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The Current Situation of Oral Health Problems in China and Its Public Health Policy Prevention Strategies

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Abstract. Oral health plays a vital role in overall health, with increasing evidence linking the oral microbiome to systemic diseases such as cardiovascular disease, diabetes, and Alzheimer's disease. This review explores the composition and mechanisms of key oral microorganisms, including commensal bacteria, opportunistic pathogens, and fungi, highlighting their roles in maintaining or disrupting oral ecological balance. The study further discusses how oral microbial imbalance contributes to local lesions (e.g., caries and periodontitis) and systemic effects through inflammation, pathogen dissemination, and molecular mimicry. Multidimensional factors such as diet, smoking, socioeconomic status, and environmental exposures are identified as key influences on oral microecology. Current oral health strategies face limitations, including overreliance on symptomatic treatment and poor coverage of preventive measures. In response, the paper proposes a graded prevention framework based on microbiome regulation, integrating tools like probiotics, AI diagnostics, and gene editing. Future directions include personalized intervention strategies, interdisciplinary collaboration, and policy reforms to address disparities. This review provides a theoretical foundation for shifting oral disease management from lesion-focused to microbiome-centered, contributing to national public health initiatives such as “Healthy China 2030”.

Keywords: Oral health, oral microbial, public health.

1. Introduction

Oral health serves as a crucial window into overall health. Globally, approximately 3.5 billion people are affected by oral diseases, with chronic oral conditions such as dental caries and periodontal disease being closely linked to various systemic diseases. In recent years, microbiome research has revealed the key role of oral microbial imbalance in both local and systemic health. Pathogens like Streptococcus mutans and Porphyromonas gingivalis are involved in the development of cardiovascular diseases, diabetes, and Alzheimer's disease (AD) through mechanisms such as inflammation and immune activation. However, current oral health management mainly focuses on symptomatic treatment and lacks systematic preventive strategies based on microbiome regulation. Additionally, public awareness and uneven distribution of medical resources further complicate prevention and control efforts.

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This article analyzes the mechanism of the association between the oral microbiome and overall health, sorts out risk factors such as behavior, society and environment, and proposes graded prevention strategies, such as probiotic intervention, AI early screening and community-based public health measures. The research finds that although existing prevention technologies (such as fluoride toothpaste) are effective, their coverage is insufficient, with significant urban-rural differences, and microbiome-targeted intervention may become a future breakthrough point. The research results supplement the microbial ecological perspective of oral health and provide a theoretical basis for optimizing public health policies (such as monitoring high-risk groups and promoting community fluoride application). Future research can further explore the causal mechanism between the oral microbiome and specific diseases, develop personalized intervention plans, and at the same time strengthen multi-disciplinary collaboration to provide comprehensive references for achieving the "Healthy China 2030" goal.

2. Key members of the oral microbiome and their mechanisms of action

2.1. Commensal bacteria: guardians of oral microecology

Oral commensal bacteria (such as Streptococcus salivarius and Streptococcus sanguinis) are the first line of defense for maintaining oral health. These resident flora exert protective effects through multiple mechanisms: Firstly, they occupy ecological niches and inhibit pathogen colonization through spatial and nutritional competition [1]; Secondly, commensal bacteria can produce antimicrobial substances such as bacteriocins, directly inhibiting the growth of pathogenic bacteria [2]. The Human Microbiome Project Consortium found in a large-scale study that commensal bacteria account for 70-80% of the oral microbiota in healthy individuals, and their metabolic products (such as hydrogen peroxide) can maintain an appropriate pH environment. Notably, some commensal bacteria also have immunomodulatory functions, promoting immune tolerance by stimulating regulatory T cells and preventing excessive inflammatory responses. Clinical studies have shown that the S. salivarius K12 strain can significantly reduce the incidence of streptococcal pharyngitis in children ($p < 0.01$), providing a theoretical basis for the application of probiotics. These findings collectively confirm that commensal bacteria are not only "stabilizers" of the oral microecology but also important "trainers" of the systemic immune system.

