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The Association between Dental Caries and Cardiovascular Disease: A Scoping Review

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Abstract

Cardiovascular disease (CVD) is the leading cause of morbidity and mortality worldwide. Several epidemiological studies have reported oral health as one of the risk factors for CVD. This scoping review aimed to present evidence from published reports regarding the association between dental caries and CVD incidence. The search strategy was conducted using available databases (PubMed, Scopus, and ProQuest) for studies published from January 2013 to December 2023 in the English language. The retrieved articles were further evaluated according to the inclusion and exclusion criteria, and 24 relevant articles were selected for review to support the evidence based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for scoping review guidelines. Furthermore, 12 cross-sectional, 5 case-control, and 7 cohort studies reported a correlation between dental caries and CVD incidence. The results of this review suggest an association between dental caries and CVD through oral infection or pathogen-induced oral inflammatory mediators. Moreover, other potential factors that increase the risk of CVD include age, hypertension, tobacco smoking, diabetes mellitus, stress, genetic predisposition, physical activity, alcohol consumption, health behaviors, obesity, antibiotic supplementation, awareness of oral health, access to health care, nutrition, and low socioeconomic status. Despite the limited number of studies, there is much evidence of an association between dental caries and CVD incidence. Understanding the association between dental caries and CVD plays a pivotal role in patient education and treatment planning. To expand the search source and evidence, future systematic reviews and meta-analyses should investigate the associations between dental caries and CVD.

Keywords
- atherosclerosis
- decayed teeth
- heart disease
- stroke

Introduction

Cardiovascular disease (CVD) is the leading cause of death globally, causing nearly 18 million deaths annually. CVDs refer to a spectrum of disorders of the heart and blood vessels and include coronary heart disease, cerebrovascular disease, rheumatic heart disease, and other conditions.[1] The total number of CVD cases increased from 271 million in 1990 to 523 million in 2019. The number of CVD-related deaths steadily increased from 12.1 million in 1990 to 18.6 million

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in 2019, representing 32% of all global deaths.[2] In several countries, CVD mortality is higher among people in low- and middle-income countries, including Indonesia.[3] Indonesia has a high and increasing burden of CVD and associated risk factors. Basic Health Research (Riskesdas), a nationally representative health survey, revealed that the prevalence of diagnosed stroke among people aged ≥15 years increased by 56% between 2013 and 2018 (from 0.7 to 1.1%). Moreover, the incidence of hypertension among people aged ≥18 years also increased by 32% (from 26 to 34%) between 2013 and 2018.[4] Epidemiological studies have reported various risk factors for CVD, such as smoking, physical activity, dyslipidemia, fruit consumption, vegetable consumption, alcohol consumption, diabetes, and oral health status.[5]

Poor oral health is often associated with CVD incidence or mortality.[6,7] Dental caries and periodontal disease are the most prevalent and severe oral conditions worldwide.[3] Existing epidemiological evidence has revealed an association between periodontitis and CVD incidence.[5,6] Two potential mechanisms explain why chronic periodontitis increases subclinical atherosclerotic CVD through direct and indirect associations.[7] Directly, periodontal pathogens enter through the bloodstream, causing bacteremia. However, these agents indirectly increase the level of systemic inflammatory mediators, which increases the risk of CVD.[7–9] A previous study reported that dental caries might be considered a potential trigger for hypertension in children/adolescents when all other potential causes of secondary hypertension have been excluded. One possible mechanism is severe dental caries, which may negatively affect coronary endothelial cells, resulting in a chronic inflammatory response.[10]

Advance dental caries and severe periodontal disease are the major causes of tooth loss.[11] *Streptococcus mutans* degrades sugars and produces lactic acid, resulting in tooth decay—demineralization of the tooth structure. If the decay progresses to the pulp, there is a risk of pain, swelling, and tooth loss.[12] A prior study reported a link between periodontal disease and tooth loss. In the early stages of periodontal disease, clinical signs and symptoms may be absent or very mild. When periodontal tissue destruction occurs, deepened pocket depths combined with alveolar bone loss cause tooth mobility, drifting, and flaring, potentially resulting in the loss of the affected tooth.[13] However, the causal relationship between dental caries and CVD incidence remains unclear, and limited clinical evidence of an association between dental caries and CVD incidence has been reported.

Appropriate strategies and interventions are needed to promote and prevent dental caries and CVD due to their high prevalence and impact on quality of life. Thus, the Indonesian government launched a national health insurance scheme, the Jaminan Kesehatan Nasional, in 2014 to address the issue of inadequate access to health services.[14,15] The Indonesian Ministry of Health also organized health promotion activities through Pos Pelayanan Terpadu (Posbindu), a community engagement program that focuses on improving public awareness of early screening and detection efforts for noncommunicable diseases.[16] Despite these efforts, evidence on the association between CVD and dental caries in Indonesia remains insufficient, consequently preventing further service response planning. Examining their associations can provide additional evidence of the link between a person's oral health status and CVD incidence. This scoping review collates and presents evidence from studies assessing the association between dental caries and CVD and the potential mechanisms of this association. Specifically, this study was conducted to define areas where new evidence of an association between dental caries and CVD is available.

