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Integrating Dental and General Healthcare: A Depth Review Study of the Evidences Linking Oral Hygiene to Systemic Health and Future Challenges

Hanan Burayk Awwadh Alsuhaymi[1], Hatim Hamoud Hamed Aljohani[2], Mohammed Salem Bunyan Al-Bunyan[2], Maryam Lbrahim M Kudaysah[3], Abed Saleem Saeed Alsubhi[4], Raed Awwad Alhejaili[4], Yasir Waslallah Alrehaili[4], Abdulnasser Ayed Alrashedi[5], Taher Muidh Owaidh Almutairi[5], Abdulmajeed Muidh Almutairi[5], Thaar Jmail Almutiri[5], Ahmed Saeed Motie Alhusainy[6], Rawdhah Abdulmonem A Alsubhi[7], Ammar Rashed Almatrafi[8], Salem Abdullah Almohammadi[9*]

[1]Ad Diriyah Hospital Riyadh, Ar Rihab, Diriyah 13717, Kingdom of Saudi Arabia

[2]Madina Cardiac Center, Khalid Ibn Al Walid Rd, Al Jamiah, Madinah 42351, Kingdom of Saudi Arabia

[3]King Salman Specialist Hospital Madinah, Mahzur, Madinah 42319, Kingdom of Saudi Arabia

[4]King Fahd Hospital-Madinah, Khaled Bin Alwaleed Street, Al Jamiah-3177, Madinah- 42351, Kingdom Of Saudi Arabia

[5]Madinah Health Cluster, Saeed Bin Alaas Street, Madinah-42351, Kingdom of Saudi Arabia

[6]Prince Abdul Mohsen Hospital - Al Ula, Alula 43543, Kingdom Of Saudi Arabia

[7]Western Hurra Health Center, Abdullah Ibn Uday-2489, Madinah-42315, Madinah 42351, Kingdom Of Saudi Arabia

[8]King Saud Hospital Unizyah, As Salhiyah, Unayzah 56437, Alqassim, Kingdom of Saudi Arabia

[9]Al-Hanakiya General Hospital, Al-Hanakiyah-42652, Madinah-42335, Kingdom of Saudi Arabia

**Corresponding author*

E-mail: salmohamadi1.gov.moh.sa (Salem Abdullah AlMohammadi)

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Abstract

Oral health is undeniably integral to holistic well-being, extending far beyond the realm of dental pathology to encompass a spectrum of functions vital to daily life. This review delves into the multifaceted relationship between oral hygiene and systemic health, drawing from a breadth of scientific evidence to underscore its significance. Central to our exploration is the acknowledgment that oral health encompasses not only the absence of disease but also optimal cleanliness and functionality, crucial for unhindered participation in social interactions and daily activities. The nexus between oral health and systemic well-being is a focal point of discussion, elucidating the profound interconnections identified in numerous scientific inquiries. From the foundational understanding of oral hygiene's broader implications to the intricate biochemical pathways mediating its influence, the intricate web of interactions between oral and systemic health is meticulously examined. In dissecting the impact of oral health on specific systemic diseases, this review highlights the compelling evidence linking oral pathogens and inflammation to conditions such as cardiovascular disease, diabetes, and respiratory infections. Through

comprehensive case studies and analysis, the intricate mechanisms underlying these associations are elucidated, emphasizing the imperative for interdisciplinary collaboration in healthcare management. Preventative strategies emerge as pivotal in mitigating the burden of oral diseases and their systemic repercussions. From advocating for meticulous oral cleaning practices and dietary habits to promoting regular check-ups and professional cleanings, a proactive approach to oral health is underscored. Moreover, policy recommendations derived from the evidence presented advocate for greater accessibility to affordable dental services, the integration of oral health within primary healthcare, and regulatory initiatives to promote oral health education and awareness. However, barriers to the integration of dental and general healthcare persist, ranging from systemic and structural obstacles to financial constraints and educational disparities.

***Keywords*:** Dental healthcare, Oral hygiene, Systemic health, Respiratory infections Cardiovascular disease, Diabetes.

1. Introduction

Oral health stands as a pivotal element in holistic health and vitality. It extends beyond the mere absence of oral pathology to encompass the broader dimensions of oral hygiene and functional capacity. This encompasses various facets such as speech articulation, facial expression, sensory perception, mastication, and swallowing, all of which contribute to an individual's overall well-being. A comprehensive understanding of oral health thus entails not only the absence of disease but also the maintenance of optimal oral cleanliness and functionality, facilitating the ability to engage confidently in social interactions and daily activities without experiencing pain, discomfort, or functional limitations (1). Evidence from numerous scientific investigations highlights the profound interconnection between oral health and systemic well-being, emphasizing the broader implications of oral hygiene (2).

1.1 Significance of oral health in overall well-being

Oral health significantly influences one's overall well-being and quality of life throughout life stages. The oral cavity acts as the primary entrance to the human body, crucial for fundamental activities like eating, speaking, and emotive expression. Maintaining oral health ensures individuals can comfortably chew and ingest food, promoting adequate nutrition and overall bodily wellness. Moreover, clear speech enhances communication skills and social engagement, fostering psychological health and boosting self-assurance (3). Oral conditions like dental caries and periodontal diseases are often associated with considerable pain and discomfort, which can severely hinder one's ability to engage in daily tasks and diminish overall well-being. Persistent oral pain may disrupt eating, sleeping, and concentration, leading to decreased productivity and social isolation. Timely intervention to address oral health concerns is imperative to relieve pain and restore normal function and comfort levels (4).

The psychosocial ramifications of oral health are profound, encompassing notions of attractiveness, confidence, and social integration. Indeed, one's oral well-being significantly impacts self-esteem, interpersonal interactions, and the perception of physical appearance. Dental aesthetics wield considerable influence over the dynamics of relationships, career prospects, and the cultivation of a favorable self-concept. Conversely, the visibility of oral imperfections, such as tooth loss or periodontal issues, can precipitate feelings of shame, societal judgment, and social detachment (5). Growing scientific evidence indicates a close relationship between oral health and systemic well-being. Neglecting oral hygiene and leaving oral diseases untreated have been linked to a higher likelihood of experiencing a range of systemic issues such as heart disease, diabetes, respiratory infections, and complications during pregnancy. Keeping one's oral health in good condition could play a role in preventing or managing these systemic ailments, emphasizing the need for healthcare strategies that integrate oral health into broader health promotion efforts (6).

1.2 Overview of the connection between oral health and systemic diseases

The intricate interplay between oral health and systemic illnesses has become a focal point in biomedical inquiry, drawing considerable interest from researchers who seek to unravel the complex mechanisms that underlie this

correlation. This comprehension is essential for healthcare providers, enabling them to deliver holistic care and mitigate the potential onset of systemic diseases by implementing efficacious interventions for oral health (7).

Affluence of epidemiological research has consistently shown a strong link between periodontal disease and cardiovascular diseases (CVD). Pathogens and inflammatory substances from gum disease, including interleukin-6 (IL-6) and C-reactive protein (CRP), can enter the bloodstream due to inflamed gum tissues, leading to inflammation throughout the body and impaired function of the endothelium (8). For example, a comprehensive analysis revealed a notable elevation in CVD risk among those afflicted with periodontal disease, irrespective of common risk elements like smoking and diabetes. Moreover, studies examining mechanisms have pinpointed particular periodontal microbes, like Porphyromonas gingivalis, which harbor virulent traits capable of fostering artery disease by directly infiltrating endothelial cells and stimulating inflammatory molecules (9).

The intricate link between periodontal disease and diabetes mellitus emphasizes the critical role of oral health in managing blood sugar levels and overall health in individuals with diabetes. Those with diabetes have a higher vulnerability to gum infections because their immune system doesn't function as effectively and their body's response to infection is altered. On the flip side, gum inflammation can worsen insulin resistance and affect blood sugar management, resulting in poorer outcomes for diabetes and a greater chance of experiencing complications (10). Inadequate oral care and periodontal ailments also have been associated with the onset of respiratory infections, such as pneumonia and chronic obstructive pulmonary disease (COPD). Microorganisms present in the oral cavity can be inhaled into the lower respiratory system, potentially establishing colonies and fueling inflammation and infection in the lungs. The elderly and individuals with weakened immune systems are especially susceptible to these respiratory challenges due to their elevated rates of oral health issues and diminished defense mechanisms (11). Extensive and diverse evidence supports the connection between oral health and systemic diseases, drawing from epidemiological, mechanistic, and interventional research. Proactively addressing oral health concerns with preventive dental care and timely interventions presents a hopeful avenue for alleviating the impact of systemic diseases and enhancing overall health outcomes.

2. The Biological Basis of Oral-Systemic Health Links

Delving into the biological mechanisms that underpin the association between oral health and systemic diseases is essential for unraveling the complex interplay between the oral cavity and the broader physiological systems of the body. This exploration is pivotal in advancing our understanding of how oral health influences systemic well-being and vice versa (7).

