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New Techniques for Prevention and Treatment of Oral Bacterial Diseases

Jin Zhang

Académie Ste-Cécile International School, Winsor, N9G 1V8, Canada
Zyii0114@gmail.com

ABSTRACT

Oral bacterial diseases include caries, periodontal disease, gingivitis, and oral cancer, and they are usually associated with an imbalance in the regulation of the oral microbiota. In the prevention and treatment of oral bacterial diseases, in addition to good oral hygiene habits and traditional treatments, studies have shown that a variety of emerging technologies, such as gingival mesenchymal stem cells (GMSCs), novel nanomaterial-based antibacterial photodynamic therapies, fluorescence molecular imaging, programmed death receptor ligand-1 positron emission tomography (PD-L1 PET), and so on, have shown high efficacy in the treatment of oral and bacterial diseases. Bacterial diseases have demonstrated high efficiency, safety, and personalized therapeutic effects. However, there are limitations such as the lack of large-scale clinical trials for many of these technologies.

KEYWORDS

Oral diseases; Oral cancer; Oral bacteria

1. INTRODUCTION

Oral bacteria have a crucial impact on human oral health, such as dental caries, periodontal disease, oral cancer, and digestive disorders, which may be caused by oral bacterial infections. Currently, knowledge and attitudes towards oral health have improved to a certain extent, but still need to be strengthened, and there are significant urban-rural differences [1]. Good oral health is closely related to people's sense of well-being in life, which not only affects the supply of nutrients to the human body from eating, but also influences interpersonal interactions such as speaking, smiling, and self-esteem. Poor oral health is associated with severe pain that interferes with sleep, learning, and work, thus negatively affecting both quality of life and human health.

2. OVERVIEW OF ORAL BACTERIAL DISEASE

The oral cavity is a complex microbial ecosystem with over 700 species within it. The environment within the oral cavity provides a favorable living environment for microorganisms including, but not limited to, bacteria, archaea, fungi, and viruses [2]. Imbalances in the regulation of these oral microbiotas can lead to a range of diseases including dental caries, periodontitis, gingivitis, and oral cancer, also known as oral bacterial diseases.

Prevention and treatment of oral bacterial diseases usually include good oral hygiene practices such as regular brushing, flossing and mouthwash, and regular dental checkups. In addition, dietary modifications, quitting smoking and limiting sugar intake are key factors in preventing these diseases.

In some cases, medication or dental surgery may be required to treat diseases that have already occurred. It is important to note that oral bacterial diseases not only affect the mouth itself, but may also be associated with heart disease, diabetes and other systemic diseases. Therefore, maintaining good oral health is also critical to preventing systemic diseases and improving quality of life.

3. PATHOGENESIS AND NEW TECHNOLOGIES FOR THE PREVENTION AND TREATMENT OF COMMON ORAL BACTERIAL DISEASES

Common oral bacterial diseases include caries, periodontitis, oral cancer, gingivitis and tartar. The main applications of new technologies in oral bacterial diseases are gingival mesenchymal stem cells (GMSCs), Novel nanomaterial-based antibacterial photodynamic therapies, fluorescence molecular imaging, programmed death receptor ligand-1 positron emission tomography (PD-L1 PET), and so on.

3.1. Dental Carries

Caries occur mainly as a result of a combination of bacterial, dietary, host and temporal factors. Bacteria are the main causative agents, such as Streptococcus mutans, Lactobacillus and Actinomyces. When sugary foods or beverages are consumed, especially sucrose, bacteria use the residues to metabolize and form organic acids that demineralize enamel, leading to caries.

The therapeutic mechanism of the multifunctional nano-system includes bacteria-responsive drug release. The system is based on maleimide-based modified polyethylene glycol-polyline/phenylboronic acid (MAL-PEG-b-PLL/PBA) block copolymers self-assembled into micellar nanoparticles together with tannic acid (TA) and sodium fluoride (NaF). These nanoparticles are pH-sensitive and capable of rapidly releasing antimicrobial drugs in the acidic microenvironment at the onset of caries for on-demand release. At the same time, the sodium fluoride (NaF) in the nano-system promotes remineralization of the enamel and increases the mineral density of the tooth [3].