Methods

In this study, we used a scoping review methodology following the guidelines of the Joanna Briggs Institute.[17] This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews (PRISMA-ScR), a modified version of the PRISMA guidelines, and was guided by two questions: (1) What is the existing evidence on the possible links between CVD and dental caries? (2) What is the possible link between dental caries and CVD?[18]

Eligibility Criteria

The assessment criteria used in this study are based on the population, concept, and context framework. Every selected study included a group of people with CVD (population), a discussion regarding the association between dental caries and CVD (concept), and original research (context). We included the following categories of studies: (1) research articles with the following study design: cross-sectional, cohort, and case-control; (2) human clinical studies that investigated the association between dental caries and CVD; (3) articles that were open access and written in English; and (4) articles that reported dental caries as the main variable as well as various forms of CVD. We excluded the following categories of articles: (1) articles that did not fit within the conceptual framework of the study; (2) systematic review articles; and (3) animal studies, case reports, case series, conference proceedings, editorials, and commentaries. Articles that met the inclusion criteria were included in the review, and the total number of studies that were excluded was recorded.

Information Sources and Article Selection

Relevant articles published within the last 10 years (from January 2013 to December 2023) were identified from several databases, including PubMed, Scopus, and ProQuest. Articles investigating the association between dental caries and CVD incidence were considered. The search terms and strategies used for each database are listed in ►**Table 1**. Another search strategy entailed searching reference lists of the included articles. All studies identified through the search strategy were imported into Mendeley libraries (version 1.19.8), and duplicate articles were removed. The selected articles were analyzed in the full-text version and were thoroughly, critically, and objectively reviewed and discussed; thereafter, an explanation of the results was

Table 1 The search strategy in database using keywords

Search engine	Search strategies
PubMed	("dental caries" [MeSH Terms] OR "caries" [Title/Abstract] OR "carious lesions" [Title/Abstract] OR "carious lesion" [Title/Abstract]) AND ("cardiovascular diseases" [MeSH Terms] OR "cardiovascular disease" [-Title/Abstract] OR "stroke" [MeSH Terms] OR "stroke" [Title/Abstract] OR "heart diseases" [MeSH Terms] OR "heart diseases" [Title/Abstract] OR "atherosclerosis" [MeSH Terms] OR "atherosclerosis" [Title/Abstract])
Scopus	((TITLE-ABS-KEY (dental AND caries) OR TITLE-ABS-KEY (caries) OR TITLE-ABS-KEY (carious AND lesions))) AND ((TITLE-ABS-KEY (cardiovascular AND diseases) OR TITLE-ABS-KEY (stroke) OR TITLE-ABS-KEY (heart AND diseases) AND TITLE-ABS-KEY (atherosclerosis)))
ProQuest	Set#: S1 Searched for: ab ("dental caries") OR ab ("caries") OR ab ("carious lesions") Set#: S2 Searched for: ab ("cardiovascular diseases") OR ab ("stroke") OR ab ("heart diseases") OR ab ("atherosclerosis") Set#: S3 Searched for: [S1] AND [S2]

compiled. A data charting form was used to extract information on the first author, country, study design, study aim, participants (number and age), outputs, key findings, and conclusion from the articles.

Article Selection, Data Charting, and Analysis

The eligibility criteria were independently assessed by two reviewers (A.R.1 and V.V.); the titles and abstracts of the articles were evaluated for topic relevance; and the full texts of potentially relevant articles were extracted. Any disagreements between reviewers were resolved through consultation and discussion with a third independent reviewer (A. R.2). The findings from studies examining the association between dental caries and CVD incidence were summarized by the authors.

Results

A total of 1,198 research articles were identified through a selected keywords search of electronic databases and references. After duplicates were eliminated and relevant studies were selected based on the title and abstract, 43 full-text articles were retrieved and evaluated for eligibility. Of these, 19 articles were excluded per the exclusion criteria. The remaining 24 studies investigating the association between dental caries and CVD incidence were considered for this review (►**Fig. 1**). The characteristics of the included studies are presented in ►**Table 2**. The countries where these studies were conducted included Germany ($n = 3$) and the United States ($n = 4$), followed by Turkey, Iran, Sudan, Finland, and the Republic of Korea ($n = 2$ each). Other countries with fewer than two studies included Brazil, Austria, Australia, Hungary, Poland, Japan, and Syria. The minimum and maximum numbers of participants included in any given study were 49 and 234.597, respectively. The research subjects varied between primary, mixed, and permanent dentition, with sample ages ranging from 3 to 79 years.

►**Table 3** presents a summary of these studies. Most of the studies were cross-sectional ($n = 12$), and the mean decayed, missing, and filled teeth (DMFT) score in the study group ranged from 0.81 ± 1.63 to 20.13 ± 8.08.[19,20] Four studies reported higher DFMT scores in patients with CVD[19,21–23] than in controls, while three studies did not.[24–26] There is a positive association between DMFT and CVD incidence.[2,20–23,26,27] One study reported that the number of decayed surfaces per tooth was associated with a greater aortic atherosclerotic burden, whereas the number of restorations was negatively correlated.[2] Compared with those in the control group, children with congenital heart defect (CHD) were more severely affected by dental caries, with an adjusted odds ratio (OR) of 1.8.[21] Moreover, children with cardiac conditions had a greater number of untreated caries than those in the control group did, even though the latter was not associated with the type of cardiac diagnosis.[28] There was a statistically significant difference between the dmft/DMFT in Sudanese children with CHD and among controls (p dmft $= 0.021$; p DMFT $= 0.008$).[22] These findings contrast with those reported by Cantekin et al, who did not observe any significant differences between the primary or permanent teeth of children with and without CHD.[19] A study of adult poststroke patients conducted in Hungary reported a significant relationship between DMFT (DMFT is the sum of the number of decayed teeth, missing teeth due to caries, and filled teeth in the permanent teeth. The dmft is used for primary teeth) ($p = 0.0025$), missing teeth ($p = 0.0259$), and stroke type, whereas no differences were observed in decayed teeth ($p = 0.3148$).[20] Conversely, Lee et al[24] and Alhadainy et al[29] reported that dental caries were not associated with obstructive coronary artery disease (CAD) or a self-reported history of stroke.