2.1 Description of how oral pathogens and inflammation affect systemic health

The influence of oral pathogens and inflammation on systemic health encompasses intricate interactions among the oral microbiota, immune responses of the host, and distant organs. Periodontal disease, in particular, acts as a conduit for oral pathogens and inflammatory agents to enter the bloodstream, thereby exerting systemic repercussions and playing a role in the development of diverse systemic illnesses (12). Periodontal disease is a prevalent oral health issue worldwide marked by chronic inflammation and degradation of the tissues supporting teeth. Its primary cause lies in the imbalance of oral microbiota, resulting in the buildup of harmful bacteria like Porphyromonas gingivalis, Tannerella forsythia, and Treponema denticola within periodontal pockets. These pathogens incite an immune reaction characterized by the secretion of pro-inflammatory molecules such as cytokines, chemokines, and matrix metalloproteinases (MMPs) by local immune cells and gingival epithelial cells.

This inflammatory cascade perpetuates tissue damage and exacerbates the progression of the disease, illustrating the intricate interplay between microbial dysbiosis and host immune responses in the pathogenesis of periodontal disease (13). The spread of inflammatory agents and oral pathogens from the gums can profoundly impact organs and tissues throughout the body. Inflammatory molecules like IL-6 and tumor necrosis factor-alpha (TNF-α) can travel through the bloodstream, causing dysfunction in the cells lining blood vessels and contributing to the development of conditions like atherosclerosis and cardiovascular diseases. This chronic inflammation stemming from periodontal disease is also linked to the onset of other persistent inflammatory disorders, such as rheumatoid arthritis and inflammatory bowel disease (14). Additionally, periodontal disease correlates with insulin resistance

and suboptimal glycemic regulation in individuals with diabetes mellitus. The release of inflammatory cytokines from inflamed periodontal tissues exacerbates insulin resistance and compromises glycemic control, heightening the risk of diabetic complications. Longitudinal investigations have elucidated a bidirectional relationship between periodontal disease and diabetes, emphasizing the imperative of addressing oral health concerns in diabetes management strategies (15). Beyond cardiovascular diseases and diabetes, substandard oral health has implications for respiratory infections such as pneumonia and COPD.

Oral pathogens can infiltrate the lower respiratory tract through aspiration, potentially colonizing and contributing to pulmonary inflammation and infection. Elderly individuals and immunocompromised individuals are particularly susceptible to these respiratory complications due to the higher prevalence of oral diseases among these populations (16). Chronic inflammation in the oral cavity has been linked to the onset and advancement of specific cancer types. Epidemiological research has established connections between periodontal disease and several cancers, such as those affecting the mouth, esophagus, pancreas, and colon. Although the precise mechanisms driving these connections are not yet fully understood, it is hypothesized that persistent inflammation and immune system imbalances within the oral environment contribute to cancer development.

This contribution is thought to occur through processes involving the generation of reactive oxygen species (ROS), DNA damage, and the activation of pathways known to promote carcinogenesis. These findings underscore the intricate relationship between oral health and systemic well-being, emphasizing the importance of comprehensive healthcare approaches that consider oral health as an integral component of overall health management (17). The correlation between oral health status and systemic health outcomes extends to vulnerable demographics, such as pregnant women and older adults. Research indicates that inadequate oral health during pregnancy correlates with unfavorable pregnancy consequences, such as premature delivery, low birth weight, and preeclampsia, emphasizing the significance of oral health initiatives in maternal and child welfare (18).

In essence, the imbalance within the oral microbiome and the persistent inflammation linked to periodontal disease hold profound significance for systemic health, playing a role in the development of diverse systemic inflammatory conditions, autoimmune ailments, and specific cancer types. Delving into the nuanced interactions between oral health and systemic illnesses is pivotal for crafting tailored preventative and treatment approaches aimed at enhancing overall health results and alleviating the global burden of chronic ailments.

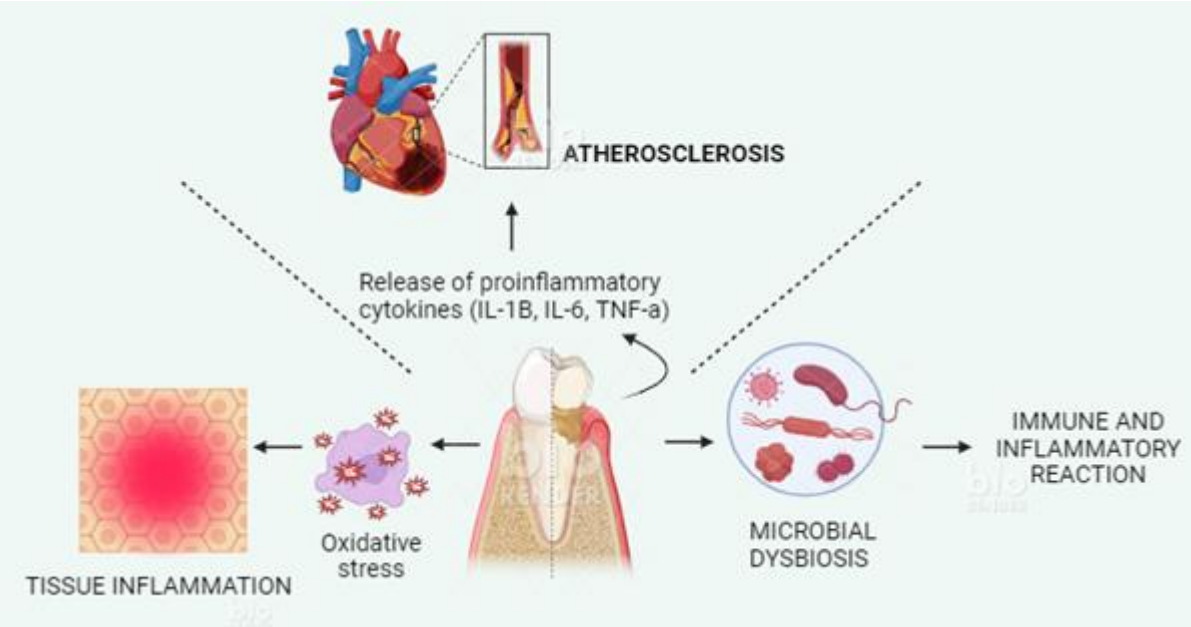


Figure 1: Biochemical pathways that illustrate how proinflammatory cytokines, oxidative stress and microbial dysbiosis in oral health influence systemic heath.

2.2 Review of biochemical pathways involved in the interaction between oral and systemic health

Delving into the complex biochemical pathways that govern the interaction between oral health and systemic well-being is essential for unraveling the mechanisms that underpin their interconnectedness. Inflammatory mediators play a pivotal role in establishing the connection between oral health and systemic well-being. Chronic inflammation associated with periodontal disease involves the release of pro-inflammatory cytokines like interleukin-1β (IL-1β), IL-6, and TNF-α, which extend their effects beyond the oral cavity. These mediators traverse the bloodstream, inciting systemic inflammation and contributing to the onset and progression of various systemic conditions, including cardiovascular disease, diabetes, and respiratory infections (14), For example, IL-6, a central player in acute-phase inflammation, has been implicated in atherosclerosis development by fostering endothelial dysfunction, vascular inflammation, and thrombosis. Elevated IL-6 levels in individuals with periodontal issues correlate with heightened cardiovascular event risks, emphasizing the pivotal role of systemic inflammation in intertwining periodontal and cardiovascular health (19).

Oxidative stress, arising from an imbalance between the production of ROS and the body's antioxidant defenses, emerges as a pivotal pathway intertwining oral and systemic health. Within the oral cavity, periodontal pathogens and their byproducts trigger oxidative stress, inciting tissue damage and inflammation. Furthermore, the systemic dissemination of these oral pathogens and inflammatory agents can intensify oxidative stress in distant organs and tissues, thereby contributing to the progression of systemic diseases (20). Reactive oxygen species, such as superoxide anion ($O2^-$) and hydrogen peroxide ($H2O2$), exert direct harm on cellular components, including lipids, proteins, and DNA, culminating in cellular dysfunction and programmed cell death. Additionally, the oxidative modification of lipoproteins by ROS can fuel the development of atherosclerosis by amplifying lipid peroxidation, endothelial dysfunction, and the formation of foam cells. Hence, oxidative stress serves as a mechanistic bridge linking periodontal disease to cardiovascular disease, accentuating the systemic repercussions of oral health on overall well-being (21)

Microbial dysbiosis, characterized by imbalances within the oral microbiome, can disrupt the harmonious equilibrium between beneficial and harmful microorganisms, thereby fostering the onset of both oral and systemic diseases. Pathogens associated with periodontal ailments, such as Porphyromonas gingivalis and Tannerella forsythia, possess the capacity to generate virulence factors, facilitating dysbiosis and evading host immune responses, thus perpetuating persistent infection and inflammation (22). The dissemination of periodontal pathogens and their virulence factors throughout the body can provoke immune reactions in distant anatomical sites, intensifying systemic inflammation and tissue impairment. Additionally, oral bacteria may engage in direct interactions with host cells and tissues in systemic organs, thereby contributing to the pathogenesis of diverse systemic maladies.

Hence, microbial dysbiosis emerges as a pivotal mechanism by which oral health intricately influences systemic health outcomes, emphasizing the imperative of maintaining a well-balanced oral microbiome for overall wellness (23). Furthermore, immune dysregulation and endothelial dysfunction serve as supplementary pathways through which oral health exerts influence on systemic health outcomes. Understanding the underlying mechanisms driving these interactions allows researchers to pinpoint new therapeutic targets and devise targeted interventions to alleviate the repercussions of oral diseases on systemic health (24). Also, healthcare practitioners can incorporate this understanding into clinical practice to enhance patient care and advocate for holistic approaches to both disease prevention and management.

