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# Oral Microbial Ecology: Balancing Symbiosis and Pathogenesis: A Review

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**Accepted:** **23/4/2025** **Published:** **30/6/2025**

## ABSTRACT

Microorganisms within the oral cavity exist in balance with one another and the host's immune system, contributing to oral health. Disruption of this balance can result in microbial activity that leads to oral diseases and oral diseases are linked to microorganisms that exist in the oral cavity. Mouth contains one of the utmost complex in addition to various microorganism ecosystems in the human body. The oral microorganism contributes to maintaining homeostasis within the oral host. However, environmental, behavioral, or systemic changes can lead to ecological shifts in the balanced microbial community, leading to oral diseases including dental caries and periodontitis. These microorganisms exist in a balanced manner with each other and with the immune system of the organism, and thus this leads to maintaining oral health. However, any imbalance in this balance leads to the microorganisms living in the mouth becoming disease-causing. This review aims for survey the structure and dynamics of the mouth microorganism, the transition from commensalism to pathogenesis, diseases caused by microorganisms present in the mouth ,the relationship of these microorganisms to people with immune deficiency , current procedures to restore microbial balance. Understanding these dynamics can guide the development of targeted therapies for oral and systemic health.

**Keywords**: oral microbiota; *Streptococcus mutans*; Porphyromonas gingivalis; dental caries; periodontitis

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## 1. INTRODUCTION

Mouth serves as a gateway to both the intestines and respiratory tracts and is continuously exposed to external environmental influences. It harbors a complex microbiome composed of bacteria, fungi, viruses, and archaea, estimated to include over 700 species [1]. In the oral cavity is found water and nutrients, and also provides a mild temperature for microorganisms[2], which adhere to the teeth and gums in the mouth in order to protect themselves from mechanical processes in the stomach. Hydrochloric acid also works to eliminate microorganisms sensitive to acids[2,3].

Several mechanisms use in oral cavity to sense their environment or escape modification within the host. The tooth and mucosal epithelium provide a favorable environment for oral bacteria[4,5]. Several factors have been found to influence bacterial colonization, including oxygen concentration and availability on specific oral surfaces, mechanical processes affecting the oral surface, saliva flow, and oral pH[5]. The oral microbiome differs between men and women depending on oral health conditions, especially during periodontitis[6]. However, the host has a defense system to eliminate microbial colonization and prevent the spread of bacteria to oral tissues, where a dynamic balance exists[4]. This review aims to analyze the complex interactions within the oral microbiome and their implications for oral and systemic health

## 2. COMMENSAL BACTERIA IN BUCCAL CAVITY

Microorganisms which naturally exist in the in buccal cavity are nothing but bacteria that have evolved to resist the host's immune system, as occurs in tooth decay[2]. It is located inside the mouth,inclusive of anaerobic bacteria: *Actinomyces*, *Arachnia*, *Bacteroides*, *Bifidobacterium*, *Eubacterium*, *Fusobacterium*, *Lactobacillus* [7] .

Also, there are fungi, incuding *Candida*, *Cladosporium*, *Aspergillus*, *Fusarium*, *Glomus*, *Alternaria* [8]. The commensal streptococci are the main colonizers found in the oral cavity and produce lectins and metabolites. Oral streptococci often oppose the bacteria that cause tooth decay and gingivitis, including: *Streptococcus mutans* and *Porphyromonas gingivalis*, respectively,The antagonistic processes include the production of hydrogen peroxide, the elimination of metabolic products, the production of nitrogen compounds, and the formation of bacteriocins[9].

## 3. THE COMPOSITION OF THE ORAL MICROBIOTA

The oral microbiota is site-specific, with different microbial communities inhabiting the tongue, buccal mucosa, hard palate, teeth surfaces, gingival sulcus, and saliva . Predominant genera include *Streptococcus, Actinomyces, Veillonella, Fusobacterium, and Prevotella* [10]. These microbes perform critical roles in colonization resistance, immune modulation, and nutrient metabolism. Fungi (e.g., *Candida albicans*) and viruses (e.g., Epstein-Barr virus, herpesviruses) also form part of the ecosystem, often in low abundance but with significant potential to influence health outcomes [11].

