Review Article

Applications of Nanomaterials in Dentistry: A Review

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ABSTRACT

Aim and Objective: Currently, the major priority in the field of nanotechnology or nanoscience is research and development at the atomic- or molecular-level sciences. Almost every aspects of human health, including pharmaceutical, clinical research and analysis, and supplemental immunological systems, are significantly impacted by it. Diverse dental applications to the realm of nanotechnology, which also reflect developments in material sciences, have given rise to the field of nanodentistry and nanocatalytic drug development, especially in oral nanozyme research and application. This review is aimed to provide readers an in-depth analysis of nanotechnology's characteristics, varied qualities, and applications toward dentistry. **Materials and Methods:** A query was carried out in PubMed and Google Scholar databases for the articles published from 2007 to 2022 using the keywords/MESH term nanomaterials, dentistry, nanoenzymes, metals, and antibacterial activity. Data extraction and evidence synthesis have been performed by three researchers individually. **Results:** A total of 901 articles have been extracted, out of which 108 have been removed due to repetitions and overlapping. After further screening following exclusion and inclusion criteria, 74 papers were considered to be pertinent and that primarily addressed dental nanotechnology were chosen. Further, the data havebeen extracted and interpreted for the review. The results of the review indicated that the development of multifunctional nanozymes has been continuously assessed in relation to oro-dental illnesses to show the significant impact that nanozymes have on oral health. **Conclusion:** As evidenced by the obtained results, with the advent of ongoing breakthroughs in nanotechnology, dental care could be improved with advanced preventive measures.

KEYWORDS: *Antibacterial activity, dentistry, metals, nanomaterials, nanozymes*

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INTRODUCTION

Teeth are considered an integral part of oral health, which is directly impacted by proper nutrition.[1] Recreating materials with structural dimensions mimicking components advances led to a shift in the paradigm toward nanotechnology, known for developing highly efficacious biomimicking biomaterials in restorative dentistry.[2] In recent years, we have seen the integration of nanotechnology into various scientific sectors as it provides solutions to several technological and medical problems.[3] Traditional dental materials possess few unavoidable setbacks, which adversely affect the success of dental treatment and ultimately lead to treatment failure. Several nanoenzymes are explored in oral research in treating oral ulcers, caries, and periodontitis. The enzymes' anti-inflammatory, antibacterial, and immunomodulatory properties are the basis of their applications. However, inadequate stability, high costs, laborious purification protocols, and less relaxed storage

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conditions are the major pitfalls halting its widespread use. Most of the research published in the previous 20–30 years has paid attention to nanoparticles, indicating that nanotechnology and the properties of resources at these scales are of tremendous interest. This significant interest has a wide range of applications in nanodentistry, including nanoceramics, restorative-like nanocomposites, nanoglass ionomers, nanometals, and nanolocal anesthesia.[4]

Fabricating nanomaterials for dental applications require intricate subject matter to generate novel regenerative, drug-releasing pods, and implant materials. When it comes to building nanodentistry products, the biomimetic technique is still in the testing phase, while the bottom-up and top-down methods are the norm. Clinicians, researchers, and material scientists working with nanomaterials for dentistry require insights into the role of nanomaterials. Although there are several review articles on the role of nanoenzymes and nanomaterials in dentistry, the data available still lack the direction toward a successful outcome. Therefore, we aim to provide a brief narrative review of this area following partial Preferred reporting items for systematic reviews and meta analysis guidelines for evidence and advances in nanomaterials corresponding to medicine and dentistry.

Materials and Methods

A query on databases such as PubMed and Google Scholar was carried out. The MESH terms "nanomaterials," "dentistry," "nanozymes," "metals," and "antibacterial activity" were used in to search in the databases using AND and OR for data extraction from peer-reviewed scientific journals from the year 2007 to 2022. The articles were included based on the following criteria: the year of publication, the initial author's name, the title's applicability, the goal of the connected publications, and articles in English. On the other hand, conference proceedings, nonoriginal papers, studies irrelevant to the fields of medical and dental, and too much information were factors for exclusion.

