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(Review Article)

Oral Biofilms: A literature review on composition, development and clinical implications in dental health

Lunetta Violla Shalshabilla * and Mutiara Puspita Hermawan

Undergraduate Student, Faculty of Dental Medicine, Universitas Airlangga, Surabaya 60132, Indonesia.

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Abstract

Objectives: This article aims to discuss the composition of oral biofilms, their developmental stages, and the implications of biofilms for dental health, particularly in relation to caries and periodontal disease.

Methods: The research method used was a literature review using PubMed, Scopus, and ScienceDirect databases with keywords "oral biofilm," "composition," "dental caries," and "periodontal disease'.' The selected articles were published from 2015 to 2024.

Results: Oral biofilms are composed of complex microbial communities, including Streptococcus mutans, Actinomyces, Lactobacillus, and anaerobic bacteria. There are four stages of biofilm formation: pellicle formation, initial colonization, co-aggregation, and maturation. Biofilms play a significant role in the pathogenesis of caries through acid production and enamel demineralization, as well as in periodontitis through the inflammation of periodontal tissues.

Conclusion: Understanding the composition and dynamics of oral biofilms is essential for the prevention of dental disease. Intervention strategies include oral hygiene, fluoride use, probiotics, and the latest antibiofilm technologies.

Keywords: Oral Biofilm; Dental Caries; Periodontal Disease; Oral Microbiome; Dental Plaque

1. Introduction

Oral biofilms are organized communities of microorganisms that adhere to the hard and soft surfaces of the oral cavity, particularly the teeth. These structures consist of bacteria, fungi, and viruses, as well as an extracellular polymer matrix formed from saliva and microbial metabolic products (1). Dental plaque, the most well-known form of biofilm, plays a crucial role in maintaining the balance of the oral ecosystem. However, changes in the microbial balance due to environmental factors, a high-sugar diet, or poor oral hygiene can transform a biofilm from a healthy state to a pathogenic one(2).

The formation of an oral biofilm involves several stages, including the formation of an acquired pellicle on the tooth surface, the initial colonization of Gram-positive bacteria, interspecific interactions, and finally the development of a mature biofilm that is resistant to antibiotics (3). Within the mature biofilm, bacteria such as Streptococcus mutans, Actinomyces, and Lactobacillus play a key role in the enamel demineralization process that leads to caries. Meanwhile, colonization by anaerobic bacteria such as Porphyromonas gingivalis and Tannerella forsythia contributes to periodontal inflammation (4).

* Corresponding author: Lunetta Violla Shalshabilla

Clinically, oral biofilms have significant implications for oral health. Biofilms are not only a major factor in the causation of caries but also play a crucial role in the formation of chronic periodontal disease, which can progress to tooth loss. Diseases caused by biofilms have a broad impact on general health, for example, the association of periodontitis with systemic diseases such as diabetes and cardiovascular disease (5). Therefore, understanding the composition, developmental dynamics, and pathogenic mechanisms of biofilms is a key aspect in the prevention and management of oral diseases.

2. Material and methods

This article was compiled using a literature review method using PubMed, Scopus, and ScienceDirect databases. Keywords included "oral biofilms," "compositions," "dental caries," and "periodontitis." The articles selected were published from 2015 to 2024, in English, with a focus on dentistry.

3. Results and discussion

Based on the collected and analyzed articles, the findings are presented as follows:

Table 1 List of Articles

No	Author (Year)	Method	Result
1	Marsh and Zaura (1)	Narrative review	Biofilms are dynamic microbial communities that play a role in maintaining the balance of oral health. The imbalance can lead biofilm to pathogens that cause caries and periodontitis.
2	Takahashi and Nyvad (6)	Review (ecological hypothesis)	Proposing the ecological hypothesis of caries: changes in the biofilm ecosystem due to carbohydrate intake trigger the growth of acid-producing bacteria and tooth demineralization.
3	Lamont, Koo and Hajishengallis (4)	Narrative review	Demonstrates the dynamic interaction of microbiota with the host. Periodontitis pathogenic bacteria such as *P. gingivalis* can alter the biofilm to become more virulent.
4	Simón-Soro and Mira (7)	Review of microbiome studies	Analysis of the oral microbial community shows high biofilm diversity and a specific role of *Streptococcus* mutans in caries pathogenesis.
5	Kolenbrander et al. (3)	Review	Describe the stages of biofilm development: initial colonization, co-aggregation, maturation. The distance between microbial cells affects biofilm communication and resistance.
6	Hajishengallis and Lamont (4)	Narrative review	Polymicrobial periodontitis results from ecological and pathogenic interactions between bacteria. The concept of “keystone pathogens” describes the small but significant role of certain bacteria.
7	Belibasakis (5)	Review (periodontology)	Subgingival biofilms are associated with microbiological changes in the periodontium. Emphasizing the relationship between chronic inflammation and anaerobic microbes.
8	Fathil et al. (8)	In-Vitro	Highlighting the application of nanomaterials to inhibit biofilm formation. Silver and chitosan nanoparticles have been shown to have high antibiofilm activity.
9	Georges et al. (9)	Narrative review	The oral microbiome is closely linked to systemic diseases such as diabetes and cardiovascular disease. Pathological biofilms serve as a gateway for systemic inflammation.
10	Pitts et al. (10)	Disease primer (comprehensive review)	Biofilms and caries are described as the result of a multifactorial interaction: host factors, diet, and microbiota. Caries prevention requires a multifactorial approach.