Five case-control studies were included in this study; two were conducted with children, and the other three were conducted with adults.[30–34] The former reported that children diagnosed with CHD presented a greater incidence of dental caries, and a significant association between CHD and the dmft score was observed.[30,33] The latter revealed that acute myocardial infarction patients presented significantly higher mean DMFT scores than did the control group ($p = 0.001$).[34] Conversely, a significantly lower mean DMFT score was observed in patients with CHD than in healthy controls ($p < 0.0001$).[31]

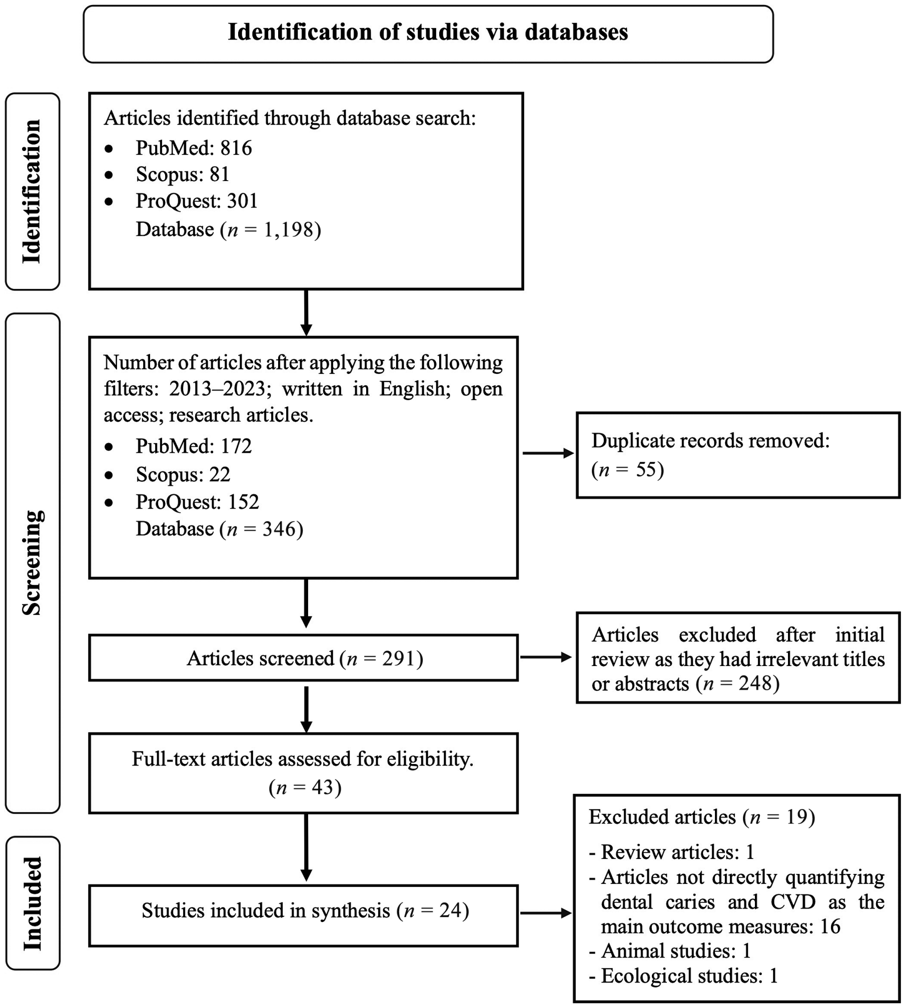

Fig. 1 Study flowchart summarizing systematic literature search. CVD, cardiovascular disease.

Seven cohort studies[10,35–40] were included. A study of participants revealed that when they underwent oral clinical examinations during childhood, when they were 6, 9, or 12 years old, and when clinical cardiovascular follow-up was performed during adulthood, oral infections in childhood appeared to be associated with subclinical carotid atherosclerosis.[35] Severe dental caries was associated with an increased risk of CHD (hazard ratio [HR] = 1.13; 95% confidence interval [CI] = 1.04–1.22) and was a risk factor for intracerebral hemorrhage (crude HR = 2.69; 95% CI = 1.02–7.06).[10,39] In contrast, a study with a follow-up period of 21 years revealed that participants with ≥1 dental caries had an increased risk of ischemic stroke (adjusted HR = 1.40; 95% CI = 1.10–1.79) but not CHD events (adjusted HR = 1.13; 95% CI = 0.93–1.37).[40] Ischemic stroke was significantly associated with increasing decayed, missing, and filled surfaces (DMFS; adjusted HR = 1.006; 95% CI = 1.001–1.011).[40]

A cohort study of hemodialysis patients with a history of heart disease reported a significant correlation between the DMFT score and the aortic calcification index among patients on hemodialysis.[36] Liu et al reported that after 27 years of follow-up, fewer permanent teeth and untreated caries were associated with greater all-cause mortality, including heart disease but not cerebrovascular disease.[37] Furthermore, a study among children with CHD revealed significant differences between DMFTs and heart defect types ($p = 0.009$).[38]