Results

Scientific papers like literature reviews, systematic reviews, clinical trials, and original studies in the past 15 years have revealed updates on nanomaterials, nanoenzymes, and their influence in the field of dentistry. A data of 429 articles have been extracted from PubMed and 472 articles from Google Scholar. Following the inclusion and exclusion criteria thoroughly, we chose and examined 74 articles published between 2007 and 2022 that have at least one of the keywords listed above in the title or abstract. After a thorough analysis of all the 74 articles, we have 37 original research articles,

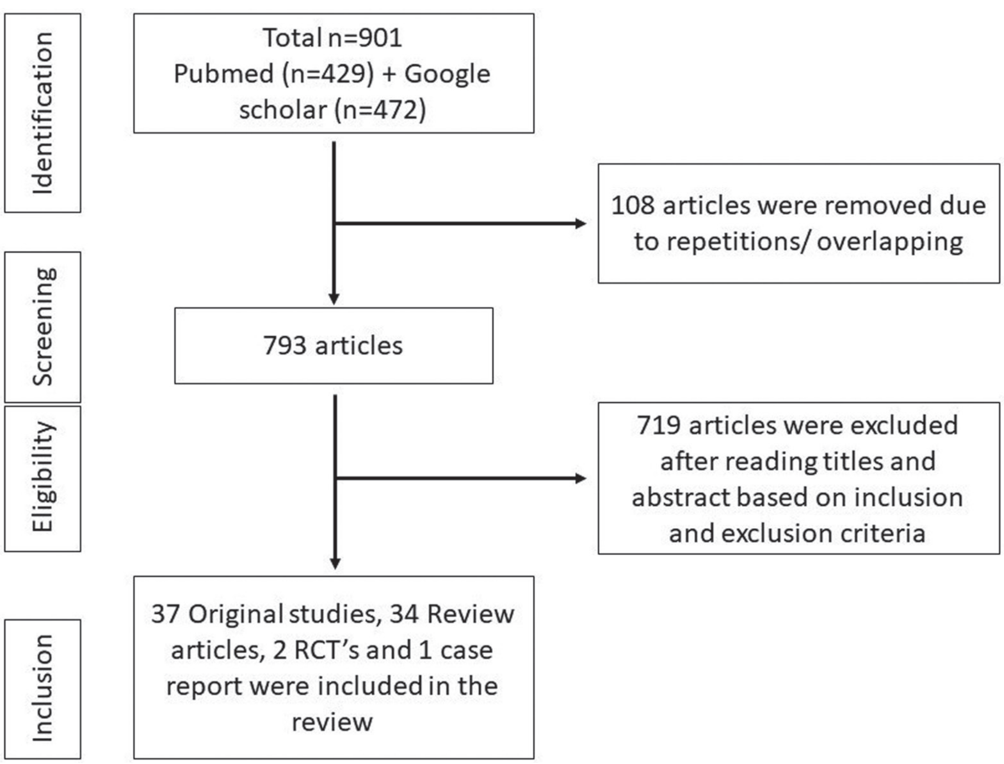

Figure 1: Evidence search and data extraction for nanomaterials in dentistry

34 reviews (comprehensive, clinical, critical, narrative, systematic, and meta-analysis), 2 randomized clinical trials, and 1 case report providing the data for the current review topic [Figure 1]. The data search, identification, and extraction have been conducted independently by three researchers in an Excel sheet. The summary of the findings from the above literature has been categorized into the following subheadings.

