MODIFIED NANOPARTICLES WITH ANTIBACTERIAL PROPERTIES INVOLVED IN ORAL PATHOLOGY

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ABSTRACT

Introduction. As the area of nano-based platforms for antimicrobial treatment aimed at pathogenic oral biofilms continues to expand, this review serves to bring together researchers from several disciplines to foster more collaboration and discovery among dental practitioners.

Key words: *nanomaterials, antibacterial, anti-inflammatory, upconversion nanoparticles, oral diseases,etc.*

BACKGROUND

It has been, and will continue to be, quite worrying that so many people are getting sick from infectious diseases. High expenses to address the outbreaks, disruptions to everyday life, economic downturns for areas and countries, and in the worst situations, loss of life, are all consequences.

The successful elimination of several of these contagious illnesses is a reality. However, several diseases that were considered to have been eliminated have made a comeback with strains that are resistant to modern medication [1].

With today's sophisticated industrialization, manufacture, and marketing of items, germs may find a way to spread through tainted commodities and products, particularly at manufacturing sites, and potentially to all corners of the globe [2].

Therefore, it is crucial to minimize, if not eradicate, the proliferation of microorganisms on industrial facilities, goods, medical devices, consumable clinical supplies, and processed and packaged meals.

That's why scientists and pharmaceutical corporations are constantly on the lookout for new, more effective antibacterial drugs to slow the development of illness and antibiotic-resistant germs [2–4].Due to the increased contact area with bacteria, nanoparticles with a size of roughly 1-10 nm have been found to have exceptional antibacterial activity efficiency [5].Therefore, a class of antimicrobial nanoparticles is currently being extensively investigated [6,7].

This includes nanoparticles with decreasingly dimensions, such as metal nanoparticles with biocidal properties such as silver, copper oxide, zinc oxide, titanium dioxide, zero-valent iron; carbon nanotubes, and bio-nanoparticles like chitosan nanocomposites.There is no need to worry about resistant strains arising because of the broad spectrum of microbes killed by these nanoparticles [8,9].That's why scientists and pharmaceutical corporations are constantly on the lookout for new, more effective antibacterial drugs to slow the development of illness and antibiotic-resistant germs. [10,11].

Nano-based platforms have been met with optimism for their potential to treat pathogenic oral biofilms, which are currently difficult to eradicate. We can overcome the difficulties of intra-oral and hard-tissue disinfection thanks in large part to the novel mechanisms of action employed by nano based platforms [11,12].

From a medical and biological standpoint, the use of nanoparticles with antibacterial properties and the mechanism by which they work have been widely studied and documented. From a materials engineering perspective, we surveyed recent developments in the use of nanoparticle antimicrobial agents [12,13].Overview of recent developments in antimicrobial nanoparticle engineering and their applications, highlighting gaps in our understanding and suggesting avenues for further study [14,15].

►Nanoparticles' antimicrobial properties

• Antibacterial effects by reactive oxygen species (ROS) that can induce the peroxidation of the polyunsaturated phospholipids in the bacterial cells to damage DNA, and subsequently, cell death.

•Antimicrobial effects by physical damage: Bacterial cell wall membranes can be damaged when interacting with sharp edges of the nanostructured material [16-18].

•Antimicrobial effects by binding: Binding materials on the bacterial cell wall can cause loss of cell membrane integrity and efflux of cytoplasmic materials [19].

•Antimicrobial effects by release of metal ions: Metal ions released from the nanomaterials into culture media can inhibit the ATP production and DNA replication to destroy the cells [20].

► Antimicrobial nanoparticles (ANPs) in oral applications

In the medical field, preventing the transmission of disease caused by germs and viruses is a top priority [20,21].

Nanoparticles with antimicrobial properties have lately gained popularity and are being vigorously explored as an effective substance against a wide range of infections due to their ability to disrupt the growth and, in some circumstances, eradicate the pathogens. Silver (Ag) and its derivatives have been studied as nanoparticles due to their broad antibacterial activity against a variety of different diseases [19,22].