3. Impact of Oral Health on Specific Systemic Diseases

3.1 Cardiovascular Disease

In 1989, Mattila et al. pioneered a study that showed a significant association between dental health and infections and coronary atherosclerosis (25). These findings garnered substantial attention in medical research and further investigations and experimental diseases have elucidated the profound impact of oral health on the cardiovascular system. Oral health plays a pivotal role in cardiovascular health through the intricate interplay between oral microbial communities and the host immune response. The dense biofilm formations on tooth surfaces, consisting of diverse bacterial populations, create complex ecosystems sustained by a balance between commensal and pathogenic bacteria. These biofilms, shielded from host antibacterial defenses, can harbor potential pathogens,

leading to chronic infections such as periodontitis. Emerging evidence suggests that oral infections, particularly periodontitis, may contribute to systemic diseases, including CVD. Animal studies have demonstrated that oral bacteria like Streptococcus sanguis can induce platelet aggregation, a crucial process in arterial plaque formation, potentially predisposing individuals to thrombotic events.

Oral bacteria, particularly Gram-negative species found in periodontal disease, can pose a risk of atherosclerosis through several mechanisms. These bacteria can enter the bloodstream through inflamed gum tissues, initiating systemic inflammation. Once in circulation, they may adhere to and infiltrate vascular endothelial cells, promoting endothelial dysfunction and increasing permeability. This facilitates the entry of lipids and immune cells into the arterial wall, triggering the formation of atherosclerotic plaques. Moreover, oral bacteria can induce the production of pro-inflammatory cytokines and activate platelets, further exacerbating vascular inflammation and thrombosis, ultimately contributing to the progression of atherosclerosis. Beck et al. posited a hypothesis that chronic periodontal infections, particularly Gram-negative bacteria, may increase the risk of atherosclerosis and thromboembolic events (26). A cohort study involving 1,147 men found that greater bone loss, indicative of severe periodontal disease, correlated with higher incidences of total CHD, fatal CHD, and stroke, even after adjusting for established cardiovascular risk factors. These findings underscore the potential significance of periodontal health in cardiovascular disease prevention and management.

Epidemiological studies have provided further support for the association between oral infections and CVDs, including heart infarction, stroke, and peripheral vascular disease. However, due to the multifactorial nature of both periodontal disease and CVDs, establishing a clear-cut consensus on their relationship remains challenging. Nonetheless, ongoing research aims to elucidate the mechanisms underlying this association, considering factors such as temporal relationship, dose-response, strength of association, consistency, and biological plausibility.

Several biomarkers have been associated with the impact of oral health on cardiovascular diseases and CVDs. Studies have linked severe gingivitis to elevated leukocyte counts and serum fibrinogen levels. Moreover, increased levels of CRP and fibrinogen, established markers for CHD, have been observed in individuals with periodontitis. Other biomarkers such as von Willebrand factor antigen, total white blood cell count (WBC), and CRP levels have also shown associations with periodontal disease. Additionally, tooth loss has been identified as a potential predictor of abnormal electrocardiogram (ECG) findings in older individuals. Hypercholesterolemia has also been linked to severe periodontitis, although causality remains uncertain due to the cross-sectional nature of the study. Holmlund, Lampa, and Lind conducted a study to investigate the association between oral health indicators and CVD: myocardial infarction (MI), stroke, and heart failure (HF) (27). A total of 8999 individuals were examined for oral health parameters such as number of teeth (NT), bleeding on probing (BOP), and number of deepened pockets (NDP) over 33 years. Incident cases of CVD were tracked through registries. Results showed that over a median follow-up of 15.8 years, there were 1338 cases of CVD, including MI, stroke, and HF. After adjusting for various factors, NT and NDP were significantly associated with future CVD, while BOP showed no significant relationship. Specifically, NT was linked to MI and HF incidence, but not stroke. BOP and NDP did not exhibit significant associations with any of the three CVD outcomes. This suggests that the relationship between oral health and different types of cardiovascular disorders may vary.

3.2 Diabetes

The complex relationship between dental health and systemic disorders, such as diabetes, has received increased attention in recent years (28). Diabetes mellitus, defined by persistent hyperglycemia, affects millions of people worldwide and carries serious health concerns such as cardiovascular disease, kidney disease, and neuropathy (29). Emerging data supports a bidirectional association between diabetes and dental health, with one influencing the other's development and progression. Chronic periodontal inflammation, characterized by the dysregulation of pro-inflammatory cytokines and chemokines, serves as a common link between oral health and diabetes. Periodontal pathogens stimulate the production of inflammatory mediators, such as tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6), contributing to systemic inflammation and insulin resistance in diabetes (30).

Conversely, hyperglycemia in diabetes exacerbates periodontal inflammation by impairing immune function and altering the oral microbiome composition, creating a vicious cycle of inflammation and metabolic dysfunction

(31). Periodontal disease has also been associated with insulin resistance, a hallmark of type 2 diabetes mellitus (T2DM). Pro-inflammatory cytokines produced in response to periodontal infection interfere with insulin signaling pathways, leading to impaired glucose uptake and utilization in peripheral tissues (10). Moreover, the chronic low-grade inflammation associated with periodontitis contributes to systemic insulin resistance and dysglycemia, predisposing individuals to T2DM development and progression.

The correlation between oral health and diabetes mellitus extends beyond shared pathophysiological mechanisms to encompass clinical manifestations, treatment outcomes, and overall disease management. Individuals with diabetes are at a higher risk of developing periodontal disease and experiencing more severe periodontal complications compared to non-diabetic individuals (32). Conversely, poorly controlled diabetes exacerbates periodontal inflammation and compromises periodontal treatment outcomes, highlighting the bidirectional nature of this relationship. Taylor performed a meta-analysis that examines the bidirectional relationship between diabetes and periodontal diseases (33). Through a comprehensive search of the literature, the review gathers evidence from primary research reports investigating the association between diabetes mellitus (DM) and periodontal diseases (PD).

Observational studies consistently demonstrate a higher prevalence, severity, extent, or progression of periodontal diseases in individuals with diabetes compared to those without diabetes (34). Treatment studies provide direct evidence that periodontal infection adversely affects glycemic control, although not all investigations show improvements in glycemic control following periodontal treatment (35). Follow-up observational studies indicate that severe periodontitis may increase the risk of poorer glycemic control over time. Overall, the evidence supports a bidirectional relationship between diabetes and periodontal diseases. Further rigorous research is needed to establish the role of treating periodontal infections in managing glycemic control and reducing complications of diabetes mellitus (36).

Moreover, emerging evidence suggests that improving oral health may positively impact glycemic control and reduce the risk of diabetes-related complications. Periodontal therapy, including scaling and root planing, adjunctive antimicrobial therapy, and surgical interventions, has been shown to improve glycemic control and reduce systemic inflammation in individuals with diabetes (37) (35). Conversely, optimizing glycemic control through lifestyle modifications, pharmacotherapy, and insulin therapy can mitigate the progression of periodontal disease and improve oral health outcomes. Wu et al. systematically reviewed the epidemiological association between periodontitis and type 2 diabetes mellitus (T2DM) (38). Through searches in electronic databases and manual searches of relevant literature, 53 observational studies were included. The findings revealed a significant bidirectional relationship: T2DM prevalence was notably higher among periodontitis patients, and vice versa. T2DM patients exhibited poorer periodontal health compared to those without T2DM, with deeper periodontal pockets, higher attachment loss, and more lost teeth. Cohort studies indicated that T2DM increased the risk of developing periodontitis, while severe periodontitis elevated the incidence of T2DM. The impact of glycemic control on periodontitis outcomes was also noted. The study underscores the importance of awareness among dentists and physicians regarding the strong connection between periodontitis and T2DM, suggesting that controlling both diseases may help prevent each other's incidence (39).

3.3 Respiratory Infections

Gingivitis and periodontitis, inflammatory conditions affecting the gums and supporting structures of the teeth, have been linked to an increased risk of respiratory infections and exacerbations of existing lung diseases (40). The oral cavity serves as a reservoir for a diverse array of bacteria, some of which can be aspirated into the lower respiratory tract, leading to pulmonary infections. In individuals with gingivitis and periodontitis, the oral microbiota composition is altered, with an overgrowth of pathogenic bacteria and a reduction in beneficial commensal bacteria. These dysbiotic changes contribute to chronic inflammation and immune dysregulation, predisposing individuals to respiratory infections and exacerbations. Moreover, the systemic inflammatory response triggered by gingivitis and periodontitis can exacerbate pre-existing lung conditions, such as asthma, chronic obstructive pulmonary disease (COPD), and bronchiectasis (41). Pro-inflammatory cytokines and

chemokines produced in response to periodontal infection can induce airway inflammation and hyperreactivity, exacerbating respiratory symptoms and reducing lung function (42).