Catalytic activity of nanoparticles

Nanotechnology has gained much popularity in the field of medicine due to its ease in analyzing and manipulating bonds at an atomic level. This adds a great advantage toward innovations of new materials, drugs, diagnostic aids, etc., especially in the field of dentistry. Based on the physical and chemical properties of various metals and composites, nanomaterials like carbon nanotubes, graphene, hydroxyapatite, titania, and silver have been manufactured in the form of crystals, nanopores, nanodrops etc., each with exclusive beneficiary properties. These materials are developed strategically to improve conventional materials' properties.[3]

Even though various nanoparticles have been evolving, synthesizing, and manufacturing these nanoparticles have been a sensitive task. One of the most commonly used and concerning syntheses is platinum and palladium groups, which have an effective catalytic activity.

Iridium, ruthenium, platinum, osmium, rhodium, and palladium make up the platinum-group metals (PGMs)—often known as the platinum family or platinum metals—which are made up of six noble, valuable metallic fundamentals grouped in the periodic table. These metals have excellent catalytic characteristics and are commonly employed in industry as catalysts. Although many other uses of these components are still highly essential, the automobile industry has materialized as the primary user of PGMs in the last three decades. To demonstrate the widespread interest in PGM nanoparticle research, keywords "nanoparticle" and "metal name" (iridium, palladium, rhodium, platinum, osmium, and ruthenium) have been used in the Scopus database. Platinum nanoparticles have 18.2×10^3 articles in the Scopus database, palladium has 13.9×10^3 articles, ruthenium has 4.1×10^3 articles, rhodium has 2.4×10^3 articles, iridium has 1.3×10^3 articles, and osmium has 1.8×10^2 articles. This article demonstrates the synthesis of nanoparticles from the least commonly used platinum family like ruthenium, osmium, rhodium, and iridium. Any further modifications in synthesis can be made to modify the electronic structure or chemical properties, improving the heterogenosity of the catalyst. It was also proved that the basic geometry and crystalline structure of the nanoparticles could be controlled on exposure to various factors like the type of precursor metal, temperature, solvent, and reagent concentration influencing their catalytic activity. The platinum-derived nanoparticles have distinctive properties like carbon monoxide oxidation, Fischer Tropsch synthesis, and a catalyst to decompose nitrogen oxide and convert carbon dioxide into organic compounds. Hydrogen storage can be applied in various fields like drug development, dental applications, a filter of X-ray devices, and automobiles. With proper synthesis knowledge, these nanoparticles customized from supported and unsupported PGMs make a huge impact as a catalyst in commercial markets, replacing the currently used ones.[5]

Nanozymes as an antibacterial agent

Dental caries is one of the most common infectious diseases of the mouth, affecting 2.4 billion individuals worldwide.[6] The oral biofilm produces a variety of illnesses that endanger oral health and can lead to systemic sicknesses, such as atherosclerosis, diabetes, and Alzheimer's disease, all of which have significant medical costs and disastrous complications.[7-9] Researchers have made significant advances in developing innovative, consistent, and effective oral antibacterial medications that promote enzymes.[10] Nanozymes aid in the prevention of root canal biofilm infection. According to Koo's findings, activating H_2O_2 can significantly eliminate biofilm plaque from the surface of a root canal and dentinal tubules.

They developed two types of antibacterial catalytic robots. When put in a limited environment, the three-dimensional catalytic antibacterial automaton is a soft robot that allows precise effects ($P < 0.0005$).[11] According to their findings, dual catalytic magnetic iron oxide nanoparticle-equipped catalytic antibacterial robots in magnetic fields may generate free radicals, break down exopolysaccharide matrix, and clear biofilm particles. When put in a limited environment, the three-dimensional catalytic antibacterial automaton is a soft robot that allows precise effects. The leaf-shaped catalytic antibacterial robot removes exopolysaccharide matrix and biofilm buildup from intricate dentinal tubules while also killing microorganisms. The study discovered that catalytic antibacterial robots might be used to treat the severely limited anatomical surfaces of human teeth. By removing biofilms and eradicating germs, these catalytic antibacterial robot systems can endure persistent biofilm-associated diseases and prevent cross-contamination of medical equipment and other surfaces.[11]