Nano-materials have a devastating effect on bacterial cells because they can quickly pass cell membranes, in contrast to bulk materials [20].The human mouth is home to about 700 different kinds of bacteria, archaea, fungus, and viruses. Caries, periodontal disease, endodontic infection, and other infectious oral illnesses have been linked to the microbiome.Oral disorders caused by microorganisms are quite common in humans, especially dental caries and periodontal disease [23].Such oral infectious illnesses are often treated with antibiotics. However, it was demonstrated that in vivo, it was difficult to achieve the minimum concentration of antibiotic necessary for the elimination of bacterial biofilm.Typically, antibiotics are used both to treat and prevent further illness. Antibiotics are commonly prescribed for a variety of illnesses, but some of them can have unwanted side effects on the liver and can trigger allergic reactions in certain patients [22].

❖ *In endodontic irrigants* .

When added to irrigants or other water-based solutions, antimicrobial nanoparticles (ANPs) can significantly boost, extend, and prevent microbial activity. This is because the huge surface areas of these particles boost the contact efficiency with microorganisms, which in turn increases their antibacterial activity against such pathogens [23].

Similarly, they can get into hard-to-reach areas, leaving germs to multiply even after the irrigant has been removed [24].A possible irrigant, silver nanoparticles in water have recently been tested by Rodrigues et al. [25].Silver nanoparticles (AgNP) were selected because of their capacity to inhibit the growth of a wide variety of gram-positive and gram-negative bacteria by adhering to their cell walls and releasing silver ions [25,26].

Comparable outcomes were seen in oxide (ZnO) nanoparticle aqueous solutions as irrigants, as compared to chlorhexidine and hypochlorite, respectively. When AgNP concentrations were decreased to 0.1%, however, there was essentially little effect on biofilm reduction [27].Despite their high price, the results imply that AgNPs are equally as effective as comparably priced alternatives at inhibiting bacterial growth in

❖ *in dental composites*

Composites made of polymer resin and inorganic fillers are frequently employed as cavity fillers, as well as in the reconstruction of artificial teeth and other oral structures. The harsh conditions of the mouth, including changes in pH and mechanical abrasion from chewing and food contact, necessitate the use of strong, durable materials [30].Nonetheless, biofilms formed by bacteria growth can cause plaque to accumulate more rapidly on certain surfaces than on others like enamel.Dental composites containing antimicrobial nanoparticles (ANPs) such as zinc oxide (ZnO) have been shown to inhibit the formation of bacterial biofilms caused by S. sobrinus by as much as 80% [31].However, as far as we're aware, no nanoparticle modification has been produced for usage as immobilized antimicrobial nanoparticles in dental composite resin applications. As with the filler in the resin, these particles need to be changed to enable for chemical bonding to occur to prevent leaching [32-33].

► *in periodontitis and peri-implantitis*

The tissues around an osseointegrated implant can become inflamed, leading to bone loss and the diagnosis of peri-implantitis. Numerous studies indicated that anaerobic plaque bacteria were the primary cause of deteriorating peri-implant tissue, however other causes of implant failure were possible. Peri-implantitis was also caused by plaque, much as periodontitis.

Nanosurface layer showed potential in infection-prevention, despite the fact that there were only a small number of papers concerning nanomaterials-based aPDT for

experiments utilizing 1% and 26% zinc

aqueous solutions without the use of surfactants or additives, and that they do so without endangering the cells of any surrounding healthy tissue. Also, the particles can remain in the cavities, where they might keep working to kill germs and hasten the recovery process [28,29].

treating peri-implantitis. Silver plating, anodization, and sintering were used to form nanocoatings of silver, titanium dioxide, and hydroxyapatite (HA) on the surfaces of implants. The dual-layer silvernHA nanocoating totally blocked the development of bacteria in the surrounding medium and decreased biofilm on the surface of implants by 97.5 %. When applied as a nanocoating to titanium alloy implants, this new technology improved upon osseointegration, bone healing, and reduced infection risk [34-36].

►*in oral fungal infections*

Infected mucosal tissue in the mouth is called oral candidiasis. Fungi were the most commonly isolated from the mouths of both healthy and ill patients, with Candida species being the most prevalent. The Candida species involved in the symbiotic connection might develop a pathogenic phenotype under specific environmental circumstances. Three factors—host, fungus, and altered oral microenvironment—contributed to the development of candidiasis [37].

