GRADUATION PROJECT

Degree in Dentistry

PERIODONTITIS AND HEART FAILURE. A SYSTEMATIZED REVIEW

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RESUMEN

Introducción: La periodontitis es una enfermedad inflamatoria crónica de alta prevalencia, caracterizada por la degradación progresiva del aparato de soporte dental, y ha sido crecientemente asociada con enfermedades sistémicas, en particular con la enfermedad cardiovascular. La insuficiencia cardíaca (IC) representa un desafío sanitario mundial sustancial y en aumento, con más de 55 millones de personas afectadas en todo el mundo y una morbimortalidad significativa. Tanto la periodontitis como la IC comparten vías inflamatorias comunes y factores de riesgo compartidos, lo que convierte su posible interrelación en un tema de creciente interés científico. **Objetivo:** El presente estudio tuvo como objetivo examinar la relación entre la periodontitis y la IC, evaluar el impacto de la enfermedad periodontal sobre el riesgo y la gravedad de la IC, y explorar si el tratamiento periodontal puede influir en los resultados cardiovasculares. **Material y métodos**: Se realizó una revisión sistematizada en cinco bases de datos electrónicas: PubMed, Scopus, MEDLINE Complete, Web of Science y Wiley Online Library. Los estudios fueron seleccionados según criterios de elegibilidad predefinidos basados en el formato PICO, y el proceso de selección fue reportado mediante un diagrama de flujo PRISMA 2020. **Resultados:** Se incluyeron diecisiete artículos de investigación primaria publicados entre 2016 y 2025, la mayoría de los cuales reportó una asociación positiva y significativa entre la gravedad de la periodontitis y un mayor riesgo o prevalencia de IC. Los biomarcadores inflamatorios y cardíacos, incluyendo la proteína C reactiva y el NT-proBNP, se encontraron consistentemente elevados en pacientes con ambas condiciones. En algunos estudios de intervención, el tratamiento periodontal se asoció con reducciones en dichos marcadores. **Conclusiones:** La evidencia disponible respalda una asociación consistente entre la periodontitis y la IC, mediada por mecanismos inflamatorios y microbianos compartidos. Sin embargo, dado que la mayoría de los estudios incluidos son de carácter observacional, no es posible establecer relaciones causales de forma definitiva y se requieren estudios longitudinales e intervencionales adicionales.

PALABRAS CLAVE

Odontología, periodontitis, insuficiencia cardíaca, enfermedad cardiovascular, inflamación

ABSTRACT

Introduction: Periodontitis is a highly prevalent chronic inflammatory condition characterized by progressive degradation of the tooth supporting apparatus, and has been increasingly associated with systemic conditions, particularly cardiovascular disease. Heart Failure (HF) constitutes a substantial and escalating global health challenge, with over 55 million people affected worldwide and significant associated morbidity and mortality. Both periodontitis and HF share overlapping inflammatory pathways and common risk factors making their potential interrelationship a topic of growing scientific interest. **Objective:** This study sought to examine the relationship between periodontitis and HF, assess the impact of periodontal disease on HF risk and severity, and explore whether periodontal treatment may influence cardiovascular outcomes. **Materials and Methods:** A systematized review was conducted across five electronic databases: PubMed, Scopus, MEDLINE complete, Web of Science and Wiley Online Library. Studies were selected according to predefined PICO-based inclusion and exclusion criteria, and the selection process was reported using a PRISMA 2020 flow diagram. **Results:** Seventeen primary research articles published between 2016 and 2025 were included, majority reporting a significant positive association between periodontitis severity and increased HF risk or prevalence. Elevated inflammatory cardiac biomarkers, including C-reactive protein and NT-proBNP were consistently observed in patients with both conditions. Periodontal treatment was associated with reductions in these markers in some interventional studies. **Conclusions:** The available evidence supports a consistent association between periodontitis and HF, mediated by shared inflammatory and microbial mechanism. However, as most included studies are observational, causal relationships cannot be definitively established and further longitudinal and interventional studies are needed.

KEYWORDS

Dentistry, periodontitis, heart failure, cardiovascular disease, systemic inflammation

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1. INTRODUCTION

1.1. Defining concepts

1.1.1. Definition and pathophysiology of periodontitis

Periodontitis, ranks among the most prevalent chornic inflammatory diseases affecting the human dentition, defined by the gradual destruction of the tissues supporting the teeth (1). Clinically, it manifests as a progressive loss of connective tissue attachment, the development of periodontal pockets and destruction of both the periodontal ligament and the alveolar bone. If left untreated, this structural deterioration eventually leads to tooth loss (2). According to the 2017 World Workshop, periodontitis is defined as a "*multifactorial inflammatory disease associated with dysbiotic plaque biofilms and characterised by progressive destruction of the tooth-supporting apparatus*" highlighting that microbial dysbiosis and the host immune-inflammatory response are the central pathogenic mechanisms driving periodontal tissue breakdown (3). In terms of global burden, periodontitis affects approximately half of the adult population worldwide, with severe manifestations estimated to occur in around 10-15% of individuals (4). Epidemiological data indicate that periodontitis disproportionately affects certain population groups, being more prevalent and severe among socioeconomically disadvantaged individuals, specific ethnic minorities and individuals with factors that increase the risk of the disease including tobacco use, diabetes mellitus and obesity (5). Beyond the oral cavity, the chronic inflammatory burden of periodontitis contributes to systemic effects, including elevated circulating inflammatory markers and increased risk for cardiovascular diseases, diabetes, adverse pregnancy outcomes and respiratory infections (6). The disease also negatively affects mastication, overall quality of life, impacting nutrition, altering aesthetics, self-esteem and social well-being (7).

1.1.2. Heart failure definition and relevance

Heart failure (HF) is a complex systemic disorder making it a syndromic condition arising from different aetiologies and complex pathophysiology rather than a single distinct pathological process (8). According to the 2023 Focused Update of the European Society of Cardiology Guidelines, HF is defined as a "clinical syndrome characterized by symptoms and/or signs resulting from a structural or functional cardiac abnormality accompanied by evidence of elevated left ventricular filling pressures" (9). In essence, the heart becomes unable to meet the circulatory demands of the body, resulting in insufficient delivery of oxygenated blood to peripheral organs and tissues (10). In response, the body initiates compensatory adaptions, notably through sympathetic nervous system activation and renin-angiotensin-aldosterone

system engagement, which transiently sustain organ perfusion but become maladaptive and drive structural cardiac deterioration when chronically maintained (11).

