



Local Oral Biological Factors Associated with Oral Conditions in Children with Congenital Heart Disease: A Scoping Review

Suci Oktavani Ritonga*, Meirina Gartika

Universitas Padjadjaran, Indonesia

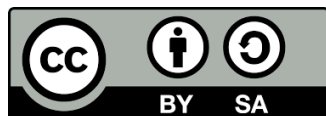
Email: drugsucioktavani@gmail.com

Keywords:

congenital heart disease;
children; biological factors;
saliva; oral microbiota

Abstract

Children with congenital heart disease (CHD) are categorized as children with special health care needs and have an increased risk of oral health problems. Local oral biological factors, including enamel–dentin structure, enamel defects, saliva characteristics, oral microbiota, dental plaque, gingivitis, and dental caries, may contribute to oral susceptibility; however, the available evidence remains fragmented. This study aimed to map and synthesize evidence regarding local oral biological factors associated with oral conditions in children with CHD. A scoping review was conducted based on the Joanna Briggs Institute (JBI) guidance and reported according to the PRISMA Extension for Scoping Reviews (PRISMA-ScR). Literature searches were performed in PubMed, Scopus, and EBSCOhost for studies published between 2014 and 2025. Primary studies involving children with CHD or oral/tooth samples from children with CHD that reported local biological factors or oral conditions were included. Data from eligible studies were narratively synthesized. Seventeen primary studies were included. The evidence demonstrated alterations in enamel–dentin structure, enamel defects, salivary characteristics, oral microbiota profiles, dental plaque biofilm, gingivitis, dental caries, and dental development. Histological and scanning electron microscopy/energy-dispersive X-ray spectroscopy (SEM/EDX) studies provided evidence of changes in dental hard tissues, while clinical studies reported a substantial burden of caries, gingivitis, and enamel abnormalities. Local oral biological factors contribute to oral susceptibility in children with CHD and should be considered in preventive dental care. Early screening, plaque control, fluoride application, caries and gingival monitoring, and interdisciplinary collaboration are recommended.



This is an open access article under the [CC BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license.

Copyright © 2026 by Author. Published by
Publikasi Indonesia

INTRODUCTION

Congenital heart disease (CHD) remains one of the most common congenital abnormalities affecting children worldwide and represents a significant public health concern due to its lifelong impact on growth, development, and quality of life. CHD occurs due to abnormalities in the structure or function of the heart and major blood vessels during fetal development. Epidemiological studies have estimated that CHD occurs in approximately 8–10 cases per 1,000 live births, making it one of the most frequently encountered congenital conditions in pediatric populations. Advances in medical and surgical management have increased survival among children with CHD, resulting in a growing population requiring comprehensive long-term healthcare, including oral health management (Sethi et al., 2025).

Children with CHD are categorized as children with special health care needs because their systemic conditions influence treatment planning, preventive strategies, infection control, and coordination among healthcare professionals. Although cardiac management remains the primary clinical focus, oral health problems represent an important concern because dental

plaque, gingivitis, dental caries, and odontogenic infections may contribute to transient bacteremia and increase clinical risks among patients with cardiac risk factors. Therefore, maintaining optimal oral health is an essential component of integrated healthcare for children with CHD.

Global evidence indicates that children with CHD experience considerable oral health challenges compared with healthy children. Previous systematic reviews have reported that children with CHD tend to demonstrate poorer oral health outcomes, including increased dental caries experience, inadequate oral hygiene, enamel defects, and greater dental treatment needs. However, the magnitude of these differences varies across populations, age groups, diagnostic methods, and healthcare settings. Some studies have identified significantly higher caries prevalence among children with CHD, whereas others have reported inconsistent differences, indicating that oral health outcomes may involve complex interactions among systemic conditions, behavioral factors, healthcare access, and biological mechanisms.

From a biological perspective, oral conditions in children with CHD cannot be explained solely by the presence of cardiac abnormalities. The oral cavity represents a dynamic ecosystem influenced by dental hard tissues, saliva, microorganisms, plaque biofilm, and inflammatory responses. Dental caries, for example, develops through complex interactions among tooth structure, microorganisms, substrate availability, saliva, and host-related factors. In children with CHD, these interactions may be affected by chronic medication use, nutritional challenges, hospitalization history, developmental disturbances, and limitations in accessing routine dental care.

Previous studies have primarily focused on general oral health outcomes in children with CHD, particularly dental caries, plaque accumulation, gingivitis, and oral hygiene status. Systematic reviews by Karikoski et al. and recent meta-analytic evidence have attempted to compare caries experience between children with CHD and healthy populations, demonstrating that oral health outcomes in this group remain an important area of investigation. Nevertheless, these studies have mainly emphasized clinical manifestations rather than exploring the underlying local biological mechanisms contributing to oral susceptibility.

Several primary studies have investigated specific biological components associated with oral conditions in children with CHD. Research has reported alterations in enamel–dentin structure, enamel defects, salivary characteristics, oral microbiota composition, plaque biofilm, gingival inflammation, and dental development. Histological, ultrastructural, and scanning electron microscopy/energy-dispersive X-ray spectroscopy (SEM/EDX) investigations have provided evidence of changes in dental hard tissues, while clinical studies have documented enamel abnormalities, dental caries, and gingivitis among children with CHD. These findings suggest that local oral biological factors may represent important pathways contributing to increased oral vulnerability in this population.