The organisms found in the mouth are considered the most complex microorganisms within the human body after the microorganisms found in the intestines[12,13]. This complexity is due to the large numbers of microorganisms present in the mouth, As in figure(1)[14–19].

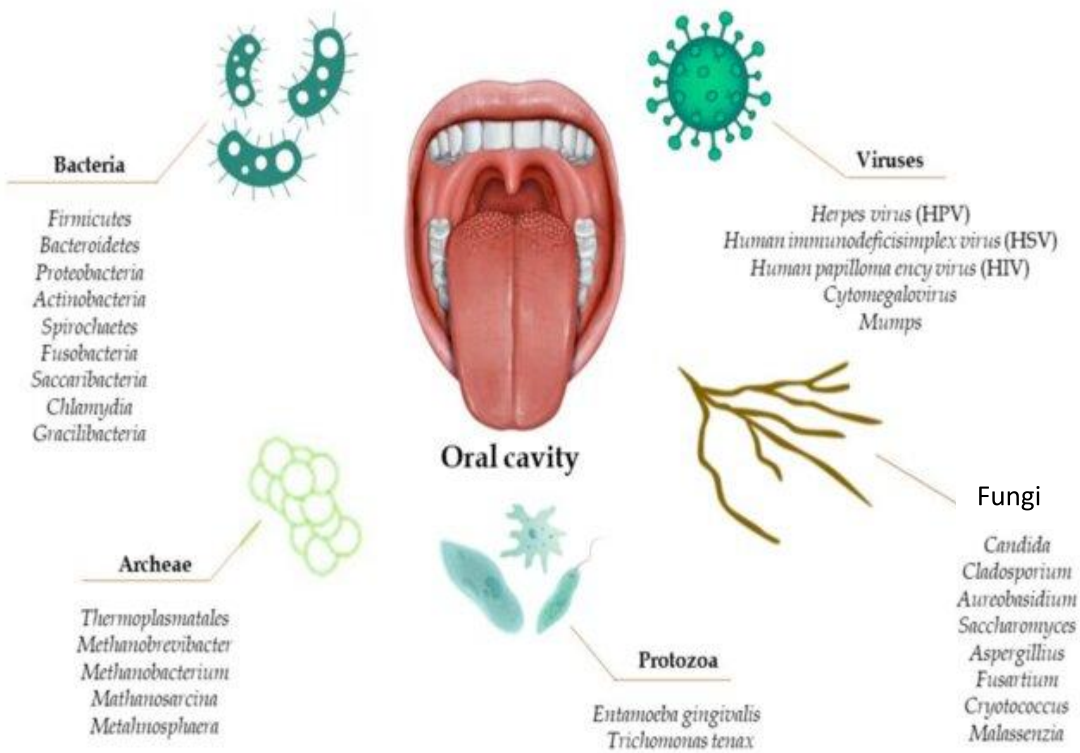


**Figure 1 : Human oral microbial community [19].**

## 4. SYMBIOSIS IN ORAL ECOLOGY

When commensal microorganisms are present in the mouth, they compete with pathogenic microorganisms for attachment sites and necessary growth materials. They produce bacteria and acids that inhibit the growth of pathogenic microorganisms. They also stimulate the immune system to prepare without causing harmful inflammation[20].

This balance ensures that even potentially pathogenic species are kept in check by commensal organisms and host defenses. Symbiotic microorganisms are naturally present in the oral cavity and are arranged with the host in a symbiotic relationship, where a dynamic balance occurs between the host, the environment, and the microorganism. However, when sugars are consumed in large quantities or saliva flow decreases, the mouth becomes highly acidic, which stops this symbiotic relationship. Consequently, the bacterial species beneficial to oral health do not grow, which leads to the growth of acid-tolerant microorganisms that produce acids and cause tooth

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decay[21].Nevertheless, different agents caused the dysbiosis of the mouth microorganism, which participates to mouth and even systemic diseases such as candidate phyla radiation ,as shown in figure (2) [22].