Discussion

Since the burden of oral symptoms in patients with CVD might be high, this scoping review aimed to summarize the available literature on the association between dental caries and CVD in this patient group. Oral infections, periodontal diseases, and dental caries are the most common chronic diseases.[3] Oral streptococcal bacteria are more common in patients with congenital heart disease than in controls.[26] Furthermore, oral streptococcal bacteria may aggravate aortic calcification in patients with CVD.[36] *Streptococcus mutans*, a major pathogen of dental caries, has been frequently detected in heart valve specimens (69%) and atheromatous plaque specimens (74%), suggesting that *S. mutans* is a causative agent of CVD.[41–43] Oral infections, their byproducts, or pathogen-induced oral inflammatory mediators can cause host inflammatory reactions locally and in other body parts. In general, advanced dental caries destroy enamel and dentin on the tooth surface, thereby exposing the pulp (which contains blood capillaries). This can allow oral

Table 2 Characteristics of included articles

Study	Country	Study design	Sample size and mean age
Pimentel et al[27]	Brazil	Cross-sectional	144 children with CHD. The mean age was 4.41 ± 0.95 y
Glodny et al[2]	Austria	Cross-sectional	Cases (*n* = 292; 54.1 ± 17.3 y)
Willershausen et al[34]	Germany	Retrospective study	Cases (*n* = 248 patients after acute AMI; 62.3 ± 10.1 y) Control (*n* = 249; 63.5 ± 10.5 y)
Cantekin et al[19]	Turkey	Cross-sectional	Cases (*n* = 72; 6.24 ± 2.85 y). Control (*n* = 56; 6.73 ± 3.01 y)
Ajami et al[26]	Iran	Cross-sectional	Total: 116 children aged 3–12 y Cases (*n* = 66 children with congenital or acquired heart disease; no age mentioned) Control (*n* = 50 healthy children; no age mentioned)
Ali et al[21]	Sudan	Cross-sectional	Cases (*n* = 111; 7.1 ± 3 y) Controls (*n* = 182; 7.2 ± 2.8 y)
Ali et al[22]	Sudan	Cross-sectional	*Total* Cases (*n* = 111; 7.15 ± 3 y) Control (*n* = 182; 7.19 ± 2.9 y) *Group 1 (3–7 y)* Cases (*n* = 62; 4.8 ± 1.4 y) Control (*n* = 101; 4.9 ± 1.4 y) *Group 2 (8–12 y.)* Cases (*n* = 49; 10.1 ± 1.3 y) Control (*n* = 81; 10.0 ± 1.3 y)
Pourmoghaddas et al[30]	Iran	Case-control	Cases (*n* = 68; 7.4 ± 1.8 y) Controls (*n* = 76; 7.8 ± 2.5 y)
Oliver et al[28]	Australia	Cross-sectional	428 CHD patients; 4.9 ± 2.4 y
Pussinen et al[35]	Finland	Cohort study (27-y follow-up study)	Cases (*n* = 755; age at baseline in 2018 was 8.07 ± 2.00 y)
Lee et al[24]	Republic of Korea	Cross-sectional	88 cases; 64.8 ± 7.7 y
Hollatz et al[25]	Germany	Cross-sectional	CHD (*n* = 112; 31.5 with a range of age 18–77 y) Control (*n* = 23; range of age 35–44 y)
Kim et al[10]	Republic of Korea	Cohort study	234.597 patients followed up for CHD*, aged 40–79 y
Folwaczny et al[31]	Germany	Case–control	Cases (*n* = 112; 34.4 ± 12.6 y) Controls (*n* = 168; 43.1 ± 18.9 y)
Alhadainy et al[29]	United States	Cross-sectional	8.634 subjects; 65.5 ± 12.3 y
Karhumaa et al[38]	Finland	Cohort study	Cases (*n* = 214; aged 19–21 y in 2018) Controls (*n* = 3.576; age not mentioned)
Misaki et al[36]	Japan	Cohort study	Cases (*n* = 80 hemodialysis patients; 67.3 ± 12.2 y)
Moldvai et al[20]	Hungary	Cross-sectional	Cases (*n* = 410 poststroke patients; 59.21 ± 14.74 y
Szerszeń et al[32]	Poland	Case–control	Cases (*n* = 151; 55.1 ± 8.0 y) Control (*n* = 160; age not mentioned)
Liu et al[37]	United States	Cohort study	24.029 adults with aged ≥30 y
Saraç et al[23]	Turkey	Cross-sectional	Cases (*n* = 217; 8.9 ± 4.8 y) Control (*n* = 364; 9.27 ± 3.71 y)
Bsesa et al[33]	Syria	Case-control	Cases (*n* = 200; aged 4–12 y) Controls (*n* = 100; age not mentioned)
LaValley et al[39]	United States	Cohort study	6.315 participants; 45–64 y
Sen et al[40]	United States	Cohort study	6.351 participants. The mean age was 62.3 ± 5.6 y

Abbreviations: AMI, acute myocardial infarction; CHD*, coronary heart disease; CHD, congenital heart defects.