2.2. Opportunistic pathogens: potential health threats

Opportunistic pathogens (such as Porphyromonas gingivalis and Tannerella forsythia) usually maintain a low abundance (<1%) in a healthy state but can rapidly proliferate and cause disease when the microenvironment changes [3]. These bacteria have unique pathogenic mechanisms: P. gingivalis can secrete gingipains (RgpA/B) to destroy the epithelial barrier, and its lipopolysaccharide (LPS) structure is special, allowing it to evade TLR4 recognition and activate atypical inflammatory pathways [4]. Clinical data show that the detection rate of P. gingivalis in subgingival plaque in patients with periodontitis is as high as 85%, significantly higher than 15% in healthy individuals ($p < 0.001$). Even more alarming is that these pathogens can spread throughout the body via the bloodstream. Lockhart et al. demonstrated that oral pathogen DNA can be detected in the blood within 15 minutes after brushing. Epidemiological studies have shown that the risk of coronary heart disease in patients with periodontitis is increased by 25% (OR = 1.25, 95% CI: 1.12-1.39), and effective periodontal treatment can reduce HbA1c in diabetic patients by 0.4-0.6% [3].

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These findings indicate that opportunistic pathogens are key mediators connecting oral and systemic diseases.

3. Fungi: neglected ecological regulators

Oral fungi (mainly Candida albicans) account for less than 0.1% in healthy individuals, but their ecological role should not be underestimated. C. albicans has a unique dimorphic nature: it exists as yeast in a commensal state and can transform into an invasive hyphal form when pathogenic. Clinical data show that the detection rate of oral Candida can increase from 10% to 65% after antibiotic use ($p < 0.01$). The latest research has found that there are complex cross-kingdom interactions between fungi and bacteria: C. albicans can form mixed biofilms with S. mutans, synergistically enhancing cariogenicity. In immunosuppressed populations, the incidence of oral candidiasis can be as high as 80%, presenting as characteristic white pseudomembranes . Even more astonishingly, Zhou et al. found that the metabolic products of Candida (such as acetaldehyde) in oral squamous cell carcinoma tissues can induce DNA damage in epithelial cells. These findings suggest that although the fungal community is scarce in number, it plays the role of an "amplifier" in the imbalance of the oral microecology and the development of diseases.

The three types of members of the oral microbiome form a sophisticated ecological network: commensal bacteria act as "builders" to maintain the stability of the microenvironment (accounting for 70-80%), opportunistic pathogenic bacteria act as "destroyers" to cause diseases under specific conditions (less than 1% in healthy individuals, but up to 15-85% in patients), and fungi act as "regulators" to influence the ecological balance (less than 0.1% in normal conditions, but up to 65% in imbalanced conditions) [1]. The disruption of this dynamic balance not only leads to local lesions but also affects overall health through mechanisms such as microbiota translocation and inflammation spread [5]. Understanding the interaction patterns among these three types of microorganisms is of great significance for developing targeted prevention and treatment strategies (such as selectively inhibiting pathogenic bacteria and promoting the colonization of commensal bacteria) [2]. Future research needs to further analyze the functional network of the microbiome to provide a theoretical basis for precision oral medicine.

3.1. The association mechanism between oral microbiome imbalance and local lesions

Oral microbiome imbalance is the initiating factor for various oral diseases, and its pathogenic mechanism is complex and diverse. During the development of dental caries, acid-producing bacteria such as Streptococcus mutans metabolize fermentable sugars in the diet to produce organic acids, lowering the local pH to a critical point (pH 5.5 or below) and causing enamel demineralization. These bacteria can also synthesize water-insoluble glucans, promoting biofilm formation and creating a protective microenvironment. Clinical data show that the detection rate of S. mutans in dental plaque of patients with high caries is 10 to 100 times that of healthy individuals ($p < 0.001$). The pathogenesis of periodontal disease is more complex. Periodontal pathogens such as Porphyromonas gingivalis secrete gingipains (RgpA/B and Kgp) to degrade host tissue proteins and simultaneously activate Toll-like receptor (TLR2/4)-mediated inflammatory responses [3]. Notably, these pathogens can also interfere with host immune responses by modifying host proteins through arginine deiminase (PPAD), inducing autoimmune reactions. Recent studies have also found that the oral microbiome is associated with oral cancer. Metabolites produced by bacteria such as Fusobacterium nucleatum (e.g., acetaldehyde and hydrogen sulfide) can directly damage epithelial cell DNA and activate pro-cancer signaling pathways (e.g., NF-κB and STAT3). In

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immunocompromised individuals, the overgrowth of Candida albicans can lead to oral candidiasis, with an incidence rate as high as 90% in HIV-infected individuals. These findings collectively indicate that oral microbiome imbalance participates in the occurrence and development of local lesions through multiple molecular mechanisms.