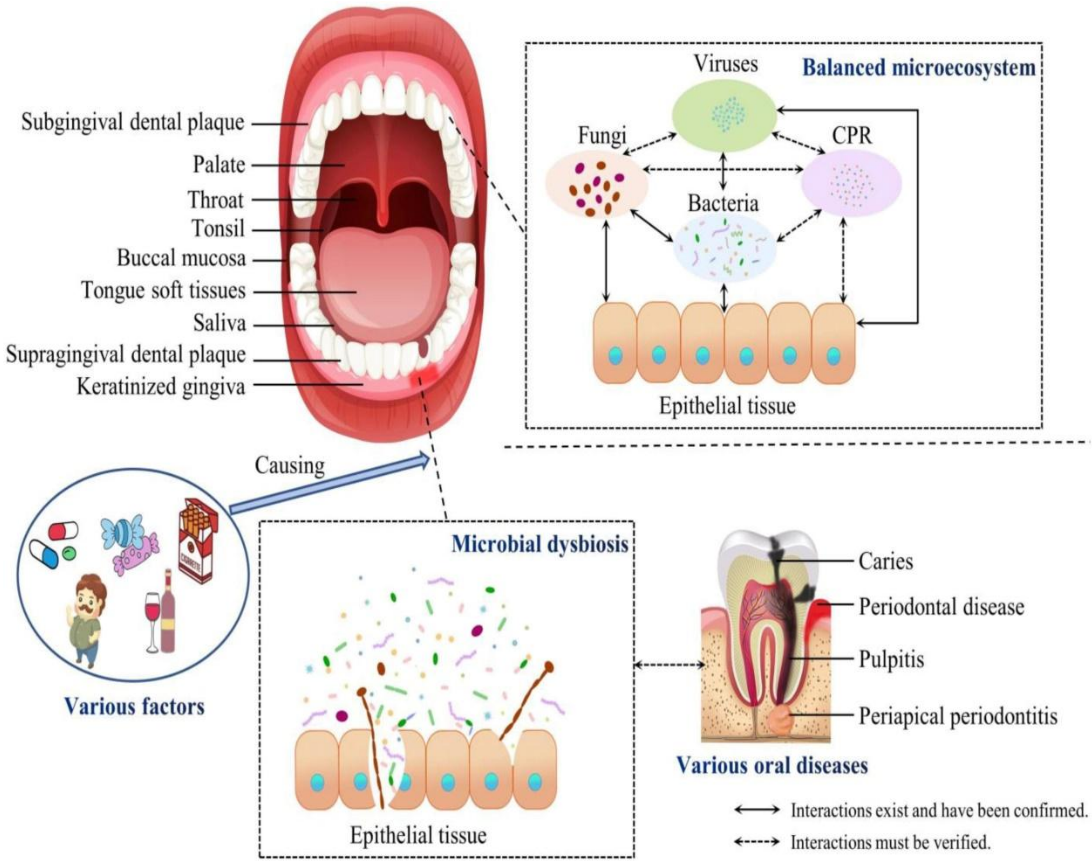


**Figure 2. Oral commensal microbiota and dynamic imbalance[22].**

## 5. DYSBIOSIS AND PATHOGENESIS

### 5.1. Dental Caries

Caries arises from ecological shifts favoring acidogenic and aciduric species, particularly *S. mutans* and Lactobacillus spp., which metabolize dietary sugars into acids, lowering pH and demineralizing enamel [23]. The frequent intake of fermentable carbohydrates and poor oral hygiene are major risk factors. Tooth decay is caused by the formation of a bacterial biofilm, which is active when the pH of the oral cavity fluctuates[24].When the dynamic balance within the mouth changes, the environment becomes acidic and caries-causing due to excessive sugar intake[25].