Table 3 Summary of research articles on the association between dental caries and CVD incidence

Study	Aim of the study	Study output		Findings and conclusion
		Dental caries	CVD	
Pimentel et al[27]	Investigated the possible associations between CHD, oral health status, and social, medical, and behavioral variables	dmft	CHD	Mean dmft score was 5.4, and 80.5% of the children had at least one caries lesion. The dmft index and decayed component were significant with cyanotic cardiac disease ($p = 0.015$ and 0.016, respectively) Conclusion: Children with CHD had high levels of caries experience at a young age. The presence of cyanosis seems to influence caries experience in children with CHD
Glodny et al[2]	Examined whether caries, pulpal caries, and chronic apical periodontitis were associated with an increased risk of aortic atherosclerosis	DMFS used computed tomography	Atherosclerosis (ACI)	Patients with caries on more than one surface per tooth had a greater atherosclerotic burden than patients with caries on less than one surface per tooth ($p < 0.0001$). Patients with at least one tooth affected by pulpal caries had a greater atherosclerotic burden than those with none ($p = 0.0046$) Conclusion: Positive association between dental caries and aortic atherosclerosis
Willershausen et al[34]	Assessed possible associations between occurrence of dental inflammatory processes (especially apical lesions) and incidence and progression of CHD	DMFT	AMI	The mean of DMFT in AMI patients was higher (20.1 ± 5.4) than the control group (18.6 ± 5.6) with $p < 0.001$. Compared with controls, the OR for dental caries on AMI cases was 0.948 (95% CI: 0.904–0.994; $p < 0.028$). Conclusion: Results showed statistically significant differences between AMI patients and the controls regarding the DMFT index
Cantekin et al[19]	Compared the formation of dental caries and developmental enamel defects between healthy children and those with CHD	dmft/DMFT	CHD	The mean of dmft between the CHD group and control was 2.80 ± 3.77 and 1.87 ± 3.31, respectively. The mean DMFT score among the case and control groups was 0.81 ± 1.63 and 0.72 ± 1.46, respectively. There was no significant difference in the primary or permanent decayed, missing, and filled teeth between children with congenital heart disease and healthy children ($p > 0.05$) Conclusion: There is no significant difference between children with CHD and healthy children in terms of the prevalence of dental caries
Ajami et al[26]	Evaluated prevalence of oral bacteria and caries in children with CHD, children with rheumatic (acquired) heart disease, and healthy children	dmft/DMFT	CHD and acquired heart disease	The mean DMFT in acquired heart disease, CHD, and control group was 1.12 ± 1.12, 2.81 ± 2.74, and 3.92 ± 3.71, respectively. There was a significant difference between the mean DMFT of three groups: CHD, acquired heart disease, and control

(*Continued*)

Table 3 (*Continued*)

Study	Aim of the study	Study output		Findings and conclusion
		Dental caries	CVD	
				group ($p = 0.013$) Conclusion: Children with CHD or acquired heart disease have lower DMFT than controls
Ali et al[21]	Compared the prevalence of oral health risk factors in children with and without a CHD and evaluated the effects of these risk factors on the prevalence of caries and gingivitis in these children	dmft/DMFT	CHD	Adjusted OR for caries on CHD cases compared with controls was 1.8 (95% CI: 1.1–3.2; $p < 0.01$) when all other background factors were controlled for Conclusion: Positive association was found between dental caries and CHD. Children with CHD were more severely affected by dental caries than those in the control group
Ali et al[22]	Compared prevalence of plaque, gingivitis, and caries between Sudanese children with and without CHD	dmft/DMFT	CHD	The mean of dmft values was significantly higher among the cases (3.7 ± 3.8) than in controls (2.3 ± 3.2); $p = 0.021$. The mean DMFT score in cases and controls was 1.3 ± 1.7 and 0.6 ± 0.9, respectively, with $p = 0.008$ Conclusion: Positive association was found between dmft/DMFT and CHD
Pourmoghad-das et al[30]	Evaluated the presence of salivary microorganisms, dental caries, and periodontal disease in children with and without CHD	DMFT	CHD	The mean DMFT score was higher in the study group (6.4 ± 2.46) rather than the control group (5.5 ± 2.16; $p = 0.14$). Among study groups, 32.43% of healthy children and 18.84% of children with CHD experienced no or mild dental caries Conclusion: There was no significant difference in the DMFT scores between CHD patients and controls
Oliver et al[28]	Evaluated caries experience of children with cardiac conditions attending the Department of Dentistry at the Royal Children's Hospital of Melbourne (RCH DoD) and examined the factors associated with it	ICDAS, dmft/DMFT	HD: simple acyanotic, simple cyanotic, complex (acyanotic and cyanotic), and acquired	Total caries prevalence was 52.1%. The burden of dental caries was high, with a mean d_{1-6} mft of 7.44 ± 4.8 for the overall study population. There was no association between caries prevalence and cardiac diagnosis ($p > 0.05$) Conclusion: Although children with cardiac conditions had a higher rate of untreated caries, occurrence of dental caries was not associated with the type of cardiac diagnosis
Pussinen et al[35]	Investigated whether signs of oral infections during childhood were associated with the presence of cardiovascular risk factors and subclinical atherosclerosis in adulthood	Dental caries and fillings	Subclinical atherosclerosis (IMT)	Childhood oral infections such as including caries are associated with an increased risk of IMT ($p = 0.008$, $R^2 = 0.022$). Conclusion: Oral infections, including dental caries (active/inactive caries) in childhood, were shown to be associated with subclinical carotid atherosclerosis seen in adulthood
Lee et al[24]	Investigate the association between	The sum of DFT	CAD	The mean DFT scores for CAD patients and controls were