Additionally, periodontal pathogens and their byproducts may directly or indirectly enter the bloodstream, further contributing to systemic inflammation and respiratory complications (43). Aspiration, the inhalation of oral or gastric contents into the lower respiratory tract, is another oral health-related factor implicated in lung diseases. Microaspiration of oral bacteria, saliva, and food particles can occur during routine activities such as swallowing, speaking, or dental procedures (44). In healthy individuals, the respiratory tract has mechanisms to clear aspirated material and prevent infection. However, in individuals with compromised immune function or impaired cough reflex, such as those with neurologic disorders or swallowing difficulties, aspiration can lead to respiratory infections, pneumonia, and aspiration pneumonitis (45). The oral-lung axis exemplifies the direct impact of oral health on lung diseases, particularly through the aspiration of bacteria into the lungs, leading to various pulmonary conditions (46). Traditional teachings highlight the role of anaerobic oral bacteria, such as Bacteroides and Fusobacterium, in causing pneumonia, pulmonary abscess, or empyema through aspiration of oral secretions (47). However, recent studies have revealed a predominance of aerobic organisms, including Haemophilus influenzae and Streptococcus pneumoniae, in aspiration pneumonia pathogens (48). The pathogenesis of infection post-aspiration likely involves multiple factors, including the volume and frequency of aspirated material, the efficacy of lung clearance mechanisms, comorbidities, immune status, bacterial virulence, and lung microbiome dysbiosis (49).

Chronic aspiration, often associated with dysphagia or gastroesophageal reflux disease (GERD), poses a particular risk for lung diseases. Aspirated material, including oral bacteria and gastric contents, can colonize the lower respiratory tract, leading to chronic inflammation, recurrent infections, and lung damage (50). Moreover, microaspiration of gastric acid can cause chemical injury to the airway epithelium, exacerbating inflammation and predisposing individuals to aspiration pneumonia and lung injury (51). Chronic microaspiration's contribution to lung disease remains unclear, but studies have associated the enrichment of oral flora like Veillonella and Prevotella in bronchoalveolar lavage fluid with increased pulmonary inflammation (52). Furthermore, certain periodontal pathogens, including Fusobacterium and Porphyromonas, have been uniquely associated with conditions like atopic asthma and protracted bacterial bronchitis in children. Additionally, the increased bacterial burden in the airways, including Streptococcus viridans and Hemophilus spp., correlates with a decline in lung function over time in individuals with stable COPD (53).

Aside from bacterial aspiration, inflammatory proteins present in saliva, such as TNF-α and matrix metalloproteinases (MMP-9), have been linked to chronic lung diseases like COPD and asthma. The persistent aspiration of these molecules from an inflamed oral cavity may exacerbate respiratory symptoms or contribute to lung parenchymal destruction (54) (55). Furthermore, patients with periodontitis exhibit elevated systemic inflammatory markers like C-reactive protein, which decrease following periodontal treatment. This systemic inflammation in periodontitis has implications beyond oral health, potentially contributing to systemic diseases like cardiovascular disease and rheumatoid arthritis (56). Similarly, systemic inflammation is evident in lung diseases like asthma and COPD, suggesting a potential interplay between oral and lung inflammation. The impact of oral health on lung diseases has significant implications for respiratory health and overall well-being (57). Individuals with gingivitis, periodontitis, or a history of aspiration may be at increased risk of respiratory infections, exacerbations of lung diseases, and complications following pulmonary procedures. Therefore, comprehensive oral care, including regular dental visits, oral hygiene maintenance, and management of risk factors for aspiration, is essential for preserving respiratory health (11) (40).

Table 1: A summary of clinical trials that assess the association between oral health and systemic diseases, including cardiovascular diseases, diabetes mellitus, and lung diseases.

NCT Number	Study Title	Study URL	Study	Brief Summary	Conditions	Interventions	Primary Outcome	Study Type			

			Status				**Measures**				
NCT03042117	Connecting Periodontal and Coronary Artery Disease Via the Inflammatory State of the Body	https://clinicaltrials.gov/study/NCT03042117	WITHDRAWN	Cardiovascular disease is one of the leading causes of death in the United States and the world. Many interventions relating to prevention have been emphasized as more risk factors for this devastating disease are discovered. Periodontal disease is known to have a close	Periodontal Diseases|Cardiovascular Diseases	OTHER: periodontal probing	Level of periodontal disease, one day	OBSERVATIONAL			

				association with cardiovascular disease, but its role as a risk factor is still not well understood. Inflammation is a driving force in both of these diseases, creating a potential bridge between the two. Specifically, periodontal disease can cause an inflammatory reaction in the body,							

				which may predispose or even directly contribute to atheroma formation in the coronary arteries. In this study, the investigators will study the link between the inflammatory state of the body and will search for a correlation between levels of coronary artery disease and							

				period ontal diseas e.							
NCT 0009 3236	Impa ct of Gum Infec tion on Heart Dise ase	https://clinicaltri als.gov/study/N CT00093236	COM PLE TED	The purpos e of this study is to determ ine the effect of gum infecti on on param eters of cardio vascul ar diseas e.	Cardiovasc ular Disease|Per iodontal Disease	Procedure : Early Periodont al Treatment |PROCE DURE: Usual Dental Hygiene	Periodo ntal disease progress ion, Three weeks after initiatio n of the study, they will return and be re-evaluate d for the need for periodon tal surgery. If indicate d, they will then receive definitiv e periodon tal surgery over the next 4 weeks. At the 12-week time point, periodon tal surgery will be reevalua ted	INTER VENTI ONAL			

NCT01358630	Vascular and Periodontal Disease - Microbial, Genetic and Histological Causalities	https://clinicaltrials.gov/study/NCT01358630	UNKNOWN	The purpose of this study is to analyze genetic polymorphisms in genes encoding pro-inflammatory cytokines and study the genetic predisposition to chronic periodontitis (CP) in combination with atherosclerotic cardiovascular (ACD) and aneurysmal diseas	Periodontitis|Vascular Disease		further therapy provided as needed, and make repeated visits as needed to achieve periodontal health.	OBSERVATIONAL			

				es. The investigators will also try to identify oral bacteria in atherosclerotic plaques aneurysmal walls and thrombus. Histological analyses of atherosclerotic plaques and aneurysmal wall will be performed.							
NCT01376791	Assess the Effect of Treating Periodontal Disease on Cardiovas	https://clinicaltrials.gov/study/NCT01376791	COMPLETED	We propose to examine a population of Native Americans who have had little	Periodontal Disease|Atherosclerosis		Determination of bacterial populations in periodontal samples before and after standard periodontal treatmen	OBSERVATIONAL			

	cular Function in Young Adults			or no dental care, and to determine if periodontal disease is associated with early signs of vascular dysfunction or systemic inflammation. We then propose to treat the periodontitis and re-evaluate vascular function. We will determine if gingivitis or mild/moderate periodontitis			t, stratified by severity of gum disease, using microbial metagenomics analysis., The study will assess if periodontal bacterial flora differ in patients with healthy gums, mild, or severe periodontal disease.				

				is associated with detectable vascular dysfunction. Microbial metagenomics will be correlated with vascular function.							
NCT02177591	Observational Study of the Association Between Periodontal Disease and Cardiovascular Disease	https://clinicaltrials.gov/study/NCT02177591	COMPLETED	The prevalence of cardiovascular disease is rising; new methods must be created to assess the cardiovascular status of patients. If cardio	Periodontal Disease|Coronary Artery Disease		Comparing level of coronary artery disease with amount of bacteria in the mouth, Will compare patients in each group with the numerical value of P. gingivalis and A. actinomycetemcomitans in the	OBSERVATIONAL			

				vascular disease can be predicted, it may facilitate prevention. An association between periodontal disease and cardiovascular has been established, but a definitive mechanism is not understood. A good first step in finding that mechanism is to look at the correlation between period			mouth., Baseline |Compare level of hs-CRP with level of bacteria, Will compare levels of hs-CRP (mg/dL) in the blood with the numerical value of P. gingivalis and A. actinomycetemcomitans				

				ontal disease and cardiovascular disease, both of which have an inflammatory component. This study observes the level of cardiovascular disease in patients and correlates it with the presence and degree of periodontal pathogens.							
NCT02289066	Impact of Periodontal Disease on	https://clinicaltrials.gov/study/NCT02289066	COMPLETED	This study examines how periodontal diseas	Periodontal Disease|Diabetes Mellitus		Changes in hemoglobin A1c, At enrollment, 3 months	OBSERVATIONAL			