Healing of oral lesions

Several studies[12] have associated oral ulcers with genetic susceptibility, bacterial and viral infections, allergies, vitamin and trace element insufficiency, systemic diseases, and other disorders. As there are no unique drugs in current treatment techniques, we must develop therapeutic methods to increase the body's immunity and facilitate ulcer healing.[13] According to Naha *et al.*,[14] vitamin B2-modified Fe_3O_4 nanozymes with anti-inflammatory and antibacterial activities hasten the healing of oral ulcers. According to the researchers, this modification raised its enzyme-like activity and significantly improved its superoxide dismutase (SOD)-like activity with ROS scavenging capability. Cellular antioxidation studies revealed that these enzymes were biocompatible and capable of protecting cells from H_2O_2. These nanozymes kill *Streptococcus* mutants and reduce local inflammatory factors and remove reactive oxygen species, which helps mice heal from oral ulcers faster. This enzyme-like antibacterial mediator could be a viable therapy for mouth ulcers.

Nanozyme in oral observing function

Oral health observation can track oral diseases and their threat aspects, providing a basis for early analysis and treatment, improving oral health, improving people's living conditions, and evaluating treatment outcomes.[15] As a result, it is critical and urgent to create and complete oral health illness observation system.[16] To this nanozymes may offer a novel approach to monitor oral illness[17] due to their good sensing properties and can monitor ions, chemicals, proteins, nucleic acid, and cancer cells.[18] The nanozyme research in dentistry is currently focused on monitoring ions and nucleic acids.[19] The color difference of the colorimetric biosensor is then used to identify the target.[20]

Nanozymes play three critical roles in this process

1) Surface modification: Nanozymes can be adsorbed with ions or nucleic acids, which act as a surface modification and boost their catalytic efficiency. As an illustration, the fluoride ion (F^-) may absorb a lot on nanoenzyme leading to alterations of charges over its surface and further elevating its catalytic efficiency.
2) Specificity and sensitivity: A nanozyme is generally bound to a specific object. If the nanozyme binds to all substances tested, it will not be monitored well.
3) Metachrosis: Nanozymes have a stronger affinity for colorimetric biosensor substrates, resulting in dramatic color changes and a monitoring role. Nanoceria can be used to monitor F^- effectively, as Liu and his colleagues discovered.[20] According to their research, pure nanoceria's catalytic activity rose by more than 100 times when F^- was added. Additionally, oxidase-like activity can be prolonged by mixing F^- and nanoceria, whereas a single nanoceria inactivates in less than a minute. The study's lower observance limit for fluoride ion in both the water and the toothpaste was 0.64 M. Due to the inability of the other anions under investigation to raise activity in the same way as F^-, F^- monitoring has become extremely sensitive. The results demonstrate that the properties of nanoceria can be used to rapidly and accurately detect F^- in toothpaste and intake water.[20]

Oral cancer monitoring

Oral cancer is the fourth most common tumor, posing a threat to oral health and carrying a high death and repetition rate, which is the most concerning issue for oral medical professionals. Tissue biopsy, formerly the gold standard for diagnosing oral cancer, is becoming unable to fulfill the demands of current analysis and therapy. Its intrusiveness causes patients uneasiness and may lead to tumor cell spread. Early on, accurate monitoring allows for early discovery, analysis, and treatment, as well as avoiding the distress of minor operations due to a mismatch between the postoperative biopsy and surgical procedure.[21,22] The nanomonitoring technology has proven highly efficient, sensitive, and quick for detecting DNA associated with oral cancer or lesions as a novel noninvasive supplementary monitoring strategy.[23]

