Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/jptcp.v30i3.2683

NANOTECHNOLOGICAL AND NANOMATERIALS DENTISTRY: NEXT-GENERATION ANTIMICROBIAL THERAPY

Kunal Kishor[1,] Pooja Jha[2]*, Farha Azmeen[3], Shefali anand[4], Keerti Singh[5]

[1]Professor, Department of Microbiology, School of Allied Health Sciences, Sharda University, Greater Noida, Uttar Pradesh, India
[2*,3,4]Research Scholar, Department of Microbiology, School of Allied Health Sciences, Sharda University, Greater Noida Uttar Pradesh, India
[5]Professor, Department of Microbiology, School of paramedical and allied health sciences, SGRR University, Patel nagar, Dehradun.

***Corresponding Author:** Pooja Jha
*Research Scholar, Department of Microbiology, School of Allied Health Sciences, Sharda University, Greater Noida Uttar Pradesh, India Email: poojajha9521@gmail.com

Abstract
Nanotechnology has made its mark on almost every current field. Nanotechnological dentistry refers to the application of nanotechnology in the field of dentistry, specifically for the diagnosis, treatment, and prevention of oral health issues. Nanotechnology involves manipulating materials and devices at the nanoscale level, which is at the scale of individual atoms and molecules. This has the potential to revolutionize dentistry by offering more precise and effective solutions for various dental problems. The use of nanotechnology as a strategy to combat antimicrobial resistance has grown over the last few years in both industry and research. This is because nanomaterials have unique size-dependent features that, when used, dramatically improve human life and health. The number of dental nanoparticles available has grown over time, and a wide spectrum of them have been explored for commercial and clinical applications. Antimicrobial nanoparticles are added to current dental compounds with restorative composite materials to prevent tooth decay and improve biocompatibility. In order to emphasize the successes of nanotechnology in dentistry as well as the present difficulties and anticipated future developments, the review thus offers a thorough analysis and in-depth examination. The management of the microbiome has undergone unprecedented breakthroughs, including the application of peptides, antibodies, phage therapy, and other nanotechnological techniques. Findings from study suggest that focused antimicrobial drug delivery employing nanoparticles modified in some way can kill resistant microbial cells. The aim of this study is to outline current research in nano dentistry and to describe the idea and development of nanoscience as well as its use in medicine.

Keywords: Nanotechnology, Nano dentistry, antimicrobial nanomaterials, targeted drug delivery

Introduction
In the discipline of endodontics, nanoparticles have been used in a variety of applications, including antibiotic medication, with the goal of enhancing general dental health, notably by removing biofilms. The primary goal of NPs acting as antiviral agents is to neutralise viruses before they can infect host cells. One of the first phases of viral infection is the contact of the virus with the receptors on the host

cell. If NPs can successfully halt viral penetration at this stage, the infection can be successfully removed. Unfortunately, the routes used by different viruses during this regulation stage might range from generic to quite particular. Recent advances in nanotechnology have shown further ways to build antiviral coatings that prevent viral transmission. Making it impossible for the virus to interact with negatively charged DNA and RNA or by acting as an anti-transfection agent were two potential modes of action.

While dental infections have been linked to specific bacteria, oral infections are typically polymicrobial in nature. The main goal of creating antimicrobial biomaterials is to stop the spread of those bacteria or their target.

Applications of nanotechnology in dentistry

The emergence of nanoscience and demonstrations of the antibacterial properties of nanostructured silver formulations has spurred research interest in silver. Silver nanoparticles (AgNPs) offer broad-spectrum antibacterial capabilities, and a variety of photochemically based synthesis methods have been established.

Types of dental nanomaterials

The most often described dental nanomaterials are nanocomposites, nanoparticles, antibacterial nanomaterials, and bio-mineralization systems.

Antimicrobial nanomaterial

The mouth cavity contains many germs that can lead to diseases including caries, calculus, gingivitis, or periodontitis. Microbial activity is highly harmful to invasive dental procedures that utilize dental materials, such as implant placement or composite restoration of caries-decayed teeth. The antibacterial activity of the NPs is dependent on their capacity to bind to cells and produce surface charges. This interaction with the peptidoglycan of the cell wall and subsequent interactions with the cell membrane limit protein synthesis, which in turn limits the replication of bacterial DNA. The key objectives of NPs' antifungal activity are hence cell wall penetration and lysis. Through redox reactions, NPs generate a significant amount of reactive oxygen species (ROS), which causes intracellular oxidative stress. Without the antioxidant defence of antioxidants, superoxide and hydroxyl radicals (ROS) harm DNA, deteriorate proteins, and destroy cell walls.