	Outcomes in Diabetes			e affects the complications of diabetes and how treatment for periodontal disease affects biomarkers associated with the complications of diabetes.			after enrollment and 6 months after enrollment.|biomarkers of inflammation (high sensitivity C-reactive protein and tumor necrosis factor-alpha), At enrollment, 3 months after enrollment and 6 months after enrollment.|markers of bone turnover (bone specific alkaline phosphatase				
NCT06125561	Periodontal Health and Its Impact on Oral Health-	https://clinicaltrials.gov/study/NCT06125561	RECRUITING	Periodontal diseases, encompassing a range of inflammator	Diabetes Mellitus|Periodontal Diseases	OTHER: Probing depth and Clinical attachment loss	oral health-related quality of life, the impact of periodontal health	OBSERVATIONAL			

	related Quality of Life Among Diabetes Mellitus Patients			y conditions affecting the supporting structures of the teeth, have long been recognized as a prevalent comorbidity in individuals with diabetes. The severity of periodontal disease is usually documented by research clinicians using clinical parameters such as bleedi			on the oral health-related quality of life, 1 day				

				ng on probing (BOP), probing pocket depth (PPD), and clinical.							
NCT05862311	The Effect of Non-Surgical Periodontal Treatment on Bone Metabolism in Type 2 Diabetes and Systemically Healthy Individuals	https://clinicaltrials.gov/study/NCT05862311	COMPLETED	In this study, it was concluded that sclerostin and irisin may be alternative markers for evaluating the effectiveness of periodontal treatment and healing of periodontal tissues by affecting bone	Periodontal Diseases	DIAGNOSTIC_TEST: ELISA	Evaluation of bone metabolism biomarkers in different periodontal conditions, The levels of bone metabolism markers (such as sclerostin, irisin, IL-6, TNF-a, RANKL/OPG) in the gingival crevicular fluid of individuals with different periodontal conditions were compare	INTERVENTIONAL			

				metabolism.			d using the ELISA (Enzyme Linked Ä°mmÃ¼nosorbent Assay) test.				
NCT01798225	Relationship of Periodontal Disease Treatment and Type 2 Diabetes Mellitus in the Gullah Population	https://clinicaltrials.gov/study/NCT01798225	COMPLETED	Our overall hypothesis is that treatment of periodontal disease will produce better diabetes glycemic control (glycated hemoglobin A1c, or HbA1c) and reduced levels of the catalytically active form of matrix metalloprote	Periodontal Disease|Type 2 Diabetes Mellitus	DRUG: Placebo|DRUG: Doxycycline	Glycated Hemoglobin A1c, Glycated Hemoglobin A1c, Change between baseline to 6-month post-treatment|Periodontal Pocket Probing Depth (PD), Change between baseline to 6-month post-treatment	INTERVENTIONAL			

				inase (aMMP-8) in the Gullah African American type 2 diabetes patients living on the Sea Islands of the South Carolina coast. The gingival crevicular fluid (GCF) aMMP-8 levels will be measured through a site-specific, novel noninvasive technique allowing the pathophysiol							

				ogical status of the periodontium tissue to be monitored.							
NCT05260814	Comparison of Two Oral Hygiene Routines on the Glycemic Control for Type 2 Diabetes Patients With Chronic Periodontitis	https://clinicaltrials.gov/study/NCT05260814	UNKNOWN	"This study aims to compare two common oral hygiene routines on the improvement of glycemic control and oral health parameters in moderate to severe periodontitis patients with uncontrolled type 2 diabetes (T2DM).							

NCT06133335	Cystic Fibrosis and Periodontal Diseases	https://clinicaltrials.gov/study/NCT06133335	RECRUITING	The number of CF adults is increasing year after year (61.7% in 2021) confirming that patients are living longer. These data do not leave aside the desire to see CF patients "age well" considering of all the comorbidities linked to aging.	Cystic Fibrosis|Periodontitis|Gingivitis	OTHER: Periodontal examination	Prevalence of periodontal disease, Periodontal Disease will be diagnosed according to the new classification of periodontal diseases (Chicago, 2017) and defined by the decision-making algorithms (Tonetti and Sanz, 2019). Diagnosis will be based on Buccal or lingual Clinical attachment level (CAL), Recession (REC).	INTERVENTIONAL			
NCT05212766	Role of the Oral Microbiome &	https://clinicaltrials.gov/study/NCT05212766	RECRUITING	Determining whether in the	COVID-19|Microbial Colonization|Oral Disease|Per	Biological: covid infection|biological: covid vaccinatio	Relationship between oral mucosal immunit	OBSERVATIONAL			

	Mucosal Immunity in COVID-19 Disease			mouth there are differences between the participant groups in the nature and activity of mucosal innate immunity, in immune responses to SARS-COV2 antigens, or in the oral microbiome	iodontal Diseases|Innate Inflammatory Response|Mucosal Infection	n|diagnostic_test: oral examination	y and microbiome on COVID outcomes in different ethnic groups, Multiple assessments, 16 weeks				
NCT05576142	Oral Findings in Pediatric Patients With Allergic Rhinitis and/or	https://clinicaltrials.gov/study/NCT05576142	COMPLETED	The aim of the study was to evaluate if there were differences in oral findings between patient	Allergic Rhinitis|Asthma in Children|Dental Caries|Periodontal Diseases	Diagnostic_Test: Oral examination	PSR - Periodontal Screening and Recording (Landry and Jean, 2002), Scoring criteria: 0: Absence	OBSERVATIONAL			

	Asthma			s diagnosed with allergic rhinitis and/or asthma a and a control group of health people.			of clinical signs 1: Bleeding on probing 2: Supra and/or subgingival calculus and/or defective margins 3: Periodontal pocket 4 mm to 5.5 nm deep (coloured band on probe partially visible) 4: Periodontal pocket 6 mm deep (colored band no longer visible).				
NCT05924711	"Association of Peri-implantitis and Maxillary Sinus	https://clinicaltrials.gov/study/NCT05924711	RECRUITING	Scientific evidence regarding the influence of peri-implan	Peri-Implantitis|Sinusitis|Sinusitis, Acute|Sinusitis, Chronic|Implant Infection|Dental	Other: Retrospective analysis of demographic and radiographic data previousl	Sinus membrane thickening changes after peri-implantitis	OBSERVATIONAL			

	itis: a Case-control Study".			titis on Schneider's membrane thickening is scarce and limited. Similarly, to date, there is no literature documenting the resolution of implant-associated maxillary sinusitis with peri-implantitis after treatment of peri-implantitis or removal of the implant. Therefore, the aim of this	Implant Failure Nos	y obtained from the patient.	treatment, Sagital and coronal linear measurements of membrane thickening, 6 months				

				case-control study is to investigate the association between peri-implantitis and maxillary sinusitis. On the other hand, the changes that occur at the level of the maxillary sinus membrane after treatment of peri-implantitis or after implant explantation will be evaluated.							

NCT04668911	Oral Health, Microbial Burden and COVID-19	https://clinicaltrials.gov/study/NCT04668911	UNKNOWN	An observational study of patients with COVID-19 confirmed cases (with various degrees of severity) and controls. Oral and nasal swabs will be taken from 150 patients (50 with mild form and 50 with severe form of COVID-19 with or without mechanical ventilation,	Covid19|Periodontitis	Other: Swab	Oral microbial signature, To assess the oral microbial signatures that relates to SARS-CoV2 in patients with no, mild and severe disease., Day 1	OBSERVATIONAL			

				50 healthy controls).							
NCT05205694	Oral Health in Covid-19 Survivors	https://clinicaltrials.gov/study/NCT05205694	UNKNOWN	Aims are to assess periodontal health and salivary stress/immunity responses in COVID-19 survivors	Covid-19|Periodontitis	Covid-19|Periodontitis	Periodontal disease stage and COVID 19, Correlation periodontitis and COVID 19 infection, one to six months after COVID-19	OBSERVATIONAL			

4. Preventative Strategies and Health Policy Implications

Maintaining good oral hygiene is not only crucial for dental health but also significantly impacts overall health. The adoption of preventive strategies to uphold oral cleanliness can substantially diminish the prevalence of dental diseases, such as cavities and periodontal diseases, which are linked to more severe health issues, including cardiovascular diseases and diabetes (2). From a health policy perspective, emphasizing the importance of oral health and integrating comprehensive dental care into general health policies are vital. By doing so, governments and health organizations can reduce the long-term healthcare costs associated with oral diseases (58). Policies could include improved access to fluoride, advocating for regular dental check-ups, and educational programs that teach effective dental care from an early age. These preventive measures not only improve the quality of life but also lessen the burden on healthcare systems by reducing the number of individuals requiring treatment for preventable dental conditions (59). Furthermore, such strategies support the reduction of health disparities by ensuring all population segments have equal access to dental care and education about oral health **Figure** 2.

Oral Cleaning Practices: Brushing and Flossing Techniques

Maintaining oral health effectively involves consistent brushing and flossing. It is advisable to brush teeth twice daily using fluoride toothpaste, which plays a crucial role in eliminating dental plaque that can lead to tooth decay and gum disease (60). Fluoride toothpaste has achieved notable success in the U.S. market, with each person purchasing an average of three tubes annually. Research spanning 70 clinical trials has shown that fluoride toothpaste prevents 24% more dental caries than its non-fluoride counterparts, a statistic that holds even in areas with fluoridated water supplies. A detailed meta-analysis focusing on fluoride concentrations indicates a dosage-dependent increase in effectiveness, peaking at a 37% reduction in caries for the highest fluoride levels tested, ranging from 2400 to 2800 ppm. Furthermore, for individuals using regular-strength fluoride toothpaste available

over-the-counter (1000–1500 ppm), 12% exhibit no new caries formations in either primary or permanent teeth when compared with those who use non-fluoride products. The method of brushing is equally important as the frequency. Employing a soft-bristled toothbrush, one should position it at a 45-degree angle to the gums, engaging in gentle, circular brushing motions. This technique enhances the removal of plaque without causing harm to the gum tissue (61). Dental professionals may also suggest fluoride mouth rinses for individuals at elevated risk of cavities. This rinse provides an additional layer of protection against tooth decay, particularly for those susceptible to dental caries. By incorporating fluoride into their oral hygiene routine through rinsing, individuals can further fortify their teeth against potential decay, helping to maintain optimal dental health (62).