3.2. Evidence and mechanisms of the oral-systemic health axis

A large number of clinical and basic studies have confirmed that oral health is closely related to systemic diseases, and this connection is mainly achieved through three pathways: direct dissemination of pathogens, diffusion of inflammatory mediators, and molecular mimicry. Periodontal pathogens such as P. gingivalis can enter the bloodstream through gingival ulcer surfaces. Experimental studies have shown that the incidence of bacteremia after periodontal treatment is as high as 40%. These bacteria and their components (such as LPS) can colonize atherosclerotic plaques, promoting foam cell formation and plaque instability. A meta-analysis by Sanz et al. showed that the risk of coronary heart disease in patients with moderate to severe periodontitis increased by 25% (RR = 1.25, 95% CI: 1.15-1.36). In the field of diabetes, periodontitis and glucose metabolism disorders form a vicious cycle: inflammatory factors such as TNF-α produced by periodontitis can interfere with insulin signaling, while hyperglycemia aggravates periodontal tissue destruction through advanced glycation end products (AGEs) [3]. Clinical intervention studies have shown that effective periodontal treatment can reduce HbA1c in diabetic patients by 0.4-0.6 percentage points ($p < 0.05$). The most astonishing connection is between the oral cavity and neurodegenerative diseases. Wu et al. (2023) detected gingipains of P. gingivalis in the brain tissue of AD patients. Animal experiments have confirmed that oral inoculation of this bacterium can increase β-amyloid (Aβ) deposition in the brain by 2-3 times ($p < 0.01$). In addition, the association between periodontitis in pregnant women and adverse pregnancy outcomes (such as preterm birth) has also been confirmed, and the mechanism may be related to the transfer of inflammatory mediators through the placenta [5]. These pieces of evidence systematically construct the theoretical framework of the "oral-systemic" health axis.

3.3. Innovative strategies for regulating the oral microbiome

Intervention strategies targeting oral microbiome imbalance are shifting from the traditional "bactericidal" model to ecological regulation. Probiotic therapy represents a typical example of this transformation. Specific strains such as Lactobacillus reuteri DSM17938 can reduce cariogenic bacteria colonization through competitive inhibition, production of antimicrobial substances, and regulation of the immune system [6]. Randomized controlled trials have shown that continuous use of probiotic preparations containing this strain can reduce the incidence of dental caries in children by 35-50% ($p<0.05$). Microbial metabolic regulation is another important direction. Research has found that short-chain fatty acids (such as butyric acid) produced by commensal bacteria not only maintain an appropriate pH environment but also promote the function of the epithelial barrier [1]. Technological innovation also brings new opportunities for microbiome management. Oral microbiome analysis techniques based on deep learning (such as 16S rRNA sequencing combined with machine learning) can achieve early prediction of caries and periodontitis with an accuracy rate of 85-90% [7]. Gene editing technology (such as CRISPR-Cas9) shows potential for precise regulation of pathogenic bacteria. Experiments have confirmed that targeting the gtfB gene of S. mutans can significantly reduce its cariogenicity [8]. These innovative methods jointly promote the

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paradigm shift in the prevention and treatment of oral diseases from "symptom management" to "etiological intervention".

3.4. Multidimensional factors influencing oral microecology

The balance of the oral microbiome is comprehensively affected by behavioral, social, and environmental factors. In terms of behavioral factors, a high-sugar diet provides metabolic substrates for cariogenic bacteria. Epidemiological data show that the risk of dental caries increases 3-5 times in people who consume more than 50g of sugar per day [9]. Smoking disrupts the microecological balance through multiple pathways: nicotine inhibits salivary secretion and alters oral pH; toxic substances in cigarette smoke (such as hydrogen cyanide) selectively inhibit the growth of beneficial bacteria; and it also inhibits the function of neutrophils, promoting the proliferation of periodontal pathogenic bacteria [10,11]. Clinical surveys show that the detection rate of P. gingivalis in the periodontal pockets of smokers is 2-3 times that of non-smokers ($p<0.01$). In terms of social factors, low-income groups face poor access to oral services. About 50% of the global population cannot obtain basic oral services [5]. Liu et al. found that implementing school oral health programs can reduce the incidence of dental caries in children by 30-40%, but the urban-rural gap remains significant (urban coverage rate is 50%, rural is less than 5%). In terms of environmental factors, water fluoridation (0.7-1.2ppm) has been proven to be a safe and effective group caries prevention measure, reducing the incidence of caries in the community by 30-50% [2]. However, the problem of antibiotic abuse is becoming increasingly serious. Broad-spectrum antibiotics can disrupt the microbiome balance and increase the risk of fungal infections [10]. These factors constitute a multidimensional network affecting oral health, and comprehensive intervention strategies are needed.

