being tested in clinical trials to improve the efficacy of antimicrobial treatments for periodontitis by targeting bacteria in biofilms. This technology could minimize systemic side effects and enhance local drug retention. **(5)**

Nanostructured Titanium Implants: Another team is exploring the use of nanostructured titanium implants, which incorporate titanium nanotubes to enhance osseointegration. Their research, currently in laboratory and early clinical trials, aims to improve the bone-to-implant connection and accelerate healing times. The nanostructured surface increases bioactivity, ensuring a stronger and faster attachment to bone. **(6)**

3. Results

Nanodentistry Applications under Research for Future Use

Nanoparticles for Dental Implant Drug Delivery: Scientists are developing nanoparticle-based drug delivery systems to improve the performance and longevity of dental implants. By incorporating nano-biomaterials, they aim to enhance antibacterial properties and improve drug delivery efficiency to treat implant-related infections and promote osseointegration. **(7)**

Treatment of Dentin Hypersensitivity Using Nano-Hydroxyapatite: A clinical trial investigates the use of nano-hydroxyapatite (nano-HA) pastes for treating dentin hypersensitivity. The study compares nano-HA's effectiveness to Pro-Argin and fluoride varnish treatments, showing promising results in reducing sensitivity after 3 months of treatment. **(8)**

Nanotechnology for Restorative Resin-Based Dental Materials: This research focuses on advancing restorative dental materials by incorporating nanoparticles into resin-based composites. These materials aim to enhance mechanical strength, wear resistance, and antibacterial properties, making them more durable and long-lasting. **(9)**

Nanotechnology for Dental Regeneration and Osseointegration: This research focuses on enhancing osseointegration of dental implants using nanostructured surfaces. By modifying implant surfaces with nanoscale materials, the team aims to accelerate bone healing and improve implant stability, making dental implants more effective in long-term use. **(10)**

3. Results

Nanodentistry Applications under Research for Future Use

Nanoparticles for Caries Prevention: Another team investigates the use of nanoparticles in restorative materials to prevent dental caries. The integration of nanoparticles in dental composites has shown improved resistance to bacterial colonization, making these materials more effective in preventing the development of caries and other oral infections. **(11)**

Nanorobots for Precise Oral Health Diagnostics: Nanorobots capable of performing precision diagnostics and therapeutic tasks in the oral cavity are being developed. These nanorobots aim to revolutionize early detection and treatment of oral diseases, providing targeted interventions with minimal invasiveness. **(12)**

Nano-Drug Delivery Systems for Oral Cancer: Nano-drug delivery systems (nano-DDS) using nanoparticles to enhance the treatment of oral cancer aim to improve the therapeutic effect of anticancer drugs by enabling controlled release and targeted delivery to tumor sites, reducing side effects and improving outcomes for oral cancer patients. **(13)**

Nanoparticle-Based Targeted Therapy for Oral Cancer: In a research is investigated the use of pH-responsive graphene oxide nanoparticles loaded with targeted peptides and anticancer drugs to treat oral squamous cell carcinoma (OSCC). This system aims to deliver drugs more effectively to cancer cells, improving treatment outcomes while minimizing damage to healthy tissues. **(14)**

4. Conclusions

Conclusions

- Nanotechnology is already **transforming several areas of dentistry**, from enhanced restorative materials like nanocomposites to improved diagnostic tools through nanosensors and contrast agents

- Nanoparticles are proving highly effective in **infection control, targeted drug delivery, and tissue regeneration**, offering new solutions to longstanding dental challenges

- Research is rapidly advancing, with promising results in **cancer therapy, periodontal treatment, and implant technology**

Future Perspectives

As nanotechnology research progresses, we can expect further developments in **non-invasive diagnostics**, **personalized dental treatments**, and **more durable dental materials**

Nanorobotics may revolutionize the precision of dental procedures and treatments, **reducing the invasiveness of surgeries** and **improving recovery times**

However, **challenges** remain in **regulatory approval**, **cost-effectiveness**, and **ensuring long-term safety and biocompatibility** of nanomaterials

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