Dental purpose of nanomaterials

Damage to tooth tissue can lead to problems such as oral precancer and cancerous lesions, tooth decay, periodontitis, hyperesthesia, and bad breath. The aforementioned problems can be treated using therapeutic techniques and biocompatible synthetic materials.[20] Nanomedicines used as dental materials have physicochemical and biological characteristics that set them apart from conventional dental therapies in overcoming side effects. Various types of nanomaterials have been found to imitate host tissue properties in studies, albeit there is no knowledge of such features among dentistry groups.[21,24] As a result, the current analysis center on the possessions of various metal- and polymer-based nanomaterials[22] utilized in dental adhesives and restoratives, acrylic resins, period ontology, tissue engineering, endodontic, and implant dentistry.[25,26]

Nanomaterials in preventive dentistry

Preventive dentistry is essential and plays a significant role because of the growing body of knowledge regarding oral problems.[27] Nanomaterials are used in preventive dentistry to regulate biofilms on the surface of teeth and to demineralize the early stages of submicron-sized enamel lesions.[28] A formulation of silver nanoparticles (Ag NPs) was developed by Schwass *et al.*[29] for the purpose of caries removal. Silver nitrate ($AgNO_3$) was chemically reduced by sodium borohydrate ($NaBH_4$) in the presence of sodium dodecyl sulfate to produce micelle aggregation structures that included mono-dispersed stabilized Ag NPs that ranged in size from 6.7 to 9.2 nm. Microplate measurements, which measure the absorption of crystal violet light at 590 nm, showed significant alterations in the biofilms that had been treated with Ag NP. Bacterial sensitivity is unaffected by the presence of sugar. This Ag NP formulation showed promise for therapeutic uses in inhibiting the formation of in vitro biofilms for several *Streptococcus* spp. and *Enterococcus faecalis* strains. Manikandan *et al.*[30] studied the production of silver oxide nanoparticles (Ag_2O NPs) and its antibacterial activity against dental bacterial strains using *Ficus benghalensis* prop root extract (FBPRE) as a stabilizing and reducing agent. They found that higher extract concentrations and time frames resulted in a significant increase in the formation of NPs. Dental bacteria *Lactobacilli* sp. and *Streptococcus* mutants showed extremely strong antibacterial activity when FBPRE and Ag_2O NPs were combined. After multiple animal tests, they concluded that combining the synthesized FBPRE with Ag_2O NPs as a germicidal component in toothpastes would be advantageous.

Nanomaterials in edentulism

Edentulism has significant negative consequences, including a decreased intake of essential foods and an unattractive appearance, and it is becoming more common in many nations.[31] Even though tooth loss estimates have dropped, the age range in which edentulism is still prevalent has widened. As a result, denture therapy is essential in public health, and its importance will only increase as the population ages.[32] Using a modified sol–gel synthesis method, to create polymethyl methacrylate (PMMA)/TiO_2 nanocomposites, Totu *et al.*[33] used nanosized TiO_2 filler; morphological and structural analyses revealed that the TiO_2 nanofiller diffused uniformly in the PMMA solution. According to experimental results, adding TiO_2 NPs to the polymer modified the structure and characteristics of the polymer; 0.4% TiO_2 NPs in the nanocomposite dramatically altered the FTIR spectrum. The addition of TiO_2 NPs in the PMMA polymer matrix produced antibacterial effects, particularly against *Candida* species, as demonstrated by using a 0.4% nanocomposite for complete denture production using a stereolithographic approach. According to Rodrigues Magalhaes *et al.*,[34] TiO_2 nanotubes might be used to improve the biological and mechanical properties of dental materials. Tetragonal zirconia poly-crystals stabilized with yttria (Y-TZP) are increasingly employed in dentistry as the foundation for crowns and fixed partial prostheses. No matter how well it performs in the clinic, Y-TZP is susceptible to issues, including microstructure-related faults introduced during the fabrication process, which could jeopardize its structural and clinical dependability. While monitoring each manufacturing phase, researchers evaluated the role of the blanks' production technique and original composition adjustments by including TiO_2 nanotubes (0%, 1%, 2%, and 5% in volume). The experimental Y-TZP characteristics were altered by including TiO_2 nanotubes in various combinations, resulting in lower flexural strength. The microstructure of Y-TZP was also modified by the nanotubes, which led to higher grain sizes, more holes, and a little increase in the monoclinic phase. Additionally, adding TiO_2 nanotubes enhanced the structural reliability and Weibull modulus values.