Nano-biomineralization

The application of nanotechnology has positive effects on the study of mineralized hard tissues. When it comes to dental tissues and issues with the root canal, where demineralization is a worry, enamel and dentin are both equally significant. In addition to bacterial involvement, a significant majority of people also experience enamel demineralization within the top layer of their teeth. Surface softening is the initial result of this erosive dissolving process. These significant concentrations of calcium and phosphate ions could theoretically be enough to promote remineralization and re-hardening. Here are some ways where nanotechnological dentistry could be applied:

Diagnostics: Nanotechnology can enable the development of highly sensitive and specific diagnostic tools for detecting early signs of dental diseases. Nanosensors could detect biomarkers related to oral health conditions, allowing for earlier intervention and treatment.

Restorative Dentistry: Nanomaterials could be used to create stronger and more durable dental restorations. Nanocomposites with enhanced mechanical properties could be used for fillings, crowns, and bridges, leading to longer-lasting dental work.

Drug Delivery: Nanoparticles can be engineered to deliver drugs precisely to the affected areas in the mouth. This could lead to more targeted and efficient treatment of conditions like gum disease and oral infections.

Bioactive Coatings: Nanotechnology can be used to create bioactive coatings for dental implants. These coatings could promote osseointegration (the bonding of bone to the implant surface) and reduce the risk of infection.

Antimicrobial Agents: Nanoparticles with antimicrobial properties could be incorporated into dental materials to prevent the growth of harmful bacteria, reducing the risk of cavities and gum disease.

Oral Cancer Detection: Nanoscale imaging techniques could enhance the detection of oral cancer at its earliest stages, improving the chances of successful treatment.
Next generation antimicrobial therapy, on the other hand, involves developing more effective ways to combat microbial infections, particularly those that have developed resistance to traditional antibiotics. Here are some ways this could be achieved:

Nanoparticle-Based Therapies: Nanoparticles can be engineered to target and destroy bacteria more effectively. These nanoparticles could be designed to disrupt bacterial cell walls or interfere with their vital processes.

Quorum Sensing Inhibitors: Bacteria often communicate through a process called quorum sensing, which allows them to coordinate their actions. Inhibiting this communication could prevent the formation of harmful biofilms and slow down infection progression.

Phage Therapy: Bacteriophages are viruses that specifically target and infect bacteria. Research into phage therapy is ongoing as a potential alternative to antibiotics.

CRISPR-Cas Systems: Gene editing tools like CRISPR-Cas could be used to selectively target and disable genes in antibiotic-resistant bacteria, rendering them harmless.

Host-Targeted Therapies: Developing therapies that modulate the host's immune response to better combat infections is another avenue of research.

Personalized Medicine: Tailoring antimicrobial therapies based on a patient's genetic makeup and the specific bacteria causing the infection could improve treatment outcome.

Cytotoxicity and risk of nanoparticles

The ability of a substance to cause cell damage, particularly in terms of structure and function, is referred to as cytotoxicity. Nanoparticles are extremely small particles with dimensions ranging from one to one hundred nanometers. Nanoparticles, due to their small size, frequently exhibit unique physical, chemical, and biological properties that can make them useful in fields such as medicine, electronics, and materials science.

However, the nanoparticles' small size and increased surface area can raise concerns about their potential interactions with biological systems, including cells. Dental professionals use cytotoxic nanoparticles to treat bacterial and fungal pathogens that are resistant to standard antibiotic therapy.
Researchers conduct a variety of studies to assess the cytotoxicity and risk of nanoparticles, including in vitro cell culture experiments, animal studies, and computational modelling. The goal of these studies is to learn how different types of nanoparticles interact with cells, tissues, and organs, and whether these interactions are harmful. Around the world, regulatory agencies and scientific organizations are working hard to develop guidelines and standards for the safe use of nanoparticles.
A better understanding of the relationship between nanoparticle properties, cellular interactions, and cytotoxicity will help inform the development of safe and effective nanoparticle-based technologies as research in this field advances.