HF represents one of the most significant and escalating challenges in global public health, with an estimated 55.5 million individuals affected worldwide as of 2021, a burden that rises sharply with advancing age and is largely attributable to ischaemic heart disease and hypertension (12,13). Despite major advances in diagnosis and therapy, HF remains a condition with high morbidity and mortality. Recent global estimates indicates that the 1-year mortality rate following a new diagnosis of HF ranges between 17% and 45%, depending on disease severity and comorbidities (14).

1.1.3. Oral systemic condition

The oral cavity, often described as the *"mirror of systemic well-being"* has come to be regarded as a fundamental dimension of overall systemic health. Far from being an isolated environment, it serves as a gateway to the body, reflecting and influencing systemic physiological and pathological processes (15). Inflammatory processes in periodontal disease contribute to a chronic low-grade systemic inflammatory state, allowing bacteria and inflammune mediators to disseminate into the bloodstream. These processes can induce endothelial dysfunction, promote atherogenesis, and exacerbate existing cardiovascular pathologies (16). Given that both periodontitis and HF involve inflammatory and immune-mediated pathways, and share overlapping risk factors such as tobacco use, diabetes mellitus and aging, their interrelationship has become an area of increasing scientific and clinical interest (16). This connection underscores the importance of adopting an integrated, multidisciplinary approach to oral and cardiovascular health.

1.2. Background

1.2.1. Historical perspectives

In the 1980s and 1990s, scientific interest in the relationship between oral systemic health began to emerge, supported by epidemiological evidence linking periodontal disease with atherosclerosis and cardiovascular disease (17). Periodontitis has subsequently emerged as a potentially modifiable contributor to both the onset and worsening of HF. Subsequent research identified elevated levels of key inflammatory

markers including C reactive protein, interleukin-6 and tumour necrosis factor-alpha in both periodontitis and cardiovascular conditions (18).

1.2.2. Shared risk factors

Periodontitis and HF share multiple modifiable and non-modifiable risk factors, which complicate the interpretation of their association. Both conditions become more prevalent with advancing age and are influenced by tobacco use, diabetes mellitus, obesity and low socioeconomic status (19,20). Moreover, genetic predisposition, dietary patterns and psychosocial stress contribute to the overlapping epidemiology of these diseases (21,22). Because many of these factors predispose individuals to oral and cardiovascular disease, confounding factors are an issue in epidemiological research. Smoking, for instance, increases the risk of periodontitis through impaired immune response and microvascular changes, and simultaneously accelerates atherosclerosis and HF progression (23). Similarly, diabetes amplifies systemic inflammation and oxidative stress, contributing to both periodontal tissue destruction and cardiac remodelling (24). Despite these shared risk profiles, some evidence suggests that the connection between periodontitis and HF could extend beyond similar risk factors. The persistence of associations after multivariate adjustments in large cohort studies seems to indicate that biological mechanisms including bacteraemia, cytokine release and endothelial dysfunction play an independent role (15). This reinforces the concept that the link between the two conditions is not merely coincidental but grounded in shared pathophysiological pathways that integrate local and systemic inflammation.

1.3. Theoretical framework

1.3.1. Systemic Inflammatory Pathways Originating from Periodontitis

Periodontitis begins as an inflammatory response to the accumulation of a complex bacterial biofilm on the tooth surface, particularly within the gingival sulcus (subgingival biofilm). This microbial community, primarily composed of Gram-negative anaerobic bacteria such as *Porphyromonas gingivalis*, *Tannerella forsythia*, and *Treponema denticola*, elicits a host-mediated immune response through activation of toll-like receptors and other pattern recognition receptors expressed on epithelial and immune cell surfaces (22,25). Activation of these receptors initiates the production of pro-inflammatory cytokines, notably interleukin-6 and tumour necrosis factor-alpha, alongside chemokines that recruit neutrophils and

macrophages to the site of infection (25,26). In susceptible individuals, this defensive inflammatory process becomes dysregulated, culminating in the irreversible breakdown of connective tissue and alveolar bone. The ulcerated pocket epithelium that forms during advanced disease stages serves as an open gateway between the oral environment and the bloodstream, allowing bacteria, endotoxins (particularly lipopolysaccharides), and inflammatory mediators to disseminate systemically (27). These episodes of transient bacteremia occur even during everyday activities such as tooth brushing or chewing and contribute to a chronic low-grade systemic inflammatory state (16). The proposed biological pathway through which periodontitis may contribute to cardiovascular damage and heart failure is summarized in Figure 1.