In addition to brushing, incorporating daily flossing into your dental care routine is essential. Flossing is designed to access and clean the tight spaces between the teeth and below the gumline—areas typically unreachable by a toothbrush. Regular flossing is critical for dislodging food remnants and plaque, thereby helping to avert oral diseases such as gingivitis and periodontitis (63). These practices, when combined, offer a comprehensive approach to dental hygiene, ensuring the removal of plaque and reduction of potential oral health issues.

Promoting Dental Health Through Dietary Practices:

Effective management of sugar consumption remains pivotal in combating tooth decay, as sugary treats and beverages are the primary culprits behind oral health issues. The fermentation of sugar by oral bacteria leads to the production of acids, which in turn corrode tooth enamel, initiating decay (64). A study conducted by researchers investigated the longitudinal impact of dietary and oral hygiene habits on dental decay in very young children. They analyzed survey data spanning from ages 2 to 5 and employed logistic regression models to predict decay by age 5. Findings revealed that children who snacked throughout the day without regular meals faced a significantly higher risk of dental decay compared to those who primarily consumed meals. Additionally, a decrease in toothbrushing frequency from age 2 was associated with increased chances of decay by age 5. However, children who brushed their teeth more frequently, especially when consuming sweets or chocolate daily, exhibited reduced odds of decay. Furthermore, the study highlighted the influence of maternal occupation on dental health outcomes, indicating that children of mothers who had never worked were more susceptible to decay compared to those with mothers in managerial or professional roles (64).

Incorporating a diverse range of nutrient-rich foods into one's diet is equally essential for sustaining optimal dental health. Apart from being mindful of sugar intake, prioritizing foods high in fiber, such as an assortment of fruits and vegetables, contributes to saliva stimulation and facilitates the remineralization of tooth enamel. Eating a diet abundant in fresh vegetables, fruits, and whole grains while minimizing added sugars and fats is crucial for preventing chronic diseases linked to dietary habits. This dietary approach not only safeguards against systemic health issues but also plays a significant role in maintaining oral health. By opting for nutrient-rich foods and minimizing the intake of sugars and fats, individuals can reduce the risk of developing oral conditions such as dental caries (cavities), periodontal infections (gum disease), and even oral malignancies (cancer). Making these dietary choices promotes overall well-being while simultaneously protecting against various oral health concerns (65). Additionally, including calcium-rich options like cheese and yogurt provides essential nutrients for maintaining strong teeth and supporting overall oral health. By adopting these dietary habits, individuals can fortify their teeth against decay while promoting general well-being (66) (67).

Importance of Regular check-ups and Professional cleanings:

Routine dental appointments are essential for maintaining optimal oral health. These regular check-ups enable dentists to detect any potential issues, such as tooth decay or gum disease, in their earliest stages, preventing them from progressing into more serious conditions. Moreover, professional cleanings performed during these visits are crucial for removing tartar buildup, which cannot be effectively eliminated through regular brushing and flossing alone. By attending these appointments consistently, individuals ensure that their teeth and gums receive the thorough care they need to stay healthy and free from disease (68) (69).

Healthy Habits for Oral Well-being:

Maintaining optimal oral health involves abstaining from detrimental habits. Firstly, the cessation of smoking is paramount, as tobacco products exacerbate gum disease and elevate the risk of oral cancer. This step not only safeguards oral health but also contributes to overall well-being (70). Additionally, moderating alcohol consumption is imperative, as excessive intake can desiccate the mouth, diminishing saliva production crucial for acid neutralization. By curtailing these habits, individuals foster an environment conducive to oral health preservation, reducing the likelihood of developing debilitating conditions such as periodontal diseases and oral malignancies. Embracing healthier lifestyle choices not only enhances oral hygiene but also promotes holistic wellness, ensuring sustained vitality and quality of life (71).

The combined use of tobacco and alcohol significantly amplifies the risk of developing oral cancer, as revealed by a systematic review conducted by Mello et al. The review, encompassing 33 articles, identified synergistic effects between these substances: the combination of alcohol and tobacco smoking resulted in a 4.74-fold increase in oral cancer risk while pairing alcohol with smokeless tobacco yielded a 7.78-fold increase. Furthermore, individuals consuming alcohol, tobacco smoking, and smokeless tobacco concurrently faced a staggering 16.17-fold rise in oral cancer risk. Early identification of high-risk smokers is imperative for preventing the onset of this debilitating disease, underscoring the importance of proactive screening and intervention strategies (72).

Maintaining Adequate Hydration for Oral Health:

Ensuring sufficient hydration is vital for oral health. Drinking an ample amount of water helps to keep the mouth moist, facilitating the removal of food particles and bacteria. This moist environment also promotes saliva production, which plays a crucial role in preventing tooth decay. Saliva helps to neutralize acids produced by bacteria in the mouth, reducing the risk of enamel erosion and cavities. Additionally, staying hydrated supports overall oral hygiene by aiding in the natural cleansing process that occurs between brushing and flossing. By prioritizing hydration, individuals can contribute to the maintenance of a healthy oral environment, reducing the likelihood of developing oral health issues such as cavities and gum disease (73) (74).

Promoting Oral Health Education and Awareness:

Enhancing knowledge about oral health is instrumental in fostering improved dental care practices. Initiatives such as awareness campaigns and dental health programs implemented in schools are pivotal in instilling positive oral hygiene habits from a young age. By educating individuals about the importance of oral health and proper dental care techniques, these programs empower them to take proactive measures to maintain their oral hygiene (75). Moreover, raising awareness about common dental issues and preventive measures can help individuals make informed decisions regarding their oral health. By promoting education and awareness, communities can work towards reducing the prevalence of oral diseases and improving overall dental well-being. This proactive approach ensures that individuals are equipped with the knowledge and resources necessary to prioritize their oral health throughout their lives (76).

Figure 2: A framework on key preventative measures to maintain good oral hygiene and prevent dental issues.

4.1 Policy recommendations

Enhancing oral hygiene and healthcare through strategic policy initiatives is paramount for ensuring the well-being of communities. These recommendations **Table 2** encompass various aspects, from improving access to affordable dental services to integrating oral health education into public health initiatives. By addressing these critical areas, policymakers can pave the way for a healthier future, mitigating disparities and fostering overall oral health excellence .

Access to Affordable Dental Services:

Enhancing access to cost-effective dental care is imperative, especially for marginalized communities and remote regions. Proposed strategies involve broadening Medicaid provisions to encompass dental services, alongside fostering initiatives to entice dental practitioners to work in underserved locales, facilitated by loan forgiveness programs. This approach aims to alleviate the financial burden on individuals while addressing the scarcity of dental professionals in areas lacking adequate access. By bolstering policy measures in this regard, communities facing disparities in dental healthcare can potentially witness substantial improvements in accessibility and overall oral health outcomes (77).

Implementing Preventable Dental Initiatives:

Instituting preventative dental initiatives across educational institutions, community hubs, and workplaces aims to offer accessible fluoride treatments, dental sealants, and oral health assessments (78). These proactive measures not only target early intervention but also promote awareness and maintenance of oral health. Moreover, incentivizing routine dental check-ups and screenings through mechanisms like tax credits or employer-driven wellness schemes encourages individuals to prioritize preventive care, potentially mitigating the onset of oral health issues (79). By integrating these strategies, communities can foster a culture of proactive oral health management, leading to long-term benefits for individuals and society as a whole.

Advancing Integration of Oral Health within Primary Healthcare:

Efforts to embed oral health services within primary care facilities aim to bolster accessibility and streamline care coordination. This integration strategy seeks to bridge the gap between medical and dental care, ensuring comprehensive healthcare delivery. By fostering collaborative practice models, where primary care practitioners and dentists collaborate to address both oral and medical health concerns, communities can benefit from holistic and synchronized healthcare services (80). Emphasizing this integrated approach not only enhances patient access

to dental care but also promotes proactive management of overall health, potentially reducing the incidence of preventable oral health issues and improving health outcomes on a broader scale.

Promoting Oral Health Through Regulatory Initiatives:

Enforcing stringent regulations on tobacco control aims to curb smoking rates and mitigate tobacco-related oral diseases (81). Concurrently, policy implementation targeting the marketing and accessibility of sugary beverages and snacks addresses the underlying cause of dental caries. These regulatory measures not only aim to reduce the prevalence of harmful behaviors and products but also prioritize preventive efforts to safeguard oral health (82). By proactively addressing the environmental and behavioral factors contributing to oral health issues, communities can strive towards fostering healthier lifestyles and reducing the burden of preventable oral diseases.

Dental Workforce for Enhanced Access to Care:

Efforts are underway to enhance the dental workforce, targeting areas with limited access to oral healthcare. This involves expanding dental education programs and offering incentives such as scholarships and loan forgiveness to students willing to practice in underserved regions. Furthermore, initiatives support the training of dental hygienists and allied professionals, extending the reach of oral health services. By investing in workforce development, communities can address disparities in dental care access, ensuring that individuals in remote or underserved areas receive essential oral healthcare services (83).

Table 2: Policy Recommendations Summary.

