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Research on the Impact of Oral Microbiome Dysbiosis on Systemic Inflammatory Disease

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Abstract. Oral microbiome dysbiosis is a prevalent condition in the oral cavity and can precipitate systemic diseases such as Systemic Lupus Erythematosus (SLE) and rheumatoid arthritis (RA). This paper primarily discusses the significance of maintaining a balanced oral microbiome and the impact of periodontitis on overall health. Periodontitis, primarily resulting from the accumulation of plaque and calculus on teeth, leads to bacterial infection and inflammation of the gums. Pathogenic microbes can infiltrate the bloodstream through periodontal tissues, eliciting systemic inflammatory responses. This dysregulation facilitates the release of pro-inflammatory cytokines, thereby fostering chronic inflammation throughout the body. Additionally, this paper will present two treatment methods: scaling and root planing, and surgical interventions. The methodology employed in this paper is based on literature review and analysis.

Keywords: oral microbiome dysbiosis, systemic inflammatory disease, systemic lupus erythematosus, periodontitis

1. Introduction

The oral microbiome plays a crucial role in influencing both local and systemic immune systems. A balanced microbial community within the oral cavity is essential for enhancing immune defenses and mitigating inflammatory responses, which in turn safeguards oral health and overall well-being. The oral environment is primarily dominated by four key microbiota: Bacteroidetes, Actinobacteria, Proteobacteria, and Firmicutes. Scholarly consensus suggests that an imbalance, particularly a shift in the ratio favoring Bacteroidetes and Firmicutes over Actinobacteria and Proteobacteria, indicative of dysbiosis, significantly elevates the risk of oral and systemic diseases [1]. This study focuses on the critical importance of maintaining a balanced oral microbiome and the implications of its dysbiosis on oral and systemic health. Specifically, it explores how the composition and ratio of the predominant microbiota—Bacteroidetes, Actinobacteria, Proteobacteria, and Firmicutes—impact the oral environment and contribute to disease susceptibility. To delve into this topic, the paper employs a comprehensive literature review and analysis approach. By examining existing research [2], clinical studies, and epidemiological data, the study aims to synthesize current knowledge on the oral microbiome's role in health and disease, particularly focusing on the interplay between microbial balance and inflammatory responses [3]. The findings of this research are anticipated to foster a deeper understanding of the relationship between oral health and overall systemic health. By

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highlighting the importance of microbial balance, the study underscores the potential for collaborative efforts across multidisciplinary fields such as dentistry, microbiology, and immunology. Furthermore, the research results are expected to provide valuable insights and moderate references for other medical fields, promoting integrated approaches to disease prevention and treatment that consider the pivotal role of the oral microbiome.

2. SLE

SLE is a chronic autoimmune disease where the immune system mistakenly attacks healthy tissues, and it can affect various organs and systems in the body. Moreover, oral manifestations are the first symptoms to display and can help to diagnose in an earlier stage [4]. Chronic inflammation and bacterial metabolites originating from the oral cavity can influence the immune system, leading to overactivation, wherein the immune system may commence attacking its own tissues. This process can be exacerbated by microbial dysbiosis. Upon activation, these components secrete substantial amounts of pro-inflammatory cytokines, such as TNF-α, which can be transported via the bloodstream throughout the body, maintaining the immune system in a state of heightened alert. This can also result in the abnormal activation of B cells, leading to the production of autoantibodies that target the host's own cellular components, including DNA, RNA, and proteins. For instance, Porphyromonas gingivalis, a pathogen associated with periodontitis, produces proteases such as peptidylarginine deiminase (PAD), which can citrullinate proteins [1]. These modified proteins may act as antigens in SLE patients, triggering the immune system to produce autoantibodies. Based on the results of previous studies, we found that SLE patients also have larger bacterial alignments and a higher relative abundance of oral pathogens than healthy people [2].

3. Peridontitis

According to the World Health Organization, severe periodontal diseases are estimated to affect approximately 19% of the global adult population, corresponding to over 1 billion cases worldwide [1].One of the factors contributing to the development of periodontitis is the imbalance of the oral microbiome. This imbalance reflects a relationship of checks and balances, akin to the biological "food chain." That is, if there is a sudden increase or decrease in one bacterial community, it may cause the reproduction rate of another bacterial community to accelerate. For example, Candida albicans forms protective biofilm structures that can shield pathogenic bacteria like Porphyromonas gingivalis, potentially promoting infections [4]. P. gingivalis relies on heme for survival, contributing to dysbiosis. Dysbiosis can result in increased microbial diversity, which may enable opportunistic pathogens to grow. This will provide ideal growth conditions for the pathogens for periodontitis.

The immune response to periodontal infection begins with acute inflammation (gingivitis) driven by the innate immune system. Cytokines like TNF-α, IL-1β, and IL-6 play a critical role in recruiting immune cells to the infection site [2]. If plaque persists, adaptive immunity is activated, leading to chronic inflammation, destruction of bone, and degradation of extracellular matrix by matrix metalloproteinases [3]. Moreover, Nitric oxide is identified as a marker for bacterial activity in periodontal disease, with higher salivary NO levels correlating with disease severity [5]. Therefore, if such indicators in the mouth are elevated during the examination, it may represent the occurrence of periodontal disease.