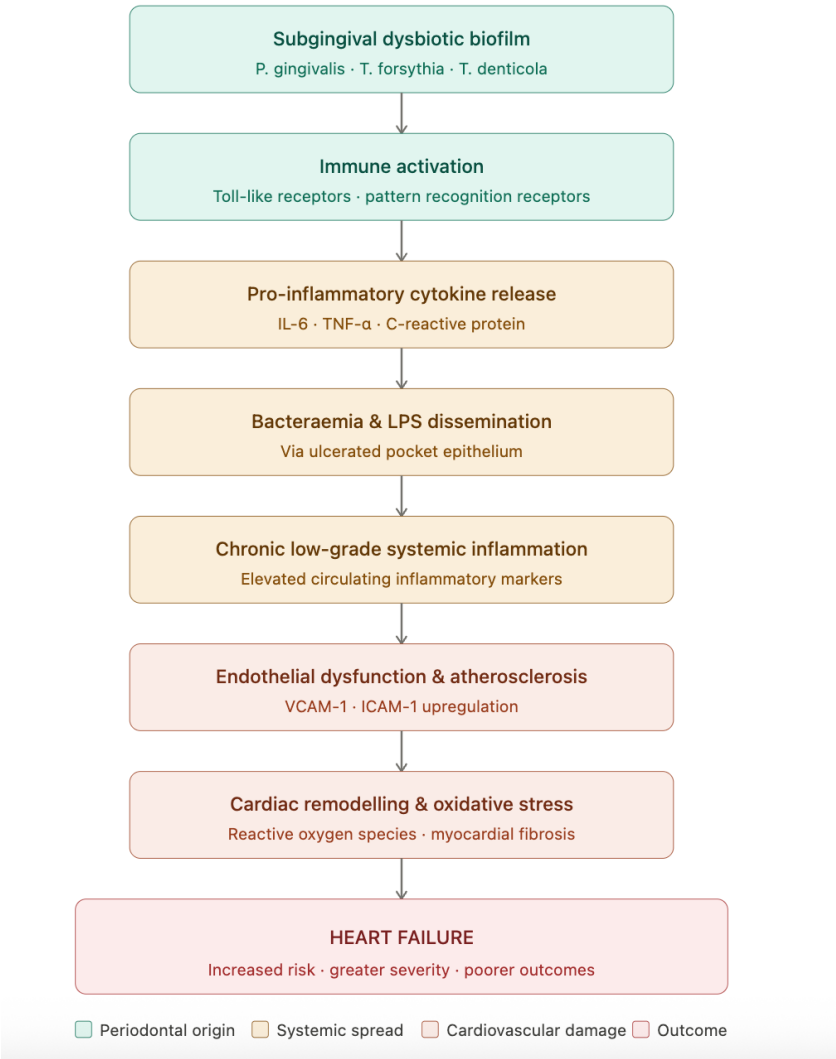


Figure 1. Proposed biological pathway linking periodontitis to heart failure. Own elaboration based on (15,16,27)

The dissemination of bacterial products and inflammatory cytokines prompts the liver to upregulate synthesis of acute-phase reactants, principally C-reactive protein, which further amplifies the inflammatory cascade (15). Persistently raised systemic concentrations of C-

reactive protein, interleukin-6 and tumor necrosis factor-alpha are well documented in periodontitis patients and constitute critical mediators of vascular damage and cardiac impairment (7,8). The persistence of these mediators promotes endothelial activation with consequent upregulation of adhesion molecules including VCAM-1 and ICAM-1, promoting leukocyte binding and migration across the vascular walls, processes that are central to the development of atherosclerosis and HF (5). Among periodontal pathogens, *P. gingivalis* has received particular attention for its ability to invade host cells, evade immune clearance, and manipulate host signaling pathways. Its virulence factors, including gingipains and fimbriae, interfere with complement activation and trigger intracellular NF-κB signaling, perpetuating cytokine release and oxidative stress (28). This sustained inflammatory response drives the overproduction of reactive oxygen species, causing lipid peroxidation and endothelial dysfunction, both of which are also hallmarks of cardiovascular and HF pathology (29).

1.3.2. Inflammatory and Neurohormonal Mechanisms in Heart Failure

HF should not be regarded solely as a hemodynamic disorder but rather as a systemic inflammatory condition driven by immune dysregulation and persistent neurohormonal activation. Elevated circulating concentrations of interleukin-6, tumor necrosis factor-α, interleukin-1β, and high-sensitivity C-reactive protein have been repeatedly observed in HF across phenotypes, with higher levels correlating with disease severity, reduced ejection fraction, and increased mortality (30–32). These cytokines contribute to myocardial remodeling by stimulating fibroblast proliferation, extracellular-matrix deposition, and cardiomyocyte apoptosis, ultimately leading to fibrosis and impaired ventricular compliance (33).

As Hf advances, both the renin-angiotensin-aldosterone system and the sympathetic nervous system, initially recruited to preserve cardiac output, undergo sustained pathological overactivation. Prolonged renin–angiotensin–aldosterone system stimulation elevates circulating angiotensin II and aldosterone, triggering macrophage recruitment and driving reactive oxygen species production via NADPH oxidase signalling (30). Similarly, sympathetic overactivity enhances β-adrenergic signaling, promoting oxidative stress, apoptosis, and mitochondrial dysfunction within cardiomyocytes (11). This maladaptive neurohormonal activation further amplifies inflammatory signaling, creating a self-perpetuating cycle of oxidative and immune injury in cardiac tissue. Importantly, these inflammatory and neurohormonal pathways resemble those triggered by chronic periodontitis, particularly the overproduction of cytokines, suggesting a shared pathophysiological axis between oral and cardiac disease. This overlap provides biological plausibility for the hypothesis that systemic inflammation originating from periodontal infection could accelerate HF progression.

Furthermore, impaired perfusion and reduced immune competence in advanced HF may reciprocally worsen periodontal health, reinforcing a bidirectional relationship driven by sustained vascular and inflammatory stress (30).

Beyond the epidemiological and mechanistic evidence linking periodontitis to HF, an emerging area of interest concerns whether periodontal treatment may positively influence cardiovascular outcomes. Given that periodontal therapy reduces the local inflammatory burden and systemic levels or pro-inflammatory mediates such as C-reactive protein, interleukin-6 and tumour necrosis factor-alpha (15,16), it has been hypothesised that successful periodontal treatment could attenuate the systemic inflammatory cascade implicated in HF progression. This hypothesis is supported by interventional studies demonstrating reductions in cardiovascular biomarkers such as NT-proBNP and mean platelet volume following non-surgical periodontal therapy in patients with coexistent periodontitis and HF (34,35). However, whether these biomarker improvements translate into clinically meaningful improvements in Hf outcomes, such as reduced hospitalisation, improved ejection fraction or reduced mortality, remains to be established through well-designed randomised controlled trials.

Despite the growing body of evidence linking periodontal disease to cardiovascular conditions broadly, studies specifically examining the relationship between periodontitis and HF as a distinct clinical entity remain limited. Most existing reviews have focused on the association between periodontitis and cardiovascular disease as a general category, without isolating HF as a specific outcome. Furthermore, the potential impact of periodontal treatment on HF prognosis remains largely unexplored. This systematized review therefore aims to consolidate the available primary evidence, clarify he nature and extent of the association between periodontitis and HF, and identify gaps in the current literature that require further investigation.

2. OBJECTIVES

1. To evaluate the association between clinically diagnosed periodontitis and the prevalence or incidence of heart failure in adult patients.
2. To assess the degree to which periodontitis modifies the likelihood, clinical severity and progression of HF.
3. To determine whether heart failure outcomes and related systemic inflammatory markers are linked to periodontal clinical measures such as clinical attachment, probing depth, gingival bleeding on probing, radiographic bone loss and disease staging according to the 2017 World Workshop.
4. To evaluate whether periodontal treatment in HF patients impacts HF prognosis.