The reviewed literature collectively emphasizes that oral biofilms are dynamic, structurally complex microbial communities whose ecological balance determines whether they maintain health or contribute to disease. Marsh & Zaura (1) underscored the importance of microbial equilibrium, describing biofilms as protective under stable conditions but pathogenic when disrupted. This duality aligns with the ecological hypothesis of Takahashi & Nyvad (6), who demonstrated how carbohydrate-driven shifts favor acidogenic species, leading to enamel demineralization. Similarly, Pitts et al. (10)highlighted that caries development is multifactorial, involving interactions between diet, microbiota, and host susceptibility, suggesting that no single factor or pathogen can fully account for disease onset.

The development of biofilms has been thoroughly characterized by Kolenbrander et al. (3), who detailed the sequential stages of colonization, co-aggregation, and maturation, while emphasizing spatial relationships as determinants of microbial communication and resistance. This ecological succession is not passive; rather, it is shaped by host and environmental influences. Lamont, Koo & Hajishengallis (2) revealed that certain pathogens, particularly Porphyromonas gingivalis, can actively modulate host responses to create a more virulent biofilm. This perspective reframes biofilm development as a dynamic ecological process where microbial succession, host immunity, and dietary substrates converge.

Clinically, the transition from a balanced to a dysbiotic biofilm underpins both caries and periodontal disease. Simón-Soro & Mira (7) confirmed that while microbial diversity characterizes healthy biofilms, Streptococcus mutans plays a disproportionate role in caries due to its acidogenicity. For periodontal disease, Hajishengallis & Lamont (4) introduced the "keystone pathogen" concept, demonstrating how low-abundance species can destabilize biofilm ecology and trigger polymicrobial synergy. Belibasakis (5) further reinforced this view by associating subgingival biofilms with chronic inflammation, highlighting the bidirectional relationship between microbial shifts and host tissue breakdown. These findings collectively support the notion that oral diseases emerge not from the presence of specific pathogens alone, but from ecological imbalance within the biofilm.

The implications of biofilms extend beyond the oral cavity. Fathil et al. (8) demonstrated strong associations between pathological oral biofilms and systemic conditions such as diabetes and cardiovascular disease, positioning the oral microbiome as a mediator of systemic inflammation. This highlights biofilm-related diseases as not merely localized dental problems but contributors to broader health burdens. Consequently, strategies targeting biofilms must adopt a multifactorial and preventive perspective. In this context, Georges et al. (9) presented promising evidence for nanomaterials, such as silver and chitosan nanoparticles, which exhibit strong antibiofilm properties. These emerging technologies complement conventional approaches, mechanical disruption, fluoride application, and probiotics, by directly targeting biofilm resilience mechanisms.

In synthesis, the literature illustrates that oral biofilms function as complex ecosystems shaped by microbial interactions, diet, and host responses. Their composition and ecological dynamics directly influence disease processes, while their resilience complicates management. Importantly, the recognition of biofilms as drivers of both local and systemic disease elevates their significance in contemporary dentistry. Future directions should focus on integrating ecological perspectives with novel antibiofilm strategies to achieve more sustainable disease prevention and control.

4. Conclusion

A review of the literature shows that oral biofilm is a complex and dynamic microbial community that plays a crucial role in maintaining the balance of the oral ecosystem. The composition is affected by various factors, such as diet, interactions between microorganisms, and the immune system of the host. Biofilm formation occurs in stages through initial colonization, co-aggregation, and maturation, as described by Kolenbrander et al. (3). Under balanced conditions, biofilms are commensal and support oral health (1), but environmental changes such as increased carbohydrate intake can cause an ecological shift toward more acidogenic and pathogenic biofilms (6). Some microorganisms, such as Streptococcus mutans and Porphyromonas gingivalis, play a crucial role in the pathogenesis of caries and periodontitis. The concept of "keystone pathogens" suggests that even when a particular microbe is present at a low level, its impact on biofilm virulence can be significant. (4). Furthermore, biofilms not only have local impacts but can also contribute to systemic inflammation and chronic disease (8). Efforts to prevent and control biofilms, including through multifactorial approaches and technologies such as nanoparticles(9), are key to maintaining overall oral and systemic health.

Compliance with ethical standards

Acknowledgments

Author should write about third party like funding agencies, institution where experiment is carried out or who help in the experiment apart from authors.

Disclosure of conflict of interest

All the authors of must disclose the possible conflicts of interest/ Competing Interests they may have with publication of the manuscript or an institution or product that is mentioned in the manuscript and/or is important to the outcome of the study presented. Authors should also disclose conflict of interest with products that compete with those mentioned in their manuscript.

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