Policy Recommendations	Description
Access to Affordable Dental Services	Expand Medicaid for dental services, incentivize practitioners for underserved areas.
Implementing Preventable Dental Initiatives	Provide fluoride treatments, dental sealants, and oral health assessments in schools and workplaces, incentivize routine check-ups.
Advancing Integration of Oral Health within Primary Healthcare	Integrate oral health into primary care, fostering collaboration between practitioners for comprehensive care.
Promoting Oral Health Through Regulatory Initiatives	Enforce tobacco control regulations, regulate sugary beverage/snack marketing for oral health.
Dental Workforce for Enhanced Access to Care	Expand dental education, offer scholarships/loan forgiveness, train allied professionals for underserved areas.

5. Barriers to Integration of Dental and General Healthcare

Integrating dental care with general healthcare faces numerous challenges that impede its seamless implementation **Error! Reference source not found.**. These obstacles encompass a range of factors, including systemic, structural, financial, and educational issues (84). At a systemic level, the division between dental and general healthcare forms isolated compartments, obstructing cooperation and dialogue among dental and medical practitioners. This division persists due to variations in reimbursement mechanisms, regulatory structures, and

administrative procedures governing dental and medical care. The separation of dental and general healthcare perpetuates silos that impede effective collaboration and communication between professionals.

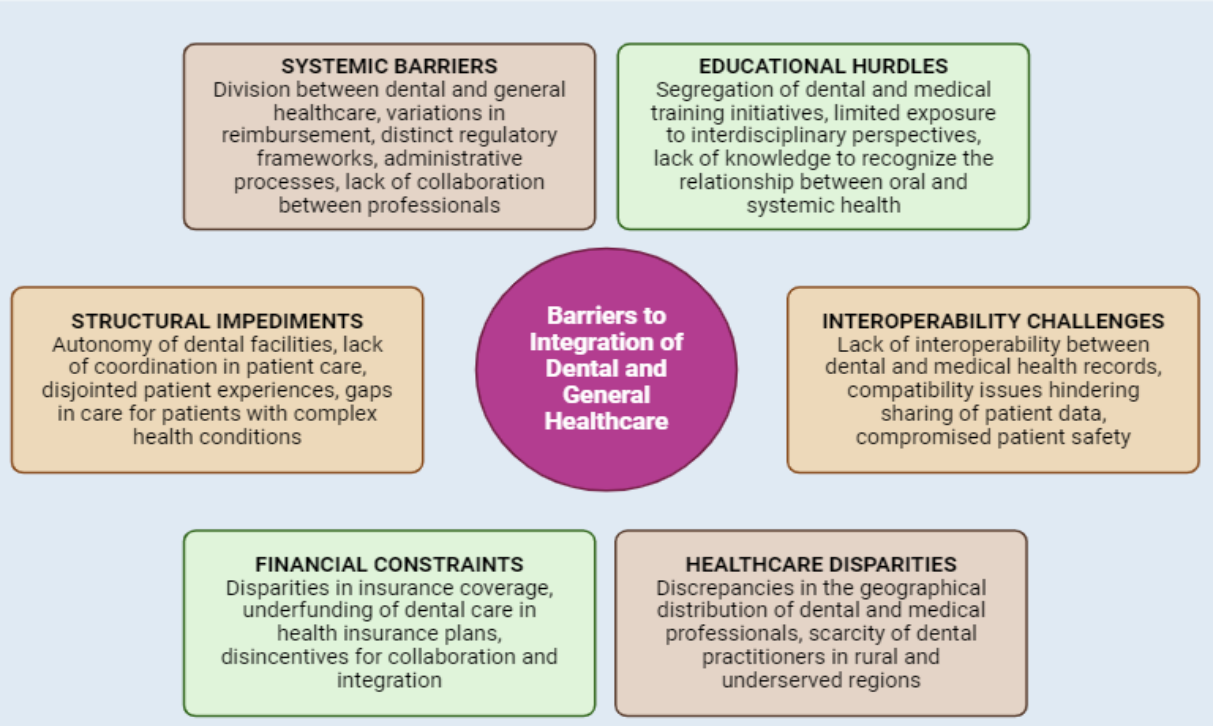
Differing reimbursement systems for dental and medical services contribute to this fragmentation, as dental care often receives separate or limited coverage compared to medical services under health insurance plans (85). Moreover, distinct regulatory frameworks and administrative processes further reinforce the divide, making it challenging for dental and medical professionals to align their practices and coordinate patient care seamlessly. As a result, patients may encounter barriers to accessing integrated healthcare services, leading to fragmented care delivery and suboptimal health outcomes (86). Addressing these systemic challenges requires efforts to harmonize reimbursement policies (87), streamline regulatory processes, and promote interdisciplinary collaboration between dental and medical sectors (86). By breaking down these silos, healthcare systems can foster greater synergy between dental and general healthcare, ultimately improving patient care and outcomes.

Structural impediments present notable challenges, given the tendency for dental and medical facilities to function autonomously, lacking effective coordination or fusion of patient care. This disjointed approach may lead to fragmented delivery of care, redundant provision of services, and less than optimal results for patients necessitating comprehensive management across various healthcare domains (88). The absence of synchronization between dental and medical practices contributes to a disjointed patient experience, with individuals often navigating separate systems for oral and general health needs. Consequently, this fragmented model increases the likelihood of gaps in care, redundant procedures, and inefficiencies in resource utilization. Moreover, patients with complex health conditions requiring interdisciplinary attention may encounter barriers to accessing integrated care due to the siloed nature of healthcare delivery (89).

Financial constraints pose another challenge, as disparities in insurance coverage and reimbursement rates between dental and medical services create disincentives for collaboration and integration (90). Dental care, in particular, is often excluded or underfunded in health insurance plans, leading to disparities in access to dental services and exacerbating oral health inequalities.

Educational hurdles exacerbate the situation, given the conventional setup where dental and medical training initiatives typically occur in distinct educational and clinical environments, offering minimal chances for interdisciplinary education or cooperation. This segregation perpetuates a dearth of consciousness, comprehension, and recognition of the interdependencies between oral health and overall well-being among healthcare practitioners (91). The entrenched separation of dental and medical training programs results in limited exposure to cross-disciplinary perspectives, impeding the holistic understanding of healthcare among future

Figure 3: Outline of multifaceted barriers that hinder seamless integration of dental and general healthcare, each representing a distinct challenge impeding the collaboration between the two sectors.



professionals. Consequently, graduates from these programs may lack the requisite knowledge and skills to recognize the integral relationship between oral health and systemic health conditions, leading to missed opportunities for early intervention and holistic patient care (92).

Enhancing Healthcare Integration: The lack of interoperability between dental and medical electronic health record (EHR) systems presents a significant challenge to the smooth exchange of patient data and coordination of care. Compatibility issues between dental software and broader healthcare IT infrastructure hinder the sharing of vital information such as diagnostic data, treatment plans, and medical histories among dental and medical providers. This limited ability to seamlessly exchange information can lead to disjointed care delivery and compromise patient safety. Overcoming these barriers requires investment in interoperable EHR systems and collaborative efforts to integrate dental and medical records, enabling comprehensive and coordinated healthcare delivery (93).

Addressing Healthcare Disparities: Discrepancies in the geographical distribution of dental and medical professionals, especially in rural and underserved regions, pose significant obstacles to integration efforts (94). The scarcity of dental practitioners, including dentists, hygienists, and dental therapists, restricts the availability of essential preventive and treatment services. Similarly, shortages of primary care physicians and other healthcare providers compound the challenge of delivering comprehensive, integrated care (95). In underserved areas, the scarcity of dental and medical professionals exacerbates existing disparities in healthcare access and quality, disproportionately affecting vulnerable populations. Limited access to dental services not only compromises oral health outcomes but also contributes to systemic health issues, as oral health is intricately linked to overall well-being (96).

5.1 Discussion on public perception and knowledge gaps

Public perception and knowledge gaps regarding dental healthcare encompass a broad spectrum of beliefs, attitudes, and understanding within society concerning oral health (97). These perceptions and knowledge gaps can vary significantly depending on factors such as culture, socioeconomic status, education, and access to dental services. Perception refers to how people view dental health, including their beliefs about the importance of oral hygiene, regular dental check-ups, and the impact of dental issues on overall health and well-being. These perceptions can be influenced by cultural norms, personal experiences, and media portrayal of dentistry (98).

Public opinion regarding dental care is multifaceted and influenced by various factors, including cultural norms, socioeconomic status, access to healthcare, and personal experiences. Understanding the nuances of these perceptions is crucial for improving oral health outcomes and promoting preventive dental practices (99). The general public's perception of dental care encompasses a range of attitudes, from proactive engagement to indifference or fear (100). Many individuals view regular dental visits as essential for maintaining oral health and preventing dental problems such as cavities, gum disease, and tooth loss. These individuals prioritize preventive measures, such as brushing and flossing regularly, and recognize the importance of professional cleanings and check-ups. They may also perceive dentists as trusted healthcare providers who play a crucial role in promoting overall well-being. However, not everyone holds such positive views of dental care. Some individuals may harbor negative perceptions stemming from past traumatic experiences, fear of dental procedures (odontophobia), or misconceptions about dental treatments (101). Moreover, disparities in access to dental care further shape public perception. Rural areas and underserved communities often face challenges in accessing dental services due to a shortage of providers or geographic barriers. As a result, individuals in these regions may perceive dental care as unattainable or low priority, leading to delayed treatment-seeking behavior and poorer oral health outcomes (102). In addition to individual attitudes, public perception of dental care is influenced by broader social and cultural factors. For example, media portrayals of dentistry, including television shows or movies, can shape perceptions of dental professionals and procedures, influencing both positive and negative attitudes toward dental care. Public health campaigns and advocacy efforts can leverage media platforms to promote positive messages about oral health and encourage behavior change (103).