3. MATERIAL AND METHODS

3.1. Formulation of the research question

The research question was structured according to the PICO framework

- **P** = Adults with periodontitis
- **I** = Presence/severity of periodontitis
- **C** = Individuals without periodontitis
- **O** = Risk or severity of heart failure. Presence or worsening of HF

The tailored research question is: In adults, does the presence of periodontitis compared with healthy periodontal status increase the risk or severity of heart failure? Hypothesis: Increasing severity of periodontitis is associated with greater severity or poorer clinical outcomes of HF patients

3.2. Study type and design

Systematized literature review.

3.3. Eligibility Criteria

- Inclusion criteria:
    - Articles involving human participants over 18 years old
    - Studies analyzing the association between periodontitis and heart failure
    - Articles published between 2010 and 2025
    - Primary evidence
- Exclusion criteria:
    - Animal or in vitro studies
    - Systematic or narrative reviews, case reports, editorials and letters

3.4. Sources of Information

Five electronic database searches were systematically searched: PubMed, Scopus, MEDLINE Complete, Web of Science and Wiley Online Library. Additional records were identified manually through the reference lists of selected articles to ensure a comprehensive search.

3.5. Search Strategy

This search was conducted using a combination of MeSH terms and free-text terms, as follows:

((Humans) OR (Adults)) AND ((Periodontal diseases) OR (Periodontitis) OR (Gum disease)) AND ((Heart failure) OR (cardiovascular disease))

MeSH terms used: Periodontal diseases, Heart failure. Free terms used: Periodontitis, Gum disease, Cardiovascular disease, Adults.

The search was performed on January 9th 2026.

3.6. Study Selection Process

The full selection process will be illustrated using a **PRISMA-type flowchart (figure 2)**.

4. RESULTS

4.1 Study Selection

A total of 488 records were identified through the selected databases. Following the removal of duplicate records, 268 references remained for title and abstract screening. During this phase, studies that clearly did not examine the relationship between periodontitis and heart failure were excluded, together with review articles, case reports, animal studies, and other forms of non-primary research (n = 238).

Twenty-nine articles advanced to full-text review. Following detailed evaluation, 12 studies were excluded due to insufficient primary data, inadequate periodontal assessment, absence of heart failure specific outcomes, or failure to meet predefined inclusion criteria regarding study population. Ultimately, 17 primary research articles fulfilled all inclusion requirements and were incorporated into the qualitative synthesis. The complete selection process is depicted in the PRISMA 2020 flow diagram (36) represented in Figure 2.

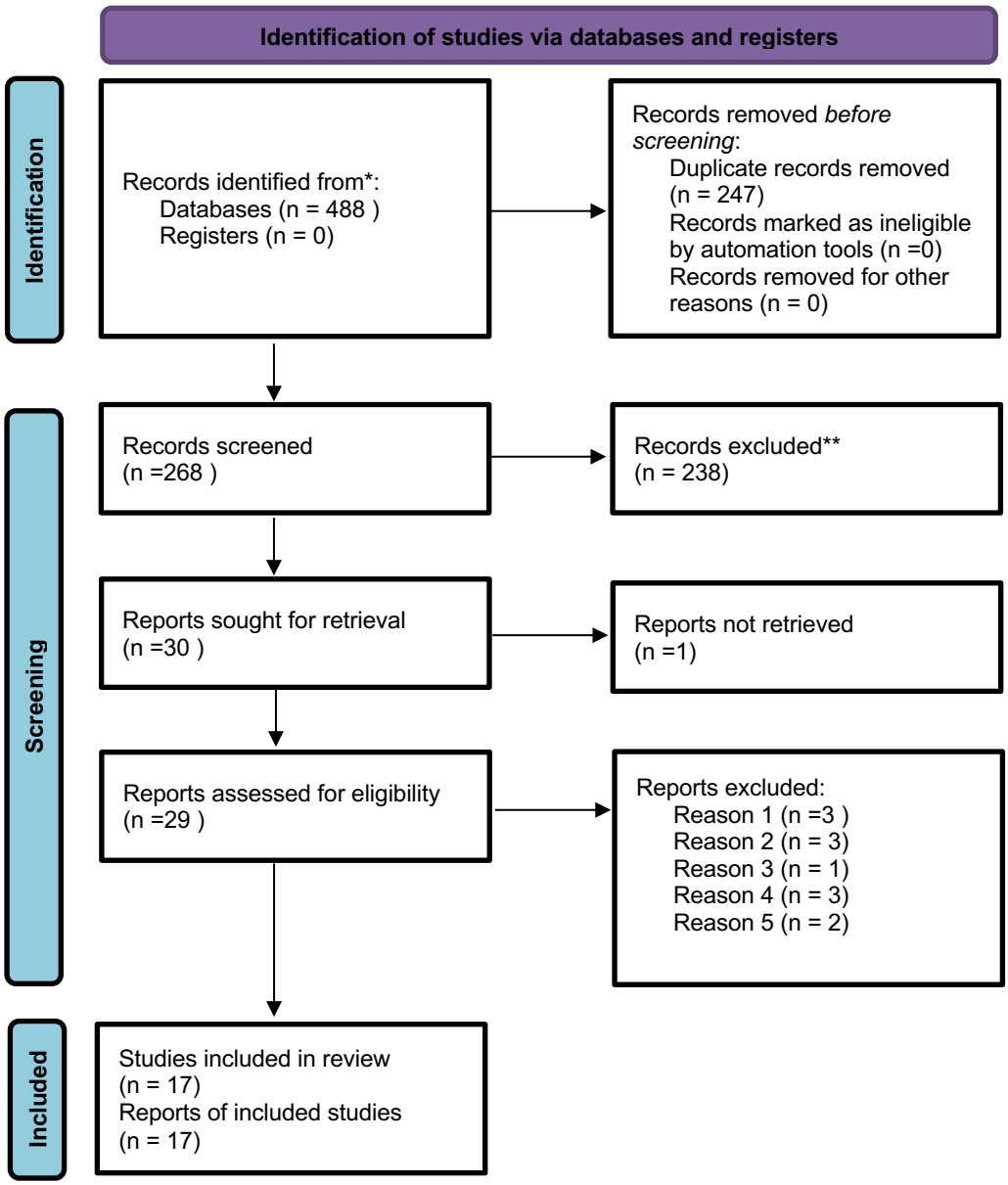


Figure 2. PRISMA flow diagram of the study selection process (36)

Reason 1: Review/consensus articles (n = 3)

Reason 2: Outcome not heart failure (n = 3)

Reason 3: Composite cardiovascular outcome (n = 1)

Reason 4: Exposure not clinically defined periodontitis (n = 3)

Reason 5: Mechanistic/genetic studies (n = 2)

4.2 Characteristics of included studies

The 17 included studies were published between 2016 and 2025 and were conducted acrosds eight countries including the United States, Germany, South Korea, Poland, Japan, Taiwan,

Romania and India. The studies included cohort studies, cross-sectional studies, retrospective cohort studies, and pilot interventional studies. Participant numbers differed substantially across studies, spanning from small-scale clinical investigations with under 100 subjects to large nationwide cohort studies including more than 160,000 individuals. The study populations included general population samples, patients with cardiovascular disease, patients with type 2 diabetes, and HF patients. An overview of the geographic distribution and study designs of the included studies is presented in Figure 3.