Table 3 (*Continued*)

Study	Aim of the study	Study output		Findings and conclusion
		Dental caries	CVD	
	dental health and CAD using multiple dental indexes			5.22 ± 4.09 and 6.88 ± 4.10, respectively, and this difference was not statistically significant ($p = 0.065$) Conclusion: The sum of the DFT score was not associated with CAD
Hollatz et al[25]	Assessed the prevalence of caries in ACHD patients and evaluated their knowledge of oral health as a risk factor for IE and cardiovascular disease	DMFT index	CHD	The mean DMFT score was 7.91 ± 6.54), with 21% of the patients in the study group exhibiting at least one untreated dental caries. The mean DMFT score in the control group was 11.2. No significant differences in the number of decayed teeth were observed between the cases and controls ($p = 0.09$). There was no significant association between DMFT index and severity of the CHD after adjusting for age ($p = 0.694$) Conclusion: There was no association between ACHD and the DMFT index
Kim et al[10]	Evaluated the association between the severity of dental caries and CHD in middle-aged men and women	Caries severity	CHD*	After adjusting for potential confounders, patients in the highest quartile of outpatient visits for advanced/severe dental caries were seen to exhibit an increased risk of CHD (HR = 1.13; 95% CI: 1.04–1.22) when compared with patients without dental caries. Patients with advanced/severe dental caries exhibited a dose‐response relationship with the number of outpatient visits for dental caries and the risk of CHD ($P_{trend} < 0.001$) Conclusion: Outpatient visits for advanced/severe stage dental caries were associated with increased CHD* risk compared with patients without dental caries
Folwaczny et al[31]	Compared level of oral care required and the prevalence and severity of odontogenic diseases between adults with CHD and the general population	DMFT	CHD	Patients with CHD exhibited a mean DMFT score of 7.91 ± 6.63, while the corresponding value in the control group was 13.6 ± 8.15 ($p < 0.0001$). The mean number of decayed teeth was higher among healthy controls (1.76 ± 2.61) compared with patients with CHD (0.33 ± 0.76; $p < 0.0001$) Conclusion: There was a positive association between CHD and DMFT score and number of decayed teeth. Adults with CHD exhibited better oral health than healthy individuals
Alhadainy et al[29]	Examined potential associations between dental diseases and a self-reported history of stroke	DMFS. The number of carious surfaces was categorized into the following: • Group I: no	Self-reported history of stroke	The mean value of the number of carious tooth surfaces was 17.2 ± 14.3. There was no statistically significant between the number of carious surfaces and self-reported history of stroke ($p > 0.05$)

(*Continued*)

Table 3 (*Continued*)

Study	Aim of the study	Study output		Findings and conclusion
		Dental caries	CVD	
		carious surface • Group II: 4–10 • Group III: 10–28 • Group IV: 29–114		Conclusion: There were no associations between the presence of caries and a self-reported history of stroke
Karhumaa et al[38]	Investigated the prevalence of dental caries and its association with the type of CHD and number of operations required in children born between 1997 and 1999	• dt/dmft • DT/DMFT	CHD	Prevalence of caries did not differ between the study and control groups. Significant differences in the DT ($p = 0.046$) and DMFT ($p = 0.009$) scores were observed at the age of 15 Conclusion: Statistically significant difference was found between heart defect type and dental caries at the age of 15 y
Misaki et al[36]	Investigated the association between dental caries status and arteriosclerosis in patients with HD and prospectively examined risk factors associated with differences in the 2-year prognosis	DMFT	ACI	Association between the DMFT score and the aortic calcification index remained statistically significant after adjusting the multiple regression model for age, sex, dialysis period, presence of diabetes mellitus, systolic blood pressure, diastolic blood pressure, serum LDL cholesterol, C-reactive protein, intact PTH, serum calcium, and serum phosphate ($p = 0.0014$). No significant associations were observed between the presence of decayed/filled teeth and the aortic calcification index ($p = 0.5943$) Conclusion: Dental caries were associated with an increased risk of arteriosclerosis in patients undergoing hemodialysis. This may indirectly affect the prognosis of arteriosclerotic patients
Moldvai et al[20]	Assessed the oral health status of patients poststroke and evaluated factors that may affect it	DMFT	Poststroke	The mean DMFT score was 20.13 ± 8.08, including 3.28 ± 4.24 DT, 15.02 ± 10.29 MT, and 1.83 ± 2.94 F-T score. Significant relationships were found between DMFT value ($p = 0.0025$), MT component ($p = 0.0259$), and stroke type, while no differences were observed in DT ($p = 0.3148$) and F-T ($p = 0.5588$) components. Patients with cerebral infarctions exhibited the highest DMFT and MT scores, while those with subarachnoid subtypes exhibited the lowest DMFT scores Conclusion: An association between dental caries and type of stroke was observed
Szerszeń et al[32]	Assessed overall oral health based on evaluating the presence of tooth loss, residual roots with necrotic pulp, carious teeth,	The number teeth with caries	MI	The association between the presence of teeth and caries was not statistically significant after adjusting for smoking, hypertension, diabetes, BMI, education, and income (OR: 0.9;

Table 3 (*Continued*)