The impact of nano-zirconium oxide nanoparticles on the mechanical properties of PMMA denture base material was examined by Gad *et al.*[35] The PMMA tensile strength of the test groups with 2.5%, 5%, and 7.5% NZ was considerably greater than that of the controls. The inclusion of nano-ZrO_2 significantly improved the tensile strength, with the 7.5% NZ group showing the largest gain. The experimental group's translucency levels were much lower than those of the controls. The 2.5% NZ group in the powered group exhibited higher values for translucency than the 5% NZ and 7.5% NZ groups. While PMMA translucency decreased as the nano-ZrO_2 concentration climbed, the tensile strength of the denture base acrylics increased.

Confront and opportunity of nanozymes in oral functions

The bulk of the catalytic activity of the nanozymes in dental applications and investigations is composed of peroxidase, SOD, oxidase, and catalase-like activities, which may bring about irreversible bacterial/biofilm destruction. Since nanozymes may significantly enhance their enzymatic activity when exposed to DNA or ions, they can be used as a colorimetric biosensor to track ions, bacteria, or DNA linked to oral cancer. By promoting cell adhesion, proliferation, and differentiation in a sterile environment, nanozymes can also help soft and hard tissue regeneration. The nanozymes genealogy has shown promising results toward dentistry as a means of overcoming the drawbacks of conventional

H_2O_2 concentrations, buffering oxidative interference brought on by the habitat during cell proliferation and differentiation, eliminating oral flora by degrading biofilms, and monitoring F^- and *Streptococcus* mutants using a quick and easy procedure. Nevertheless, there are still a lot of aspects of nanomaterials that have not been appropriately used, as well as benefits from other fields of medicine that have not been thoroughly examined in dental scenario. Few researchers have linked their study on nanozymes with this understanding of these aspects of dentistry, but their combined work could encourage more people to utilize nanozymes. Because of its superior mechanical properties and X-ray resistance, gutta-percha is the most approved root canal sealing material and is widely utilized in dentistry.[36] On the other hand, because gutta-percha is not antibacterial, it is difficult to get rid of germs from the root canal. Antibacterial nanozymes can be used to produce gutta-perchas, or nanomaterials' mechanical and thermal properties can be fully exploited to produce antibacterial things. Robots that clean root canals were developed by Koo's team. It would be interesting to know if these robots can be recycled using nanoparticle magnetic characteristics. Plaque treatment and other dental procedures, including cleaning root canals and teeth, also employ ultrasound technology. If nanozymes can multiply when exposed to ultrasound, this question has to be explored further.[37]

Other therapeutic background

Nanozymes and other catalytic nanomaterials have contributed to the development of the idea of nanocatalytic medicine, which has promise for tissue regeneration, antibacterial activity, tumor therapy, and monitoring.[38] Although there is little research on nanozymes in dentistry, the advantages of nanozymes in other medical specialties may shed some light on this issue. Only a small number of research have used nanozymes in dentistry, compared to numerous that have used them in biomedicine for tumor surveillance, treatment, and prevention. Because the blood vessels and lymph nodes in the mouth and face are so large, cancers frequently spread and are challenging to treat.[39] Maxillofacial surgeons have been hard working to develop a solution toward oral cancer for years. In order to reduce distant metastasis and prevent recurrence, the removal of excessive tissues and further resections are still employed in oral and maxillofacial surgery, which may eventually reduce the quality of life of the patient.[40] Without needing cofactors or reagents, Fan *et al.* discovered that magnetoferritin nanoparticles straightly adhered to cancer cells to overexpress transferrin receptors. By observing the color reaction, the tumor tissue can be identified.[41] Clinical samples were used to verify the nanozymes' excellent specificity and sensitivity. If the findings are applied to oral and maxillofacial surgery, surgeons can remove malignant lesions more precisely and prevent the agony caused by expanded excision. Das discovered that nanozymes have neuroprotective properties, suggesting that they could be used to help repair face nerve damage caused by oral and maxillofacial surgery.[41]