Future applications

Nanotechnology has the ability to impact a wide range of products, including dental restorative and antibacterial materials. The addition of new nanoparticles to materials can have a positive impact on more than one aspect, as is common with NPs introduced for reinforcing or antibacterial capabilities. Endodontists have employed nanoparticles in a variety of applications, such as antibiotic medication, with the primary goal of enhancing general oral health, notably by removing biofilms. Both nanotechnological dentistry and next generation antimicrobial therapy hold great promise for improving oral health and combating infections. However, it's important to note that while these concepts are exciting, they may still be in the research and development stages, and practical applications could take time to become widely available.

Challenges

Currently, the biggest challenges in nanomedicine and nano dentistry are determining the toxicity and biocompatibility of nano-biomaterials and developing tailored treatment plans. Nanotechnology has both substantial threats and advantages that have not yet been completely investigated. Evaluation of nanoparticle toxicity is necessary. The intriguing characteristics of the particle size may also be harmful to people's health. To lessen the negative effects of nanomaterial production on the environment, green nanomaterial synthesis is necessary.

References

1. Angel Villegas, N., Silvero Compagnucci, M.J., Sainz Ajá, M., Rocca, D.M., Becerra, M.C., Fabián Molina, G. and Palma, S.D., 2019. Novel antibacterial resin-based filling material containing nanoparticles for the potential one-step treatment of caries. Journal of healthcare Engineering, 2019.
2. Bapat, R.A., Joshi, C.P., Bapat, P., Chaubal, T.V., Pandurangappa, R., Jnanendrappa, N., Gorain, B., Khurana, S. and Kesharwani, P., 2019. The use of nanoparticles as biomaterials in dentistry. Drug discovery today, 24(1), pp.85-98.
3. Bruniera, J.F.B., Gabriel-Silva, L., Goulart, R.S., Silva-Sousa, Y.T.C., Lara, M.G., Pitondo-Silva, A. and Miranda, C.E.S., 2020. Green synthesis, characterization, and antimicrobial evaluation of silver nanoparticles for an intracanal dressing. Brazilian Dental Journal, 31, pp.485-492.
4. Chaloupka, K., Malam, Y. and Seifalian, A.M., 2010. Nanosilver as a new generation of nanoproduct in biomedical applications. Trends in biotechnology, 28(11), pp.580-588.
5. Durán, N., Durán, M., De Jesus, M.B., Seabra, A.B., Fávaro, W.J. and Nakazato, G., 2016. Silver nanoparticles: A new view on mechanistic aspects on antimicrobial activity. Nanomedicine: nanotechnology, biology and medicine, 12(3), pp.789-799.
6. Gronwald, B., Kozłowska, L., Kijak, K., Lietz-Kijak, D., Skomro, P., Gronwald, K. and Gronwald, H., 2023. Nanoparticles in Dentistry—Current Literature Review. Coatings, 13(1), p.102.
7. Li, X., Wang, C., Wang, L., Huang, R., Li, W.C., Wang, X., Wong, S.S.W., Cai, Z., Leung, K.C.F. and Jin, L., 2022. A glutathione-responsive silica-based nanosystem capped with in-situ polymerized cell-penetrating poly (disulfide) s for precisely modulating immuno-inflammatory responses. Journal of Colloid and Interface Science, 614, pp.322-336.
8. Montoya, C., Roldan, L., Yu, M., Valliani, S., Ta, C., Yang, M. and Orrego, S., 2023. Smart dental materials for antimicrobial applications. Bioactive Materials, 24, pp.1-19.
9. Wang, Y., Ding, Y., Deng, J., Nie, R. and Meng, X., 2023. Antibacterial one-step self-etching dental adhesive with silver nanoparticles synthesized in situ. Journal of Dentistry, p.104411.
10. Vazquez-Muñoz, R., Meza-Villezcas, A., Fournier, P.G.J., Soria-Castro, E., Juarez-Moreno, K., Gallego-Hernández, A.L., Bogdanchikova, N., Vazquez-Duhalt, R. and Huerta-Saquero, A., 2019. Enhancement of antibiotics antimicrobial activity due to the silver nanoparticles impact on the cell membrane. PloS one, 14(11), p.e0224904.