Identifying knowledge gaps in dental healthcare is crucial for improving the quality of dental services and addressing emerging challenges in the field. These gaps refer to areas where there is a lack of understanding or insufficient evidence to inform clinical practice, public health initiatives, or policy development related to dental care. By identifying and addressing these gaps, stakeholders can better allocate resources, guide research efforts, and implement interventions to improve oral health outcomes (104). One significant knowledge gap in dental healthcare pertains to the effectiveness of preventive measures and interventions in reducing the prevalence of oral diseases. While there is ample evidence supporting the efficacy of practices such as regular brushing, flossing, and dental check-ups, further research is needed to explore the impact of emerging preventive strategies, such as community water fluoridation programs or dental sealant applications, particularly in high-risk populations.

Thus Addressing these perception and knowledge gaps is crucial for promoting better oral health outcomes and reducing disparities in dental care access and utilization. Education campaigns, community outreach programs, and improved access to affordable dental services are some strategies that can help bridge these gaps and improve public understanding of dental healthcare.

6. Future Directions in Research

Interdisciplinary collaboration between dentistry, medicine, and other healthcare disciplines is essential for advancing our understanding of the intricate interplay between oral and systemic health and developing holistic patient care strategies. By bringing together diverse expertise and perspectives, interdisciplinary teams can design comprehensive research approaches that explore the bidirectional relationship between oral health and systemic diseases. This collaboration enables the integration of oral health considerations into medical practice and vice versa, fostering a more holistic approach to patient care. Dentists and physicians can work together to identify common risk factors, such as inflammation and microbial dysbiosis, shared by oral and systemic diseases, and develop targeted interventions to address them. Moreover, interdisciplinary collaboration promotes knowledge sharing, cross-disciplinary training, and the development of innovative healthcare solutions that transcend traditional disciplinary boundaries. Ultimately, by breaking down silos and fostering collaboration, interdisciplinary teams can optimize patient outcomes and promote overall health and well-being (105) (106).

Mechanistic investigations in the realm of oral health and systemic health explore the intricate biological pathways that underlie the relationship between the two domains. Specifically, these studies delve into the molecular and cellular mechanisms through which oral health conditions, such as periodontal disease, influence systemic diseases like cardiovascular disease, diabetes, and respiratory conditions. By elucidating these mechanisms,

researchers aim to uncover key mediators, such as inflammatory cytokines, immune cells, and microbial metabolites, that contribute to disease pathogenesis and progression. Understanding these mechanisms not only provides insights into the etiology of systemic diseases but also identifies potential therapeutic targets for intervention. Moreover, mechanistic investigations enable the development of targeted interventions aimed at modulating specific pathways to mitigate the impact of oral health conditions on systemic health outcomes. Overall, these studies play a critical role in advancing our understanding of the complex interplay between oral health and systemic health, paving the way for more effective prevention and treatment strategies (7) (107). Microbiome research in the context of oral health seeks to unravel the complex interplay between the oral microbiome and systemic health. The oral microbiome comprises a diverse array of microorganisms inhabiting the oral cavity, playing a crucial role in maintaining oral homeostasis and influencing systemic health. Dysbiosis, or imbalance, within the oral microbiome has been implicated in various systemic diseases, including cardiovascular disease, diabetes, and inflammatory conditions. By elucidating the mechanisms underlying microbial dysbiosis and its systemic implications, researchers aim to identify key microbial taxa, metabolites, and immune responses that drive disease pathogenesis. This deeper understanding can inform the development of targeted interventions, such as probiotics, prebiotics, and microbiome-modulating therapies, to restore microbial balance and mitigate systemic disease risk. Furthermore, microbiome research may uncover biomarkers of disease susceptibility and facilitate personalized approaches to oral and systemic health management, ushering in a new era of precision medicine in dentistry and healthcare (108) (109) (110). Precision dentistry represents a paradigm shift in oral healthcare, emphasizing personalized approaches tailored to individual patient needs and characteristics.

This approach integrates advanced technologies, such as genetic testing, biomarker analysis, and digital imaging, to assess oral health status comprehensively. By leveraging these tools, dental professionals can identify genetic predispositions, biomarkers of disease susceptibility, and unique anatomical considerations, enabling tailored treatment plans and interventions. Precision dentistry also encompasses targeted therapies, including customized medications, minimally invasive procedures, and tissue engineering techniques, to optimize treatment outcomes while minimizing adverse effects. Furthermore, this approach extends beyond treatment to include preventive strategies tailored to each patient's risk profile, lifestyle factors, and oral microbiome composition. By embracing precision dentistry, dental practitioners can enhance treatment efficacy, improve patient satisfaction, and contribute to overall systemic health and well-being. As research continues to elucidate the intricate interactions between oral and systemic health, precision dentistry will play an increasingly pivotal role in advancing personalized oral healthcare delivery (111) (112).

Technology integration in oral health research holds immense potential to revolutionize how we collect data, monitor patients, and intervene to improve systemic health outcomes. Artificial intelligence (AI) algorithms can analyze vast amounts of data, from oral imaging to patient records, to identify patterns, predict disease progression, and personalize treatment plans. Wearable devices equipped with sensors can continuously monitor oral health parameters, such as pH levels and bacterial activity, providing real-time feedback and facilitating early intervention for preventive care. Additionally, telemedicine platforms enable remote consultations and monitoring, enhancing access to oral healthcare services, particularly in underserved communities. By harnessing these innovative technologies, researchers can gain deeper insights into the oral-systemic health connection, develop more effective preventive and therapeutic interventions, and empower patients to actively engage in their healthcare journey. Ultimately, technology integration has the potential to transform oral health research and practice, leading to improved systemic health outcomes on a global scale (113) (114).

Investigating the role of social determinants of health (SDOH) in the oral-systemic health connection is critical for understanding and addressing health disparities. SDOH encompass a broad range of factors, including socioeconomic status, access to healthcare services, education, employment, and environmental conditions. These factors profoundly influence individuals' health outcomes, shaping their risk of developing both oral and systemic diseases. Socioeconomic status (SES) is a key determinant of health disparities, with lower SES individuals experiencing higher rates of oral health problems and systemic diseases (115). Limited access to dental care due to financial constraints often results in untreated dental conditions, which can exacerbate systemic health issues.

Additionally, individuals from disadvantaged socioeconomic backgrounds may face environmental challenges such as inadequate housing, exposure to pollutants, and food insecurity, further contributing to poor health outcomes. Research into the oral-systemic health connection within the context of SDOH can uncover disparities in disease prevalence, access to care, and treatment outcomes (116). By identifying the underlying social factors driving these disparities, targeted interventions can be developed to address root causes and improve health equity. For example, community-based programs that provide free or low-cost dental services to underserved populations can help bridge the gap in access to care.

Preventive strategies play a crucial role in mitigating the risk of systemic diseases associated with poor oral health. Early detection and intervention for oral health conditions, such as periodontal disease and dental caries, can prevent complications and reduce the systemic inflammatory burden. Regular dental check-ups, education on proper oral hygiene practices, and lifestyle modifications can empower individuals to maintain optimal oral health and lower their risk of systemic diseases. Emphasizing preventive care requires a shift towards a proactive approach to healthcare delivery, focusing on wellness and disease prevention rather than reactive treatment. Integrated healthcare models that incorporate dental screenings and preventive services into primary care settings can enhance early detection and intervention efforts. Additionally, public health initiatives aimed at promoting oral hygiene education and improving access to preventive dental services in underserved communities can help address disparities and improve overall health outcomes. In conclusion, investigating the role of social determinants of health and emphasizing preventive strategies are essential for reducing health disparities and improving oral and systemic health outcomes. By addressing underlying social factors and promoting early intervention and preventive care, healthcare systems can work towards achieving health equity and better overall health for all individuals (117) (118).

7. Conclusion

In conclusion, the integration of dental and general healthcare stands as a crucial imperative in promoting holistic well-being and mitigating the burden of oral diseases and their systemic implications. This review has underscored the profound interconnections between oral hygiene and systemic health, elucidating the intricate mechanisms and pathways through which oral health influences overall well-being. By highlighting the significance of preventative strategies and evidence-based interventions, it provides a roadmap for healthcare stakeholders to address the complex challenges posed by oral diseases. Moreover, the policy recommendations outlined herein offer actionable steps towards enhancing accessibility to dental services, advancing integration within primary healthcare, and promoting oral health education and awareness. However, the persistence of barriers such as systemic disparities, structural obstacles, and knowledge gaps necessitates a concerted effort to overcome these challenges and realize the vision of truly integrated healthcare. In moving forward, concerted efforts must be made to bridge these gaps, foster interdisciplinary collaboration, and empower individuals to prioritize oral health as an integral component of their overall well-being. Through collective action and a commitment to evidence-based practices, we can pave the way for a future where oral and systemic health are seamlessly integrated, ultimately improving the quality of life for individuals and communities alike.

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Authors Contribution

All authors are involved and contributing in data collection and manuscript preparation including table, figures and final proof of manuscript.

Conflict of interest statement

Authors declare they do not have any conflict of interest.

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