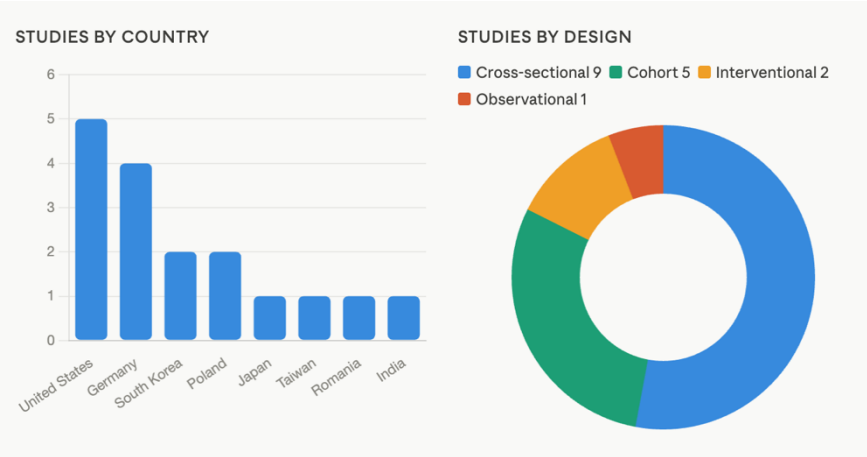


Figure 3. Geographic distribution and study design of included studies (n = 17)

As illustrated in Figure 3, the United States and Germany contributed the lardest number of studies, with five and four studies respectively, while South Korea and Poland each contributed two studies. The remaining four countries, Japan, taiwan, Romania and India, each contributed one study. Regarding study design, cross sectional studies wer the most fequently used methodology, accounting for more than half of the included studies, followed by cohort studies. Periodontal status was assessed using a variety of clinical indicators among them pocket probing depth (PD), clinical attachment loss (CAL), bleeding on probing (BOP), periodontal indices, and number of missing teeth. Certain studies additionally incorporated self-reported oral hygiene practices, including brushing habits, frequency of professional dental scaling and regularity of dental visits, as indicators for oral health status.

HF outcomes were evaluated using different measures across studies, including incident heart failure diagnosis, hospitalization due to heart failure, clinical HF classification, and cardiac biomarkers such as N-terminal pro-B type natriuretic peptide (NT-proBNP).

A comprehensive summary of the characteristics of each included study is provided in Table 1.

Table 1. Characteristics of the studies included in the systematic review on the association between periodontitis and Heart Failure (HF).

Author	Year	Country	Study Design	Population	Sample size	Periodontal Assessment	Heart failure outcomes	Key findings
Frölich et al. (37)	2016	Germany	Cross sectional study	Patients with stable chronic HF attending an outpatient HF clinic	71 HF patients	Periodontal Screening Index, PB, BOP, calculus	Presence and severity of chronic heart failure (NYHA classification, LVEF)	Periodontitis prevalence was significantly higher in chronic HF patients compared with the general population
Schulze-Späte et al. (38)	2017	United States	Cross sectional study	Patients with advanced HF post-heart transplant patients and controls	109 participants (39 HF, 38 transplant, 32 controls)	Full clinical periodontal exam: PB, CAL, BOP, plaque, cumulative pocket depth	Presence of advanced heart failure (NYHA classification)	Patients with advanced HF showed more severe periodontal disease than controls
Czerniuk et al. (34)	2017	Poland	Pilot clinical study	Patients with chronic congestive HF and periodontitis	39 patients	Clinical periodontal exam (CAL, PD, plaque index, BOP)	NT-proBNP biomarker levels before and after periodontal treatment	Periodontal treatment significantly reduced NT-proBNP and TNF-α levels, indicating improved inflammatory status in HF patients
Peng et al. (39)	2017	Taiwan	Retrospective cohort study	Patients with type 2 diabetes and periodontitis	15,195 patients (3,039 advanced periodontal treatment; 12,156 non-advanced)	Periodontitis identified using ICD-9 diagnostic codes and periodontal treatment records	Incidence of cardiovascular outcomes including myocardial infarction, stroke, and heart failure	Advanced periodontal treatment significantly reduced the risk of HF

Aoyama et al. (40)	2019	Japan	Cross-sectional study	Hospitalized patients with cardiovascular diseases	348	Periodontal examination (PD, CAL, BOP) + salivary bacterial analysis and IgG antibodies against periodontal pathogens	Heart failure prevalence compared between high and low antibody groups	Higher antibody levels against *Porphyromonas gingivalis* were associated with increased prevalence of HF
Czerniuk et al. (35)	2019	Poland	Pilot interventional study	Patients with congestive HF and periodontal disease	50 patients	CAL, PD, plaque index, BOP	Mean platelet volume (MPV) related to CHF status	Periodontal treatment significantly reduced mean platelet volume levels and improved inflammatory markers in patients with HF
Chang et al. (41)	2020	South Korea	Nationwide population based cohort study	Adults aged 40-79 from the Korean National Health Insurance Health Screening Cohort	161,286	Periodontal disease diagnosis, number of missing teeth, tooth brushing frequency, dental visits, professional dental cleaning	Incident heart failure identified using ICD-10 code I50 during follow-up	Frequent tooth brushing and professional dental cleaning were associated with lower risk of HF
Yan et al. (42)	2022	United States	Cross-sectional study (NHANES III)	Adults ≥18 years with periodontal examination data	13,202 participants	Clinical periodontal exam using PD and CAL (classified as no/mild vs moderate/severe periodontitis)	Self-reported physician diagnosis of heart failure	Moderate to severe periodontitis was significantly associated with increased risk of HF
Molinsky et al. (43)	2022	United States	Prospective cohort study (ARIC study)	Community-based adults aged 53-75 years	6707 participants	Full-mouth periodontal examination (PD, CAL, BOP); categorized as healthy, periodontal disease, or edentulous	Incident heart failure including HFpEF and HFrEF during follow-up	Periodontal disease and edentulism were associated with increased risk of incident HF