This change may be clinically unnoticeable, or it may leads to loss of tooth minerals, resulting in visible caries[24].Therefore, human caries is considered a microbial nutritional disease [26],that

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requires the presence of a necrotic biofilms and the consumption of fermentable carbohydrates. Behavioral, psychological, and social factors are also important in the development of the disease[27].Fluoride use can prevent tooth decay, but insufficient fluoride use is a causative factor in tooth decay[28]. The caries lesion contains a high percentage of microbial, including *S. mutans*, *Streptococcus sobrinus*, and *Lactobacilli*, which were isolated from an advanced case of caries[29]. *S. mutans* is closely associated with dental caries, and no caries progression occurs unless this bacteria is present in the decayed area[26].

### 5.2. Periodontitis

Periodontitis involves a microbial shift from a symbiotic to a dysbiotic biofilm dominated by anaerobic and proteolytic bacteria for example *P. gingivalis* [30]. These organisms disrupt host immune responses, leading to chronic inflammation and periodontal tissue destruction. The formation of a biofilm of plaque leads to the development of gingivitis. This biofilm is caused by *P. gingivalis* and *Treponema denticola*. Inflammation of the gum tissue around the tooth occurs due to the presence of these types of bacteria in the gum tissue[31]. If left untreated, it leads to gradual tooth damage and inflammation of the gum tissue. Diagnosis is made by visually examining the gum tissue surrounding the teeth or using X-rays to observe bone loss around the teeth[32].

### 5.3. Opportunistic Infections

Opportunistic pathogens such as *C. albicans* and herpesviruses can cause oral mucosal infections under immunosuppressive conditions or after antibiotic use, further disrupting microbial balance [33]. Oral thrush, also known as candidiasis, is caused by an opportunistic fungal infection that invades the mucous membrane of the oral cavity. *C.albicans* is a commensal organism that adapts to the host, but changes in the host's environment can transform the commensal state into a disease-causing state. This depends on virulence factors, including the secretion of proteolytic enzymes, adhesion, and drug resistance of the fungus.The synergistic relationship between oral bacteria and *Candida* promotes colonization of the host. The immune response in the oral cavity shifts toward a more tolerant state, thus, the innate immune defenses play a role in keeping *Candida* in its commensal situation[34].

## 6. HOST–MICROBE INTERACTIONS

The oral immune system continuously monitors microbial communities. Saliva contains immunoglobulins, lysozyme, lactoferrin, and antimicrobial peptides that limit microbial growth [35]. The gingival epithelium and immune cells detect microbial patterns via receptors (e.g., TLRs), initiating controlled inflammatory responses. In dysbiosis, these responses become chronic and destructive. Studies indicate that α-defensins, β-defensins, LL-37, histatin and other antimicrobial peptides and proteins play important roles in keeping oral health and inhibition adherence bacteria, fungi, and viruses[36].

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# 7. RESTORING MICROBIAL BALANCE

## 7.1. Probiotics and Prebiotics

Probiotics (e.g., *Lactobacillus reuteri*, *Streptococcus salivarius*) can inhibit pathogenic biofilm formation and modulate immune responses [37]. Prebiotics, like arginine and xylitol, promote the growth of beneficial oral microbes. Currently, Probiotics are used to maintain the health of the digestive system, and studies have shown that they have an effective role in preventing and treating oral diseases such as tooth decay, inflammation of the oral mucosa, and bad breath[38].

## 7.2. Antimicrobial and Anti-Biofilm Agents

Selective antimicrobials and quorum-sensing inhibitors are under investigation to target pathogenic species without disrupting commensals [39].

## 7.3. Lifestyle and Preventive Care

Regular brushing, flossing, dietary moderation of sugar, and the use of fluoride or antimicrobial rinses help maintain ecological balance.

# 8. CONCLUSION

Oral microbial ecology is a dynamic interplay of microbial communities and host responses. The transition from symbiosis to pathogenesis underlies many common oral diseases. By understanding the ecological and molecular mechanisms that drive this shift, we can develop strategies to prevent and reverse dysbiosis, promoting both oral and systemic health.

## Conflict of interests.

There are non-conflicts of interest.

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