Study	Aim of the study	Study output		Findings and conclusion
		Dental caries	CVD	
	type of tooth deficiencies, and periodontal status in patients <70 y of age and diagnosed with MI			95% CI: 0.56–1.667; $p = 0.4394$) Conclusion: No association between the presence of teeth, caries, and MI was observed after adjusting for several confounding factors
Liu et al[37]	Examined the association between tooth count, untreated dental caries, and risk of all-cause and cause-specific mortality after adjusting for potential confounders in a nationally representative sample of U.S. adults	Untreated caries	HD	After adjusting for confounders, patients with untreated caries were seen to exhibit a higher risk of all-cause (HR: 1.26, 95% CI: 1.15–1.39) and heart disease–related mortality (HR: 1.48, 95% CI: 1.17–1.88) but not cerebrovascular disease/cancer-related mortality when compared with those without untreated caries and at least 25–28 teeth. Patients with untreated caries and between 1 and 16 teeth exhibited a 53% increased risk of all-cause mortality (HR: 1.53, 95% CI: 1.27–1.85) and a 96% increased risk of heart disease–related mortality (HR: 1.96, 95% CI: 1.28–3.01) Conclusion: Untreated caries and the presence of fewer permanent teeth were associated with an increased risk of all-cause and heart disease–related mortality. However, no such associations were observed with cerebrovascular diseases
Saraç et al[23]	Assessed the oral and dental health status of children diagnosed with various types of CHD who underwent treatment and follow-up	• dmft/dft/DMFT • dmfs/dfs/DMFS • pufa/PUFA	CHD	In the mixed dentition stage, the mean dmfs score of the study group (5.7 ± 5) was significantly higher than that of the control group (4 ± 3.4; $p = 0.031$), while the mean dfs score of the control group (10.7 ± 7.4) was significantly higher than that of the study group (8.2 ± 5.8; $p = 0.047$). In the primary dentition stage, the mean pufa score (3 ± 1.4) of the control group was significantly higher than that of the study group (1.5 ± 0.5; $p = 0.039$). However, no such differences were observed between the study and control groups in the permanent dentition stage Conclusion: The caries index scores of CHD-affected children in the primary and mixed dentition stages were higher than those of healthy children
Bsesa et al[33]	Evaluated the presence of caries, dental plaque, dental abnormalities, gingivitis, and Oral Health-Related Quality of Life in children with (cases) and without (controls) CHD	• dmft/DMFT	CHD	The mean dmft mean score was higher in the study group (5.245 ± 3.982) compared with the control group (2.660 ± 2.244; $p < 0.000$). No statistically significant difference between the study (1.615 ± 1.928) and control groups (1.540 ± 1.424) in the DMFT mean score ($p = 0.731$)

(*Continued*)

Table 3 (*Continued*)

Study	Aim of the study	Study output		Findings and conclusion
		Dental caries	CVD	
				Conclusion: The mean dmft scores were significantly higher in the CHD group compared with the control group
LaValley et al[39]	Evaluate the association between dental caries and incident ICH	• Dental/root caries	ICH	Significant association was observed between caries and ICH (crude HR: 2.69, 95% CI: 1.02–7.06), and this association strengthened after adjusting for age, gender, race, education level, hypertension, and periodontal disease (adjusted HR 3.88, 95% CI: 1.34–11.24) Conclusion: Presence of surface and/or dental caries was associated with an increased risk of ICH incidence ≤10 y after detection
Sen et al[40]	Investigated the association between dental caries and incident of atrial fibrillation	DMFS/DMFT	CHD, ischemic stroke	Participants with ≥1 dental caries had an increased risk of ischemic stroke (adjusted HR: 1.40, 95% CI: 1.10–1.79) but not for CHD events (adjusted HR: 1.13, 95% CI: 0.93–1.37). Ischemic stroke was significantly associated with increasing decayed, missing, and filled surfaces (adjusted HR: 1.006, 95% CI: 1.001–1.011) but not CHV event (adjusted HR: 1.002, 95% CI: 1.000–1.005)

Abbreviations: ACHD, adults with congenital heart defects; ACI, aortic calcification index; AMI, acute myocardial infarction; CAD, coronary artery disease; CAD, coronary artery disease; CHD*, coronary heart disease; CHD, congenital heart defects; DFT, decay and filled teeth; DMFS, decayed missing filling surface; DMFT/dmft, decayed, missing, and filled teeth; DT/dt, decayed teeth; FT, filling teeth; HD, heart disease; ICDAS, International Caries Detection and Assessment System; ICH, intracerebral hemorrhage; IE, infective endocarditis; IMT, intima media thickness; MI, myocardial infarction; MT, missing teeth; NCD, noncommunicable disease.

bacteria (including *S. mutans*) to enter the bloodstream.[41] For oral inflammation to be linked to the pathogenesis of atherosclerosis, the following four fundamental pathogenic mechanisms have been proposed: (1) low-level bacteremia and vascular wall invasion; (2) inflammatory mediator-induced systemic inflammation; (3) host immunological response to specific oral pathogen components; and (4) proatherogenic effects from specific bacterial toxins.[44] Direct invasion of the vascular endothelium by *S. mutans* and its products, or the induction of systemic immunological responses, may accelerate plaque development and spread to the circulation, increasing the risk of CVD.[44,45]