Oral cavities physiological location

The mouth cavity is where the digestive tract begins. Food and saliva will carry the nanozymes that remain in the oral cavity after local activity into the body. Restocking *Streptococcus gordonii* is advised by several research methodologies in order to preserve oral biofilms ongoing suppression. *S. gordonii* is a common oral bacterium, although some investigations have shown that it can cause endocarditis when it enters blood vessels. It is also important to take into account the body's protracted accumulation of nanozymes. Nanozymes can be absorbed through the gastrointestinal tract, albeit the concentration is likely very low. Furthermore, pH-dependent nanozymes may react significantly under gastric acid, increasing the strain on the gastrointestinal system.[42] The body may promote weight loss and experience more oxidative stress in the blood and liver if there are an excessive number of nanozymes present. DNA damage from nanomaterials is also a possibility. The immunogenicity of nanozymes was not taken into account in the bulk of reported toxicity studies since they only utilized mice or cells for a short duration. Potential threats must be examined in a long-term evaluation. Nanozymes can originate cytotoxicity in varying degrees depending on their type and dosage. There is currently no assessment standard in place; thus, these issues must be resolved.[42]

Discussion

Oral disorders, such as periodontal disease, oral cancer, and dentalcaries, afflict nearly 3.5 billion people worldwide, according to a series of papers published in *The Lancet* in 2019.[15] In order to significantly aid in the prevention and treatment of oral diseases, stomatology is developing in lockstep with biomaterials.[43] On the other hand, traditional dental materials (such as silver amalgam alloys) have some restrictions (like tooth weaking, fractures) that can guide to problems and treatment malfunction.[44,45] Nanomaterials have opened up a world of possibilities for improving oral health, restoring oral purpose, and improving the superiority of life.[46,47] Natural enzymes like proteolytics and amylase have antibacterial,

Table 1: Nanomaterials used in the field of dentistry

S. No.	Enzyme activity	Nanomaterials	Application	Reference
1.	Catalase and peroxidase	Iron oxide nanoparticle (modified) and vitamin B	Mouth ulcer healing	[1]
2.	Peroxidase	Ferumoxytol-iron oxide	Preventing tooth decaying	[2]
3.	Oxidase	Cerium oxide	Peri-implantitis prevention	[3]
4.	Peroxidase	Iron oxide nanoparticle	Suppress dental caries	[4]
5.	Peroxidase	Iron oxide DNA engineered	Dental bacteria detecting	[5]
6.	Peroxidase	Manganese oxide	Detection of immune	[6]
7.	Glutathione peroxidase	Graphene oxide	Biosensing	[7]
8.	Peroxidase	Iron oxide nanoparticle-dextran coated	Disrupt oral biofilm	[8]
9.	Sulfite oxidase	Molybdenum trioxide	Cytoprotection	[9]
10.	Glutathione peroxidase	Vanadium pentaoxide	Antioxidant	[10]

anti-inflammatory, and immunity-boosting capabilities were constantly studied and utilized in conditions like periodontitis, oral ulcers, and dental caries.[48,49] On the other hand, natural enzymes have certain drawbacks, including poor stability under extreme conditions (heat and high pH), expensive procedure, labor-intensive separation and purification, and challenging long-term storage, among others [Table 1].[50] Nanozymes have several outstanding biological effects, including antibacterial[51-55] antioxidant, anti-inflammatory[2,54,55] and biosensor,[7] in addition to the intrinsic features of nanomaterials, such as fluorescence, photothermal effect, and near-infrared imaging.[56-58] Many researchers have recently proposed using it to detect disease, regrow tissue, anticancerous and antibacterial agents.[58-61] Earlier, nanozymes were employed to treat oral plaque biofilm in 2016[62,63] and have achieved greater results toward disrupting the biofilm formation with the help of dextran coated iron oxide nanoparticles.[8] Since then synthesis and characterization of nanoenzymes have developed into significant level.