C. albicans induced oral infections often manifested themselves on the skin's surface and in a variety of ways. However, if left untreated, fungal sepsis, endocarditis, meningitis, and other serious problems may arise. The throat, digestive tract, and respiratory system are all potential sites of infection. Strong antifungal and bactericidal activity was demonstrated by complexes 1 and 2 of aluminum phthalocyanine conjugated with gold nanorods and bipyramids, respectively. Oral bacteria such S. aureus, S. mutans, and C. albicans were eliminated using erythrosine (Ery). As a catalyst, TiO_2 NPs improved the efficiency of the reaction [38].

►Nanoparticles As Photosensitizers

Members of the family of closed-cage carbon molecules, fullerenes (Cn, n=60, 70, 72, 76, 84, or 100) were made up exclusively of sp^2 hybridized carbon atoms, The irradiated Tetrakis[3-(N-ethylcarbazoyl)]porphyrin-C60 (TCP-C60) film showed a 4 log decrease in Staphylococcus aureus (S. aureus) and Escherichia coli (E. coli) with 30 and 60 min irradiations [40-42].

Another kind of carbon-based scaffolds used to encapsulate antimicrobial drugs was carbon nanotubes (CNTs). The CNTs were carbon allotropes with a high aspect ratio (length to diameter) and a huge surface area, created by folding a sheet of graphene into a cylindrical nanostructure.

Unique optical, biocompatible, and biodegradable qualities distinguished ZnO and TiO_2, two semiconducting materials.As an illustration, Pillai et al. investigated the efficacy of fluorinated (F-doped) ZnO nanopowders as photocatalysts against Escherichia coli and Staphylococcus aureus.In an effort to tackle E. coli, Sethi et al. produced ZnO/TiO_2 nanocomposites.

The ZnO/TiO_2 nanocomposite was more effective in killing off E. coli when exposed to light than either ZnO or TiO_2 NPs alone. Coating nanostructured anatase TiO_2 on the roughened implant surface has a bactericidal effect against the dental periodontal pathogens Actinobacillus actinomycetemcomitans and Fusobacterium nucleatum, as discovered by Suketa et al [43].

Polymer-based NPs possessed several advantages as drug delivery : 1) with pentagons and hexagons grouped in a soccer ball structure.Fullerene and its derivatives were shown to have potent antibacterial photodynamic activity against a wide variety of microorganisms, including bacteria and fungus.With the addition of KI, the antimicrobial effects of photoactivated fullerenes against Gram-negative bacteria, Gram-positive bacteria, and fungi may be enhanced.

flexibility in surface modification for better efficiency, 2) ability to prevent degradation of PSs in biological environment, 3) ability to load and deliver large amounts of PS to the target area, 4) excellent biocompatibility and biodegradability, and 5) ability to load multiple components such as targeting agents.

► Nanomaterials' Bioavailability

Size, surface area, shape, aspect ratio, surface charge, composition, crystalline structure, concentration, aggregation, coating, roughness, and solubility were all factors in determining the bioavailability and biocatalytic activities of nanomaterials. The toxicity to cells and tissues is affected by these physicochemical characteristics.

The potential toxicity and the causes of toxicity were not well understood, despite the fact that numerous nanomaterials were produced and some were employed in clinical therapies. All the properties of nanomaterials should first be rigorously and frequently examined in animals to get eco-friendly nanomaterials for a wide variety of biomedical applications.

Long-term studies were also required even for medications that had no short-term side effects. Therefore, biocompatibility, biodegradability, and excellent solubility were required for oral medicine applications to meet the environmental issues [44].

CONCLUSIONS:

Nanoparticles, due to their large surface area and enhanced interaction with bacteria, have shown significant promise for antimicrobial activity and applications. Furthermore, antimicrobial nanoparticles are unaffected by the antibiotic resistance of microbes since their mechanisms of action culminate in the destruction of the microorganisms' cell wall.

Nanotechnology's use in targeting and building nanoparticles for antimicrobial applications in a wide range of industries, including healthcare, personal care, water treatment, industrial coating, and food management, has resulted in the translation of fundamental research from the literature into applicable and commercially available materials and applications.

Although silver, gold, titanium oxides, copper, and their compounds are all effective antibacterial nanoparticles, they may be rather pricey. They efficiently inhibit bacterial growth at low concentrations and throughout a wide size spectrum, saving money by requiring little resources.

In addition, the usage of these antimicrobial nanoparticles is practical when weighed against the expense of healthcare brought on by the treatment of microbial infections and other personal loss.

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