4. Current problem analysis and prevention and control suggestions

4.1. Systematic analysis of existing problems

The current oral health management system is confronted with multi-dimensional and multi-level challenges, which seriously restrict the effectiveness of oral disease prevention and treatment. At the clinical treatment level, traditional dentistry still adheres to the "mechanical debridement" treatment paradigm, overly relying on symptomatic measures such as fillings and root canal therapy. Baker et al. in their research published in Nature Reviews Microbiology clearly pointed out that this treatment model neglects the ecological balance regulation of the oral microbiome, resulting in the ineffectiveness of treatment being difficult to sustain. Clinical data shows that after simple mechanical debridement, the re-colonization speed of periodontal pathogenic bacteria (such as P. gingivalis) is astonishing, with a recurrence rate of 60-80% within six months. Even more worrying is the increasingly serious problem of antibiotic abuse. The prescription rate of metronidazole for periodontitis patients exceeds 70%, and this non-selective killing not only disrupts the microbial balance but also leads to the excessive proliferation of opportunistic pathogenic bacteria such as Candida albicans.

The shortcomings of the public health system are also prominent. Peres et al. published a global burden of oral disease study in The Lancet, which showed that the coverage rate of fluoride application programs for children in China was only 20%, far lower than the 80% level in developed countries. Liu et al. further revealed the severity of the urban-rural disparity: the coverage rate of fluoride application in urban schools was 50%, while in rural areas it was less than 5%. This uneven

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distribution of resources directly leads to health inequality, with the incidence of dental caries among low-income groups being 2-3 times that of high-income groups [11]. Data from the World Health Organization also shows that about 50% of the global population cannot access basic oral health services, and this figure is as high as 70% in rural areas of developing countries.

The third obstacle lies in the public's misconceptions. Wang et al. found in a decade-long tracking study that 60% of the Chinese public still hold the erroneous belief that dental care is only necessary when experiencing toothache. The latest survey by New Weekly reveals that this proportion is even higher among the 18-35 age group, reaching 71%. Such cognitive biases lead to a significant delay in disease detection. The Third National Oral Health Epidemiological Survey shows that the periodontal health rate among the 35-44 age group has dropped to a staggering 8.4%, while the rate of seeking medical treatment is less than 20%. Sheiham and James pointed out that this "treatment-oriented and prevention-neglected" medical-seeking pattern not only increases the difficulty and cost of treatment but also imposes a huge disease burden.

4.2. Innovative pathways for the graded prevention strategy

Based on the above issues, we urgently need to establish a new hierarchical prevention system based on the concept of microbiome regulation. This system should break through traditional thinking and reconstruct the oral health management model from an ecological perspective. At the primary prevention level, microbiome testing technology should become a fundamental tool. The research of the Human Microbiome Project Consortiumconfirmed that 16S rRNA sequencing technology can accurately identify the state of microbiota imbalance and predict disease risk 3-6 months in advance. Clinical data shows that specific microbiota characteristics (such as an imbalance in the ratio of Prevotella to Streptococcus) can predict orthodontic treatment failure with an accuracy rate of up to 85%. The application of probiotics also holds great promise. A randomized controlled trial by Hasslof et al. demonstrated that continuous use of a preparation containing L. reuteri DSM17938 can reduce the incidence of dental caries in children by 35-50%. The mechanisms of action include competitive colonization (reducing the adhesion rate of cariogenic bacteria by 42%), production of antimicrobial substances (such as reuterin), and regulation of local immunity (increasing sIgA secretion by 25%).

Secondary prevention should focus on precise intervention for high-risk groups. The clinical guidelines of Genco and Sanz emphasize that diabetic patients should receive professional periodontal examinations every six months, as their risk of periodontitis is two to three times that of the general population. The introduction of AI technology has brought revolutionary changes to early diagnosis. The new deep learning algorithm developed by Tian et al. can identify early caries with 90% accuracy using only oral photos taken by ordinary smartphones, making this technology particularly suitable for areas with scarce medical resources. Koo et al. also found that photodynamic therapy (PDT) targeting biofilms can achieve a clearance rate of 85% for periodontal pathogenic bacteria and is less likely to develop drug resistance.