Antimicrobial photodynamic therapy (aPDT) is an emerging therapeutic approach that utilizes photosensitizers (PSs) and specific wavelengths of light to generate cytotoxic Reactive Oxygen Species (ROS), especially mono-linear oxygen species (^1O2), to destroy microorganisms. Dental caries is caused by the production of acids in biofilms, and the use of photosensitizers such as metronidazole aniline (Methylene Blue (MB)) in combination with light irradiation at specific wavelengths can be used to achieve a reduction in caries-associated bacteria, such as Streptococcus mutans [4].

3.2. Periodontitis

Periodontitis is a chronic inflammatory disease caused by bacterial erosion of periodontal tissues, leading to the destruction of periodontal supporting tissues, pocket formation, loss of attached gingiva, and alveolar bone resorption; it is strongly associated with oral hygiene, but also with certain systemic diseases, such as diabetes, which can also induce as well as aggravate periodontitis [5].

The treatment of periodontitis is mainly categorized into non-surgical periodontal therapy (NSPT) and surgical periodontal therapy (SPT). Non-surgical periodontal therapy focuses on infection control through scaling and root planning (SRP), removal of plaque and tartar, reduction of probing pocket depth (PPD) and increase of clinical attachment level (CAL). In addition, daily interdental cleaning with flossing or interspace brushing is the most effective way to reduce plaque and gingivitis scores and is the least costly prophylactic treatment. Surgical treatment (SPT), on the other hand, generally refers to regenerative procedures such as guided tissue regeneration and enamel matrix derivatives for deep sub-bone defects. Systemic antibiotics, such as the combination of amoxicillin and metronidazole, have been shown to be useful as adjunctive therapy for cleansing and root planning.

In addition, topical antibiotics, such as doxycycline microspheres and chlorhexidine chips, are used for the treatment of deep periodontal pockets [6].

The use of e.g. ICG (Indocyanine Green) loaded nanoparticles in antimicrobial photodynamic therapy (aPDT) reduces periodontal pathogens and biofilms such as Porphyromonas gingivalis [4].

3.3. Oral Cancer

The pathogenesis of oral cancer involves multiple factors and is a complex process. Behavioral risk factors are mainly smoking, alcohol consumption and betel nut chewing. This is because the chemicals in them, such as nicotine, alcohol and betel nut juice, gradually denude the oral tissues, leading to oral cancer [7]. In addition, factors that contribute to the development of oral cancer include viruses (especially HPV16 or 18 [8]), among others.

Early detection and treatment of oral cancer is essential to help improve survival and reduce mortality. The diagnostic process begins with a clinical oral examination that includes a visual inspection and digital palpation of the mouth. Autofluorescence Imaging (AFI) is a technique that uses specific wavelengths of light to excite tissues to produce autofluorescence, which helps in the diagnosis and differentiation of lesions that require biopsy [9].

Nanotechnology has been used in the treatment of oral cancer in several ways: nanoparticles can be designed to respond to pH, temperature, or other biomarkers to achieve controlled release in the tumor microenvironment; nanodiamonds can be used to immobilize proteins complexed with chemotherapeutic drugs, allowing for longterm drug release [10]; and the use of nanoparticles as drug carriers to achieve targeted therapies allows for the delivery of the drug directly to the tumor tissues, reducing side effects on surrounding healthy tissues [11]. For example, drugs such as cisplatin, 5-fluorouracil, methotrexate, and doxorubicin, when coated by nanopolymers, can more effectively target oral cancer cells [12,13].

Nanoparticles can also be used as gene carriers to deliver therapeutic genes such as HSV-TK (herpes simplex virus thymidine kinase gene) to cancer cells, which can be activated by specific drugs to achieve killing of cancer cells. If nanoparticles such as photosensitizers are used, photodynamic therapy can be achieved to kill cancer cells by producing a toxic response to light irradiation at specific wavelengths. For example, chlorin e6 (Ce6) is used as a photosensitizer to enhance the efficacy of photodynamic therapy through a nanoparticle delivery system [10].

Recent findings now show that neoadjuvant PD-1 blockade prior to surgery with the PD-1 inhibitor nivolumab, an immune checkpoint inhibitor, boosts the patient's own immune system to fight cancer. PD-1 blockade therapy is designed to reduce tumor size and eliminate microscopic metastases in order to reduce the extent of surgical resection and improve long-term survival [14].

3.4. Calculus or Tartar

Calculus or tartar is a type of hardened plaque. It is caused by the deposition of minerals from saliva and gingival crevicular fluid (GCF) in the plaque on the teeth. Tartar formation tends to vary from person to person and is influenced by many factors, such as dietary habits, oral hygiene, plaque composition, age, and so on.