Nanozymes are still inferior to natural enzymes, which have long been available for medicinal usage and toothpaste addition. They have an efficient catalytic mechanism, high catalytic activity, and are physiologically safe while whitening teeth and reducing dental plaque and calculus. Nanozymes catalytic mechanism, on the other hand, is still a topic of discussion. How nanozymes may perform enzyme catalysis without catalytic activity centers baffles us.[63] Recent studies have steadily shown that the catalytic activity of nanozymes is correlated with the fundamental characteristics of nanomaterials, such as size, composition, and form, as well as the reaction environment, such as temperature, pH, and reactants. The problem of poor catalytic activity, however, may only be partially resolved by altering these features. Metal sulpfdes, for example, are utilized as proton-trapping tools to produce H_2S and expose Fe^{3+} in order to boost catalytic effectiveness.

The most often employed nanozymes with enzyme-like capabilities in dental research were peroxidase, catalase, oxidase, and SOD. DNase activity was incorporated by the researchers into the alteration process. Thanks to DNA engineering that enables substrate-specific binding of nanozymes for an efficient oral monitoring. However, unlike a conventional catalyst, nanozymes are unable to selectively link to substrates because they lack the intricate anatomy of a genuine enzyme substrate-binding bag.

In conclusion, numerous potential obstacles exist to nanozyme research and implementation in dentistry. Scientists must put effort to comprehend the clear energetic mechanism of nanozymes and to manufacture new varieties of nanozymes to meet the therapy demand on the technique to clinically experimental application. Dental researchers must address urgent clinical concerns, collaborate to understand nanozyme mechanisms at the molecular biology point, and analyze potential troubles in nanozyme use.[64] Due to the limited data available on the performance of nanomaterials, a systematic review was not conducted pertaining to the title that can be made possible in the future research with much more beneficial literature added into the databases.

Here the review concerns on various physical challenges to be faced while studying the nanomaterials, synthesis, and advancements. With the rise in research in an *in vitro* and *in vivo* level, we faced a deficit in data-based significance in the extraction data. It would be of great advantage if future experimental studies can carry out on a higher sample level, and further systematic reviews to be conducted to assess the efficacy of these research experiments.

Conclusion

The goal of nanotechnology is to take advantage of the fascinating physicochemical characteristics of nanomaterials in various cutting-edge applications that are both energy saving and beneficial from an economic and environmental standpoint. These applications are anticipated to impact several different economic sectors. With these solutions, there may be a chance to relieve the environmental burden. The greatest challenge currently in the field of medicine is to understand the process of the pathophysiology of any disease, followed by diagnosis and treatment opportunities. Scientific platforms conducting larger forms of research in nanotechnology have led to clinical breakthroughs leading to greater opportunities toward diagnostics and treatment procedures, including developing preventive measures. With an increase in the usage of nanomaterials due to their unique physiochemical properties, there comes the risk related to the exposure of nanomaterials too. Hence, it is essential for researchers and technological development platforms to study more about nanomaterials toward their life cycles and assess the possible risks and hazardous effects for a universal benefit.

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Conflicts of interest

All the authors declare no conflict of interest

Authors contribution

Dr. Jerry Joe Chokkattu: Data curation, investigation, original draft preparation, software.

Dr. S. Neeharika: Visualization, writing, validation.

Dr. Mahesh Ramakrishnan: Conceptualization, reviewing, supervision.

Ethical policy and institutional review board statement

Not applicable.

Patient declaration of consent

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Data availability statement

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