Walther et al. (44)	2022	Germany	Cross-sectional study	Adults from the Hamburg City Health Study	6209	Clinical periodontal examination (PD, CAL, BOP; Eke & Page classification)	Heart failure phenotypes (HFpEF, HFmrEF/HFrEF) assessed using echocardiography and ESC guidelines	Severe periodontitis was significantly associated with HF with reduced/mildly reduced ejection fraction
Schmalz et al. (45)	2023	Germany	Retrospective cohort study	Patients with severe HF, heart transplant or LVAD	329 patients	Probing PD, CAL, BOP, Periodontal Inflamed Surface Area (PISA), periodontal staging/grading	Infection outcomes and survival in HF patients	Periodontal inflammation was associated with increased infections but not with overall survival in HF patients
Huh et al. (46)	2023	South Korea	Nationwide retrospective cohort study	Adults ≥40 with type 2 diabetes from Korean NHIS	173,927	Dental examination assessing periodontal disease, dental caries, and number of missing teeth	Incident heart failure identified using ICD-10 code I50 during hospitalization	Greater tooth loss increased HF risk, while good oral hygiene practices reduced risk
Wang et al. (47)	2023	United States (NHANES database)	Cross-sectional study with machine learning prediction model	Adults > 40 years with periodontitis from NHANES 2009-2014	2876 participants	Full mouth periodontal examination performed by dental hygienists	Presence/ risk of heart failure	Machine learning models identified periodontal diseases as an important predictor of HF risk
Schulze et al. (48)	2024	Germany	Cross-sectional study	Patients with chronic HF (NYHA I-II)	58 patients	Periodontal Screening and Recording (PSR)	Cardiac biomarkers (NT-proBNP, hsTroponin T) and echocardiographic parameters (EF, E/A, MAPSE)	HF patients with periodontitis showed higher NT-proBNP and troponin T levels and impaired cardiac function

Guan et al. (49)	2025	United States (NHANES database)	Observational cross-sectional study	Adults ≥20 years from NHANES 2009–2014	12,236	CAL and PD using CDC/AAP definitions	Congestive heart failure, cardiovascular mortality, and all-cause mortality	Periodontitis was associated with increased risk of CHF, cardiovascular mortality and all-cause mortality
Cinezan et al. (50)	2025	Romania	Cross-sectional study	Patients hospitalized with myocardial infarction	200	Number of missing teeth categorized (0–8, 9–20, >20) and oral hygiene questionnaire	Heart failure defined as LVEF <40% or clinical diagnosis	Severe tooth loss (>20 teeth) was associated with higher HF prevalence and reduced ejection fraction
Sharma et al. (51)	2025	India	Cross-sectional study	Patients with chronic HF NYHA II–III, LVEF <40%)	154 patients	Periodontal Screening Index (PSI), PD, plaque, bleeding	NT-proBNP levels	Moderate to severe periodontitis was associated with significantly higher NT-proBNP levels in CHF patients

4.3 Main findings of the included studies

4.3.1 Association between periodontitis and HF

Several studies reported a significant association between periodontitis and HF risk or related cardiovascular outcomes. Population-based cohort studies demonstrated that individuals with moderate to severe periodontitis or poor oral health indicators carried a greater probability of developing HF relative to periodontally healthy individuals (42,49). Large epidemiological studies demonstrated that tooth loss, periodontal deterioration, and poor hygiene behaviors were were linkied to a heightened risk of adverse cardiovascular events, including HF. Conversely, enhanced oral hygiene behaviours, notably regular tooth brushing and professional scaling were inversely associated with HF risk (41,46). Additionally, studies conducted among patients with existing cardiovascular disease or HF documented a substantial burden of periodontitis among these patients, suggesting a possible relationship between oral health status and progression or severity of cardiovascular disease.

4.3.2 Biological mechanisms linking periodontitis and heart failure

In addition to epidemiological associations, some studies explored the pathophysiological pathways through which a periodontal disease may be mechanistically connected to HF, with particular focus on inflammatory cascades and cardiac biomarker profiles.

Increased concentrations of both inflammatory markers, particularly C-reactive protein and cardiac biomarkers such as N-terminal pro-B-type natriuretic peptide (NT-proBNP) were observed in individuals with both periodontal disease and HF. These findings support the hypothesis that periodontal inflammation may contribute to systemic inflammation, which plays an important role in cardiovascular disease development and progression (48,51).

Furthermore, periodontal treatment was shown to reduce cardiovascular related biomarkers, such as reductions in mean platelet volume, inflammatory markers and NT-proBNP levels suggesting that periodontal therapy may potentially contribute to improved cardiovascular health (34,35).

Other studies focused on specific periodontal pathogens and inflammatory burden. For instance, higher antibody levels against *Porphyromonas gingivalis* were associated with increased prevalence of HF (40).

Regarding the impact of periodontal treatment on HF prognosis, two pilot interventional studies specifically examined whether non surgical periodontal therapy could influence cardiovascular outcomes in patients with coexistent periodontitis and HF. Czerniuk et al. (34) reported that periodontal treatment led to a significant reduction in plasmatic NT-proBNP concentrations, a

key biomarker of cardiac dysfunction, as well as decreased levels of tumour necrosis factor-alpha, indicating an imprpovement in the systemic inflammatory profile of HF patients following periodontal intervention. A subsequent study by the same group (35) demonstrated that periodontal treatment also significantly reduced mean platelet volume, an emerging marker of platelet activation and cardiovascular risk, in patients with congestive HF and periodontal disease. While these findings are preliminary given the small sample sizes and pilot nature of both studies, they provide early evidence suggesting that periodontal treatment may have a beneficial effect on the inflammatory and cardiovascular burden of HF patients, supporting the potential clinical relevance of periodontal care in this population.