Dental health and oral hygiene appear to be especially crucial in patients and children with heart disease, as bacteremia and even the brief presence of bacteria during routine activities such as tooth brushing and flossing are associated with a higher risk of infective endocarditis (IE).[46] Several factors, either independently or in combination, increase susceptibility to oral cavity disease in children with CHD,[22] including (1) malnutrition and growth retardation, often with extra food to compensate, specifically at night[47]; (2) long-term treatment with antibiotics supplemented with sucrose[48]; (3) impaired salivary flow induced by CHD drugs[49]; and (4) the lack of parental concern for their children's oral health due to parental concern for their children's overall health.[50] Additionally, a recent study has shown that deciduous tooth enamel and dentin structures in children with CHD are structurally and chemically altered, with low calcium and phosphorus levels.[51] A previous study revealed the prevalence of dental caries in children and teenagers with CHD in industrialized countries such as Germany; surprisingly, these studies revealed a significantly increased incidence of caries and poor oral hygiene. In patients with CHD, concerns regarding the maintenance of good oral hygiene and the prevention of complications associated with IE may also underlie this.[46]

Compared with the general pediatric population, children with heart disease have more caries, even though there is no relationship between the occurrence of caries and cardiac diagnosis.[28] The caries score was mainly due to more extracted and filled teeth in patients at high risk of IE, whereas the number of decayed teeth did not significantly differ. As these high-risk patients were more often aware of the importance of good oral health, this may have led to more frequent dental treatments.[25] A significantly lower incidence of caries and periodontitis among adults with CHD was also found. This could be due to better oral supportive care and more rigorous maintenance of oral health.[31] Pediatric patients with CHD experience more dental decay, although the difference between them and control participants is not statistically significant.[30,38] The patients were referred from cardiac clinics with special routine dental examinations, which may partly explain the lower DMFT findings than those of the healthy population. Conversely, the mean DMFT score in the healthy group was moderate, indicating that healthy children may have poor dental hygiene.[30] Healthy children consume more carbohydrates, and *S. mutans* grows more significantly in their saliva.[30]

A worse dental caries status is associated with high pulse pressure among patients on hemodialysis, indicating that such patients might have arteriosclerosis.[36] The DMFT index was significantly greater among hemodialysis patients than among healthy controls.[52] Regression analyses demonstrated a significant correlation between the DMFT score and the aortic calcification index, which indicates that oral status is an important risk factor for arteriosclerosis, as is the incidence of mineral and bone disorders in patients on hemodialysis.[36] The bacteria present in the root canal system may increase the risk of CAD. Thus, with an increase in the number of dental visits for the treatment of advanced/severe caries, the incidence of CAD has increased significantly.[10] A cohort study revealed an association between DFMS and ischemic stroke.[40] *Streptococcus mutans* was found at higher frequencies and amounts than periodontal pathogens in both heart valve tissues collected after heart valve surgery and atheromatous plaque samples obtained from aorta samples during CHD procedures.[41] This bacterium may cause ischemic stroke through cardioembolism (infective endocarditis), atherothrombosis, and vascular risk factors (e.g., diabetes).[40]

The number of missing teeth caused by severe dental caries is significantly associated with the presence of obstructive CAD,[24] and a self-reported history of stroke.[29] Thus, tooth loss is the result of untreated dental disease and reflects the cumulative effects of past illnesses and treatments. Moreover, patients with cerebral infarction had the highest number of missing teeth and the highest DMFT index, whereas the lowest DMFT index was observed in the subarachnoid subtype.[20,29,53] The high DMFT index for cerebral infarction could be because oral health diseases and ischemic stroke are influenced by common risk factors or confounders, including old age, hypertension, diabetes mellitus, stress, genetic predisposition, tobacco smoking, alcohol consumption, health behaviors, obesity, diet, physical activity, access to health care, nutrition, and low socioeconomic status.[54]

This review had a few limitations. First, most of the studies were cross-sectional, which may make it impossible to establish causal relationships between dental caries and CVD incidence. Second, the studies included varied oral health assessment methods and instruments used to assess dental caries and CVD, making it very difficult to draw solid conclusions. Third, this review did not include studies published in languages other than English or literature from other databases that were not searched. Finally, this scoping review did not analyze the quality of the studies included when summarizing the results. Therefore, the results should be interpreted cautiously, and the information presented should be complemented with a systematic review and meta-analysis to investigate the association between dental caries and CVD, expanding the search source. Evidence from animal studies was also not included, and future studies should aim to incorporate this evidence. However, the findings of this study provide evidence for the association between dental caries and CVD incidence, identifying research gaps and emphasizing the need to explore dental caries prevention strategies to mitigate CVD risk. Understanding the association between dental caries and CVD plays a pivotal role in patient education and treatment planning.

Conclusion

Limited clinical evidence linking dental caries with CVD is available. However, there is evidence of an association between dental caries and CVD through causal pathways, including oral infection or pathogen-induced oral inflammatory mediators. Other potential risk factors include age, hypertension, tobacco smoking, diabetes mellitus, stress, genetic predisposition, physical activity, alcohol consumption, health behaviors, obesity, antibiotic supplementation, oral health awareness, access to health care, nutrition, and low socioeconomic status. Medical practitioners should also determine the increased risk of CVD associated with poor oral hygiene. A sense of responsibility must be present among physicians and dentists to inform patients about the short- and long-term dangers of having a high DMFT index and poor oral hygiene, including potential relationships with risk factors for CVD and mortality. However, further evidence is needed to understand the possible association between dental caries and CVD incidence and to develop an effective dental caries management strategy.

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Conflict of Interest
None declared.

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