Er: YAG laser is capable of precisely removing tartar from diseased root surfaces, including water-mediated explosive ablation through photomechanical or photothermal effects, a process that does not produce carbonization or cracking. Er: YAG laser treatment not only removes tartar, but also stimulates the surrounding periodontal tissues, inducing biological effects such as promoting the proliferation of gingival fibroblasts, periodontal ligament fibroblasts, and osteoclasts, and the calcification of primary osteoblast-like cells [15].

3.5. Gingivitis

Long-term accumulation of plaque on the teeth is the direct cause of gingivitis. Localized factors include misaligned and crowded teeth, food impaction, poor restorations, and mouth breathing. Systemic factors such as smoking, high blood sugar, and nutritional factors can exacerbate gingivitis manifestations.

Daily interdental cleaning has a significant impact on the management of gingivitis. An oral hygiene program including an oscillating rotating electric toothbrush, bioavailable tin-fluoride toothpaste, cetylpyridinium chloride mouthwash, and dental floss was found to significantly improve periodontal health over a 2-year period compared to routine care using only a manual toothbrush and sodium fluoride toothpaste. The program was generally well accepted [16].

Herbal extracts are effective in the treatment of gingivitis and oral mucosal diseases. Studies have shown that products containing CHE and CHEB (Complex Herbal Extracts with Benzocaine) are highly effective in the treatment of gingivitis and periodontitis. These products not only reduce plaque and bleeding gums, but also reduce pain and swelling. Certain components of herbs, such as flavonoids, have anti-inflammatory properties. They reduce inflammation by inhibiting enzymes that produce inflammatory mediators (e.g., phospholipase A2, cyclooxygenase, and lipoxygenase) to reduce the concentration of prostaglandins and leukotrienes. The ellagitannin component of herbs coagulates proteins and forms a protective barrier that protects mucosal surfaces from harmful and irritating factors and contributes to tissue regeneration [17].

4. DISCUSSION

Although new technologies for the prevention and treatment of oral bacterial diseases have certain advantages and potential, and have the advantages of high efficiency, high acceptance, and fewer side effects, some of the new technologies (e.g., antimicrobial photodynamic therapy, etc.) have limitations, such as relatively high costs and the lack of large-scale clinical trials, as compared with traditional treatment methods.

At this stage, studies have shown that a variety of emerging technologies (e.g., nanotechnology, antimicrobial photodynamic therapy, Er: YAG laser, etc.) have demonstrated good efficacy in the treatment of oral bacterial diseases, and are able to effectively achieve the inhibition of the growth of oral bacteria.

The future direction of oral bacterial prevention will focus on raising public awareness of the importance of oral health, strengthening personal hygiene habits such as regular brushing and flossing, and promoting a healthy lifestyle, including a sensible diet and smoking cessation. As technology advances, innovative drug treatments and the application of emerging technologies will be key, such as the use of nanotechnology and antimicrobial photodynamic therapy (aPDT) to enhance the precision and effectiveness of treatments. The development of personalized treatment plans, which take into account patient-specific conditions through artificial intelligence algorithms, will further improve treatment outcomes. In addition, interdisciplinary research will promote a deeper understanding of the pathogenesis of oral bacterial diseases, and the development of early diagnostic techniques will help in the timely detection of diseases.

5. CONCLUSION

Oral health is closely linked to systemic health, and the balance of oral bacteria is essential for the prevention of dental caries, periodontal disease, and oral cancer. The occurrence of oral bacterial diseases not only affects the oral cavity itself, but may also be associated with systemic diseases such as heart disease and diabetes. Therefore, in-depth research on new technologies for the prevention

and treatment of oral bacterial diseases will help to improve the quality of life and prevent systemic diseases.

Current preventive and therapeutic measures for oral diseases include good oral hygiene practices, regular dental checkups, dietary modifications and smoking cessation. Medication and dental surgery are also used to treat oral diseases when necessary. As technology advances, emerging technologies show great potential. Nanotechnology, for example, offers significant advantages in antimicrobial treatment of oral diseases and drug delivery; antimicrobial photodynamic therapy (aPDT) offers the possibility of non-invasive treatments, reducing pain and speeding up recovery, as well as the ability to generate personalized treatment plans based on the patient's condition.

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