4.3.3 Overall findings

Overall, the included studies consistently suggest a positive association between periodontitis and HF. Poor periodontal health, tooth loss, and inadequate oral hygiene practices were frequently associated with increased cardiovascular risk, while improved oral hygiene behaviors and periodontal treatment were associated with potential protective effects. Regarding methodological quality, it should be noted that the majority of included studies were observational in design, comprising cross-sectional and cohort studies, which limits the ability to establish causal relationships between periodontitis and HF. Furthermore, considerable heterogeneity was observed across studies in terms of periodontal assessment methods, with some studies relying on full clinical periodontal examinations while others used proxy measures such as tooth loss or self reported oral health behaviours. Similarly, HF outcome definitions vaired across studies, with some reelying on clinical diagnosism others on ICD diagnostic codes, and others on cardia biomarker levels. This methodological variability may affect the comparability of results across studies and should be considered when interpreting the overall findings of this review. However, the studies varied in methodology, population characteristics, and periodontal assessment methods. Therefore, while the available evidence supports a significant association between periodontal disease and HF, further well-designed prospective studies are needed to better clarify the causal mechanisms and clinical implications of this relationship.

5. DISCUSSION

The findings of this systematized review consistently support a positive association between periodontitis and heart failure, corroborating the biological plausibility outlined in the theoretical framework. Across diverse populations, study designs and geographic settings,

periodontal disease emerged as a condition significantly linked to HF risk, severity and progression. Importantly, the evidence extends beyond simple epidemiological association — several studies demonstrated that periodontal inflammation correlates with established cardiac biomarkers such as NT-proBNP and C-reactive protein, suggesting a shared pathophysiological axis rather than mere coincidental co-occurrence.

What is particularly notable is that this association persisted across different HF phenotypes, periodontal assessment methods and population characteristics, lending robustness to the overall findings. Furthermore, the preliminary interventional evidence suggesting that periodontal treatment may reduce cardiovascular inflammatory burden represents a clinically significant observation, as it implies that periodontitis is not merely a marker of systemic inflammation but potentially a modifiable contributor to HF progression.

Nevertheless, important caveats must be acknowledged from the outset. The predominance of observational study designs, considerable methodological heterogeneity and variability in both periodontal and HF outcome definitions limit the strength of causal inference that can be drawn. These considerations will be examined in detail throughout this discussion.

5.1 Possible biological mechanisms linking periodontitis and HF

One of the most widely proposed mechanisms linking periodontitis and HF is systemic inflammation. Through ulcerated periodontal tissues, pathogens and inflammatory mediators enter the systemic circulation, causing transient bacteraemia and a chronic systemic immune inflammatory state. This inflammatory cascade facilitates endothelial dysfunction, increased arterial stiffness and atherosclerosis, which are key precursors to the development and progression of HF.

Keystone periodontal pathogens such as *Porphyromonas gingivalis* stimulate the production of pro-inflammatory cytokines including tumour necrosis factor-α, interleukin-6 and C reactive protein. These signalling molecules are well established as key drivers of cardiovascular pathology and disease advancement, including HF, by promoting myocardial injury, adverse ventricular remodelling and progressive deterioration of cardiac functions.

A further potential mechanism involves direct immune and vascular responses triggered by periodontal bacteria. These pathogens can directly infiltrate vascular tissues or induce maladaptive immune reactions which, over time, result in progressive structural and functional deterioration of the cardiovascular system, thereby amplifying an individual's vulnerability to HF. Taken together, these biological pathways provide a plausible mechanistic basis for the epidemiological associations observed between periodontitis and Hf in the included studies.

From a therapeutic standpoint, the biological mechanisms described above provide a rationale for investigating whether periodontal treatment could modify HF outcomes. By reducing the periodontal inflammatory burden, non-surgical periodontal therapy may decrease the systemic dissemination of bacterial products and pro-inflammatory cytokines, potentially alleviating the inflammatory and oxidative stress that drives cardiac remodelling and HF progression (15). The pilot interventional studies included in this review, provide preliminary support for this hypothesis, demonstrating significant reductions in NT-proBNP and mean platelet volume following periodontal treatment in HF patients (34,35). These findings suggest that periodontal therapy may represent a novel and accessible adjunctive strategy in the management of HF, though the evidence remains preliminary and larger interventional studies are needed to confirm these effects.

5.1.1.Pharmacological effects of HF treatment on periodontal health

An important and often overlooked consideration in the relationship between periodontitis and HF concerns the potential iatrogenic effects of HF pharmacotherapy on oral health. Several medications commonly prescribed in the management of HF, particularly diuretics such as furosemide, chlorothiazide and hydrochlorothiazide, are known to induce xerostomia, a clinically significant reduction in salivary flow, as a recognised side effect (52). Saliva plays a pivotal role in the maintenance of oral health by providing antimicrobial defence, buffering acids and facilitating remineralisation of dental tissues. A reduction in salivary flow therefore compromises these protective mechanisms, creating an oral environment more susceptible to dysbiotic biofilm accumulation and periodontal inflammation (52). Indeed, patients taking diuretic medications have been shown to exhibit a significantly higher prevalence of periodontal disease compared with non-medicated controls (53). This pharmacologically induced xerostomia may therefore represent an additional and clinically relevant pathway through which HF indirectly contributes to the worsening of periodontal health, further reinforcing the bidirectional nature of the relationship between these two conditions. Dental professionals should therefore be aware of the potential oral health consequences of long-term diuretic therapy, and physicians managing HF patients may benefit from incorporating routine dental referral intro comprehensive patient care pathways.

5.2 Comparison with previous literature

The results of this systematized review corroborate a growing body of prior evidence pointing towards a clinically meaningful connection between periodontal disease and cardiovascular

conditions. Several epidemiological studies and consensus reports have previously reported that periodontitis confers an elevated risk of cardiovascular conditions encompassing coronary artery disease, cerebrovascular events and HF. The results of the present review support these observations as many of the included studies demonstrated a direct relationship between periodontal disease severity and HF risk or related cardiovascular outcomes.

Previous higher-order evidence syntheses have also reported associations between periodontal disease and cardiovascular pathology, highlighting the role of chronic inflammation as a possible linking mechanism. These studies suggest that the systemic inflammatory burden caused by periodontal infections may accelerate the onset or advancement of cardiovascular diseases. The findings of the present review align with the evidence, as several included studies identified elevated inflammatory markers and cardiovascular biomarkers in patients with both periodontitis and HF.

Furthermore, previous literature has emphasized the importance of oral hygiene and periodontal treatment in reducing the systemic inflammatory burden and improving cardiovascular health. Similarly, some of the studies included in this review reported that improved oral hygiene practices or periodontal treatment were associated with lower cardiovascular risk or improved inflammatory profiles. These findings greatly support the hypothesis that maintaining good periodontal health may play a role in cardiovascular disease prevention.