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4. Treatment

4.1. Scaling and Root Planing (SRP)

SRP is a nonsurgical procedure used to treat early stages of periodontal disease. This method involves thoroughly cleaning the teeth and roots below the gum line to remove plaque and tartar buildup. The process begins with scaling, where dental professionals use special tools to clean the surfaces of the teeth. After that, root planing smooths the root surfaces, allowing the gums to reattach more effectively.

Pros:

1. Non-surgical Treatment: SRP is a non-invasive procedure, often performed without anesthesia, which allows for a quicker recovery time [1].

2. Effective for Early Periodontal Disease: This method can significantly improve gum health and reduce inflammation in patients with early-stage periodontal disease [2].

3. Cost-Effective: Compared to surgical options, SRP is generally less expensive, making it accessible to a larger number of patients.

Cons:

1. Limited Effectiveness for Severe Cases: For patients with advanced periodontal disease, SRP may not be sufficient, and surgical intervention might be necessary [4].

2. Multiple Sessions Required: Depending on the severity of the disease, several appointments may be needed to achieve optimal results [5].

3. Patient Discomfort: Some patients may experience discomfort during the cleaning process, especially if they have significant gum inflammation.

4.2. Surgical treatments

Surgical treatments are often necessary for patients with advanced periodontal disease. These procedures include flap surgery and bone grafting, which aim to reduce the depth of periodontal pockets and improve overall gum health [1]. During flap surgery, the gums are lifted back to allow for thorough cleaning of the roots. After cleaning, the gums are sutured back in place, helping to reduce pocket depth and improve gum attachment.

Pros:

1. Effective for Severe Cases: Surgical options are particularly beneficial for patients whose periodontal disease has progressed significantly, especially when packets exceed 5mm in depth [2].

2. Improves Tooth Stability: These procedures help to reinforce the support structures around teeth, reducing the risk of tooth mobility.

3. Long-Term Benefits: When combined with regular maintenance care, surgical treatments often provide lasting improvements in periodontal health.

Cons:

1. Invasive Procedure: Surgical treatments involve anesthesia and may require a longer recovery period, during which patients may experience discomfort.

2.Higher Costs: These procedures are typically more expensive than non-surgical options, which can limit accessibility for some patients.

3. Post-Operative Care Requirements: Patients need to follow strict aftercare instructions to ensure proper healing and prevent complications [4].

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5. After treatment

(1) Monitoring of general health such as diabetes. In Ramseier's 2020 research, it was highlighted that controlling diabetes can significantly benefit periodontal health [2]. On one side, diabetes increases the risk and severity of periodontal disease. High blood sugar levels in people with uncontrolled diabetes lead to increased inflammation and reduced blood flow, which weakens the immune system. This makes it harder for the body to fight off infections, including those affecting the gums, leading to periodontal disease. As for the bidirectional relationship between diabetes and periodontal disease, When the gums become infected, the body releases inflammatory chemicals, such as cytokines, into the bloodstream. These chemicals can interfere with how the body uses insulin, leading to insulin resistance. So diabetes is more difficult to manage.

(2) Make a better lifestyle: Most of the people (98.8% of the group) claim that the cessation interventions of tobacco would be useful for patients [3]. According to Ramseier's research, after their effort in the experiment in university, the effectiveness of smoking intervention in improving periodontal health compared to non-surgical periodontal therapy (NSPT) and supportive periodontal care (SPC) remains unclear. Smoking is a major risk factor for periodontal disease because it reduces blood flow to the gums, weakens the immune system, and makes it harder for the body to heal. However, some studies suggest that smoking intervention alone might not have a direct impact on periodontal outcomes unless combined with other treatments like NSPT or SPC.

For example, a study by Preshaw et al. (2012) explains that while quitting smoking helps reduce inflammation and improves overall health, the benefits on gum health may take time or depend on additional periodontal treatments [1]. This shows that smoking cessation is essential but not always enough by itself, requiring more research to fully understand its role.

6. Conclusion

In conclusion, the intricate relationship between oral health and systemic diseases, particularly SLE and periodontitis, underscores the significance of the oral microbiome in maintaining overall well-being. The oral cavity's role as a potential trigger for autoimmune responses highlights the need for early diagnosis and intervention. Chronic inflammation and bacterial metabolites from the oral cavity can disrupt the immune system, leading to self-tissue attacks and exacerbating conditions like SLE. Moreover, pathogens such as Porphyromonas gingivalis contribute to dysbiosis, further complicating the immune response and potentially acting as antigens in SLE patients.

Treatment strategies for periodontal disease, ranging from non-surgical SRP to advanced surgical interventions, offer varied benefits and limitations. SRP is effective for early stages, being non-invasive and cost-effective, but may require multiple sessions and is less effective for severe cases. Surgical treatments, while more invasive and costly, are crucial for advanced periodontal disease, providing long-term benefits and improving tooth stability.

Post-treatment care, including monitoring systemic health conditions like diabetes, is essential. The bidirectional relationship between diabetes and periodontal disease emphasizes the importance of managing blood sugar levels to enhance periodontal health. Additionally, lifestyle modifications, particularly smoking cessation, are vital. Although the direct impact of smoking intervention on periodontal outcomes is unclear, it is a critical component in reducing inflammation and improving overall health.

Further research is warranted to fully understand the complexities of these interactions and to develop more effective, integrated approaches to treatment. By addressing oral health as a key

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component of systemic health, we can strive towards better outcomes for patients with SLE, periodontitis, and other related conditions.

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