The core of tertiary prevention lies in establishing a multidisciplinary collaborative treatment model. A meta-analysis by Sanz et al. demonstrated that standardized periodontal treatment could reduce HbA1c levels in diabetic patients by 0.4 to 0.6 percentage points, an effect equivalent to adding an oral hypoglycemic agent. The latest breakthrough research has further found that fecal microbiota transplantation (FMT) has a remission rate of up to 75% for recurrent oral ulcers, providing empirical support for the regulation of the "gut-mouth axis" [12]. Wu et al. also confirmed in animal experiments that targeted elimination of P. gingivalis could significantly reduce Aβ deposition in the brain, opening up new avenues for the prevention and treatment of AD.

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5. Future development trends

Oral health management is currently undergoing an unprecedented technological revolution and conceptual update. Gene editing technology is set to bring about breakthrough progress. The research by Zhang et al. demonstrated that after the CRISPR-Cas9 system targeted and edited the gtfB gene of S. mutans, the incidence of dental caries in experimental animals decreased by 60%, without affecting other commensal bacteria. This precise regulation represents the future direction.

Policy integration is imperative. Data from the "Medical-Educational Collaboration" pilot project in Ningxia shows that after incorporating oral examinations into students' regular physical check-ups, the rate of fissure sealant application soared from 35% to 92.2%, and the incidence of dental caries dropped by 40%. This successful experience should be promptly promoted nationwide, especially in rural areas [13]. Interdisciplinary research will give rise to new breakthroughs. The latest research has found that the intestinal symbiotic bacterium Akkermansia muciniphila can enhance oral mucosal immunity through the TLR-MYD88-NF-κB pathway, providing a molecular basis for the "gut-mouth axis" therapy [14]. Meanwhile, studies in microbial metabolomics have revealed that short-chain fatty acids such as butyric acid not only maintain oral pH but also promote epithelial barrier function, pointing the way for the development of new prebiotics.

6. Suggestions

The oral microbiome, as an "ecological bridge" connecting local and systemic health, has been fully confirmed for its significance. Existing evidence shows that the imbalance of oral flora can affect systemic health through multiple pathways (such as flora translocation, inflammatory spread, molecular mimicry, etc.) [5]. Wu et al. in the research published in Science Advances further confirmed that P. gingivalis infection can increase Aβ deposition in the brain by 2-3 times, providing direct evidence for the "oral-brain axis" theory. Therefore, at the policy level, it is necessary to incorporate microbiome testing into the national basic public health service package and set clear coverage targets: by 2025, the coverage rate of fluoride application for children should reach 80%, and the coverage rate of pit and fissure sealants should reach 90% [2]. At the same time, a monitoring system for oral health inequality should be established, with a focus on ensuring the accessibility of services for rural and low-income groups.

In clinical practice, it is imperative to accelerate the transformation of the treatment paradigm. The focus should shift from mere "lesion removal" to "ecological regulation", with priority given to microecology-friendly interventions such as probiotics and photodynamic therapy [3]. Medical institutions should establish a multidisciplinary collaboration mechanism, especially a joint diagnosis and treatment model involving dentistry and specialties such as endocrinology and neurology.

Public education needs innovative forms. It is suggested that September 20th be designated as the "National Oral Microbiota Health Day" every year, and the scientific concept that "the mouth is the gateway to overall health" be popularized through new media and other channels [10]. School health education courses should incorporate content related to the microbiome to cultivate correct oral health concepts from an early age.

Only through this comprehensive prevention and control strategy led by the government, involving multiple departments and the participation of the entire society, can the oral health goals proposed in the "Healthy China 2030" planning outline be truly achieved. Let's join hands and work together to make every smile shine with health and every tooth a strong fortress safeguarding the health of the whole body.

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7. Conclusion

This paper systematically analyzed the complex relationship between the oral microbiome and both oral and systemic health. It highlighted how commensal bacteria act as ecological stabilizers, opportunistic pathogens as disease triggers, and fungi as amplifiers in dysbiosis. The mechanisms through which oral microbiota imbalance contributes to caries, periodontitis, oral cancer, cardiovascular diseases, diabetes, and neurodegeneration were thoroughly reviewed. It was found that current oral health management systems are limited by symptomatic treatment paradigms, lack of preventive strategies, and unequal access to care—especially in rural or low-income populations. As a solution, the paper proposes a graded prevention strategy based on microbiome regulation, emphasizing early detection, probiotic therapy, AI-based risk screening, and multidisciplinary care. Emerging technologies like CRISPR-Cas9 and microbial metabolomics are also promising tools for precision interventions. Future efforts should focus on integrating microbiome health into public policy, expanding access to preventive services, and strengthening public education on oral-systemic health. Only through a coordinated and comprehensive strategy can we transition from passive treatment to active prevention and truly achieve the vision of “Healthy China 2030”.

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