Despite the convergence of evidence linking periodontal to cardiovascular conditions, whether this relationship is truly causal in nature continues to be uncertain and debated. Some researchers suggest that shared risk factors, such as smoking, diabetes, aging and socioeconomic status may partly explain the observed associations. However, the persistence of significant associations after multivariate adjustment in several large cohort studies suggests that biological mechanisms beyond shared confounders may be operative, supporting the hypothesis of an independent relationship between periodontitis and HF.

5.3 Strengths and limitations

The present review presents several methodological strengths. The study followed a structured methodology for identifying and selecting the relevant literature to conduct the study, including a comprehensive database search and a transparent article selection procedure based on explicitly defined eligibility criteria applied consistently throughout. The use of the PRISMA framework helped ensure a reproducible approach to the study identification and reporting. Furthermore, the inclusion of studies conducted across multiple countries and diverse

populations provides a broader and more generalisable overview of the association between periodontitis and HF.

Despite these strengths, several limitations should also be considered. First, most of the included studies were observational in design. As shown in Figure 3, cross sectional studies accounted for more than half of the included studies, which inherently limits the ability to establish temporal relationships or causal inferences between periodontitis and HF. As a result, a causal relationship between periodontitis and HF was not definitively established. Second, considerable heterogeneity was evident across the included studies, spanning differences in research design, participant characteristics, periodontal measurement approaches and HF outcome definitions. Third, differences in the measurement of periodontal disease, such as the use of probing depth, clinical attachment loss, tooth loss or proxy measures such as self-reported oral hygiene behaviours, may have influenced the reported associations. Some studies also relied on self-reported diagnoses or administrative data to identify HF outcomes, which may introduce potential measurement bias. Finally, as only published studies were included, the possibility of publication bias cannot be excluded.

5.4 Clinical implications and future research

The evidence gathered in this review underscores the clinical relevance of periodontal health as part of a broader cardiovascular disease prevention and management framework. If periodontitis contributes to the development or progression of HF, maintaining good periodontal health may represent an additional and accessible strategy to reduce systemic inflammatory burden and potentially improve cardiovascular outcomes. As periodontitis is a common and largely preventable condition, early detection and appropriate periodontal treatment could have beneficial implications not only for oral health but also for broader systemic health outcomes. These findings also emphasize the importance of interdisciplinary collaboration between dental and medical professionals. Dentists may play a key role in identifying individuals with poor periodontal health who may be at increased risk of cardiovascular complications, while physicians managing patients with HF or other cardiovascular conditions may benefit from considering oral health status as part of a comprehensive patient assessment. Promoting good oral hygiene practices, including regular tooth brushing, professional dental cleaning and routine dental examinations may therefore contribute to improved overall health outcomes and represents a low-cost preventive strategy. Despite the growing body of evidence suggesting an association between periodontitis and HF, further research is needed to clarify the nature and directionality of this relationship. Future

studies should prioritise well-designed randomised controlled trials and longitudinal interventional studies to determine whether periodontal treatment can directly and causally influence cardiovascular outcomes including Hf incidence, severity and progression. In addition, further investigation into the specific biological mechanisms linking periodontal inflammation and cardiac dysfunction, including the role of specific periodontal pathogens, cytokine profiles and oxidative stress pathways, may help to better explain the observed associations and identify potential therapeutic targets. Standardisation of periodontal assessment methods and HF outcome definitions across future studies would also greatly improve comparability and strengthen the evidence base in this field.

6. CONCLUSIONS

1. The available evidence consistently supports a positive association between periodontitis and HF. Multiple studies demonstrated that individuals with moderate to severe periodontitis, greater tooth loss or poor oral hygiene practices had a higher prevalence or incidence of HF compared with individuals with good periodontal health. This association was observed across diverse populations and study designs, suggesting that periodontitis may represent an independent risk factor for HF development.
2. Periodontitis appears to exert a measurable impact on HF risk, severity and progression. Large population-based cohort studies reported that greater periodontal disease severity was associated with increased HF incidence, while studies conducted in patients with established HF demonstrated higher periodontal disease prevalence and severity compared with control populations. These findings suggest that the burden of periodontal disease may contribute to the development and worsening of HF.
3. Several periodontal clinical parameters were found to be associated with HF outcomes and related systemic inflammatory markers. Clinical attachment loss, probing depth, periodontal inflammation and tooth loss were frequently linked to elevated cardiovascular biomarkers including NT-proBNP and C-reactive protein, as well as to indicators of cardiac dysfunction such as reduced ejection fraction. These findings suggest that periodontal disease severity may reflect and contribute to the systemic inflammatory burden observed in HF patients.
4. Preliminary evidence from pilot interventional studies suggests that non-surgical periodontal treatment may have a beneficial impact on HF prognosis by reducing systemic inflammatory and cardiac biomarkers, including NT-proBNP, tumour necrosis factor-alpha and mean platelet volume. However, given the small sample sizes and pilot

nature of the available interventional studies, definitive conclusions cannot yet be drawn. Further well-designed randomised controlled trials are needed to clarify whether periodontal treatment can directly and causally improve cardiovascular outcomes in HF patients.

7. SUSTAINABILITY

The sustainability of this research lies in its contribution to long-term improvements in both oral and systemic health, in alignment with Sustainable Development Goal 3 (Good Health and Well-being). Understanding the association between periodontitis and heart failure provides a foundation for preventive strategies that can be maintained within healthcare systems over time.

From an economic perspective, investing in early periodontal assessment and promoting oral hygiene habits are cost-effective strategies. Preventing periodontal disease progression may minimise cardiovascular complications, reduce hospitalisations related to heart failure and decrease the long-term economic strain on health systems, supporting a more efficient use of healthcare resources.

From a social perspective, raising awareness of the connection between oral and cardiovascular health fosters behavioural changes sustained across generations. Interdisciplinary collaboration between dentists, cardiologists and primary care providers contributes to a healthcare model that prioritises prevention and patient empowerment.

Finally, by identifying gaps in current evidence and highlighting the need for longitudinal and interventional studies, this dissertation encourages continued scientific inquiry. Strengthening the evidence base supports the integration of periodontal health into cardiovascular risk assessment frameworks, ultimately contributing to healthier and more resilient populations.

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