Despite increasing evidence, a significant research gap remains regarding the comprehensive mapping of local oral biological factors associated with oral conditions in children with CHD. Existing reviews have predominantly examined overall oral health status or dental caries prevalence, while evidence regarding biological factors such as enamel–dentin characteristics, saliva, microbiota, plaque biofilm, and developmental abnormalities remains scattered across different study designs and clinical contexts. Consequently, an integrated

synthesis is needed to clarify how these local biological factors contribute to oral susceptibility and how they may inform preventive dental strategies.

Understanding local oral biological factors is clinically important because early identification of biological risks may support more targeted prevention and management approaches for children with CHD. Preventive dental care in this population should not only address existing diseases but also consider underlying risk factors, including enamel defects, altered salivary conditions, microbial imbalance, and plaque accumulation. A better understanding of these mechanisms may facilitate interdisciplinary collaboration among pediatric dentists, cardiologists, and other healthcare professionals in developing individualized oral healthcare strategies.

This study provides novelty by specifically focusing on local oral biological factors associated with oral conditions in children with CHD through a scoping review approach. Unlike previous reviews that mainly evaluated general oral health outcomes or caries prevalence, this study systematically maps diverse biological domains, including dental hard-tissue structure, enamel defects, saliva, oral microbiota, plaque biofilm, gingival inflammation, dental caries, and dental development. The scoping review methodology enables the identification of evidence patterns, methodological variations, and remaining knowledge gaps across different research approaches.

Therefore, this study aimed to map and synthesize available evidence regarding local oral biological factors associated with oral conditions in children with CHD. The findings are expected to contribute to pediatric dentistry by providing a comprehensive understanding of biological mechanisms underlying oral susceptibility in children with special health care needs. Furthermore, this review may support future research directions by encouraging longitudinal studies, standardized assessment methods, and integrated evaluations of systemic and local factors influencing oral health outcomes in children with CHD.

METHOD

Study design

This study was a scoping review conducted according to the Joanna Briggs Institute (JBI) guidance and reported in accordance with the PRISMA Extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018). The scoping review approach was used to map available evidence, investigate local oral biological factors, and identify remaining research gaps rather than to quantitatively synthesize effect estimates.

PCC framework

Table 1. PCC Framework for Defining the Scope of the Scoping Review

Component	Definition
Population	Children aged 0-18 years with congenital heart disease or tooth/oral samples obtained from children with CHD.
Concept	Local oral biological factors associated with oral conditions, including enamel-dentin structure, enamel defects, dental anomalies, dental development, saliva, oral microbiota, dental plaque, gingivitis, calculus, and dental caries.

Component	Definition
Context	Clinical, observational, case-control, cross-sectional, microbiological, salivary, histological, or laboratory studies using subjects/samples from children with CHD in the context of pediatric dentistry.

Source: Developed by the authors based on the Joanna Briggs Institute (JBI) PCC framework for scoping reviews.

Information sources and search strategy

Searches were performed in three electronic databases: PubMed, Scopus, and EBSCOhost. The search was limited to articles published from 2014 to 2025, written in English or Indonesian, and available in full text for analysis. Keywords were developed to cover three main concepts: congenital heart disease, pediatric population, and local biological factors/oral conditions.

The main search string used and adapted for each database was: ("congenital heart disease*" OR "congenital heart defect*") AND (child* OR infant* OR adolescent* OR pediatric* OR paediatric*) AND ("enamel defect*" OR "enamel hypoplasia" OR "developmental defect* of enamel" OR "dental anomal*" OR "dental development" OR "dental age" OR "tooth structure" OR "teeth structure" OR saliva OR salivary OR microbiota OR microbiome OR "oral bacteria" OR "dental plaque" OR gingivitis OR "dental caries" OR dmft OR DMFT).

Inclusion and exclusion criteria

The inclusion criteria were: (1) primary articles; (2) subjects aged 0-18 years with CHD or oral/tooth samples obtained from children with CHD; (3) reporting at least one local biological factor or oral condition, such as tooth structure, enamel defects, saliva, microbiota, plaque, gingivitis, calculus, dental caries, or dental age; (4) articles published from 2014 to 2025; and (5) full text available for analysis.

The exclusion criteria were review articles, systematic reviews, meta-analyses, editorials, comments, letters, conference abstracts without full text, animal studies, purely in vitro studies without samples from children with CHD, studies in adult populations, and articles that did not provide data relevant to the review concept. Review articles were used only as supporting references in the introduction and discussion, not as data for the main synthesis.

Study selection and data synthesis

Study selection was performed through title and abstract screening, full-text assessment, and documentation of reasons for exclusion. Extracted data included author, year, country, study design, population or sample, local biological factors or oral outcomes, main findings, and synthesis meaning for the review. Data were presented in tables of study characteristics and narrative synthesis.

Ethical considerations

This study used data from published articles and therefore did not require new ethical approval or informed consent.

RESULTS AND DISCUSSION

Study selection

The search in PubMed, Scopus, and EBSCOhost yielded 339 records after the initial filter. After 128 duplicates were removed, 211 records were screened based on title and abstract. A total of 165 records were excluded because they did not meet the topic and population criteria, leaving 46 reports for full-text retrieval. Of these, 23 reports were not available in full text. Twenty-three full-text articles were assessed for eligibility, and six articles were excluded because they were not primary articles, did not match the focus on local biological factors, or did not provide extractable data. Finally, 17 primary articles were included in the qualitative synthesis.

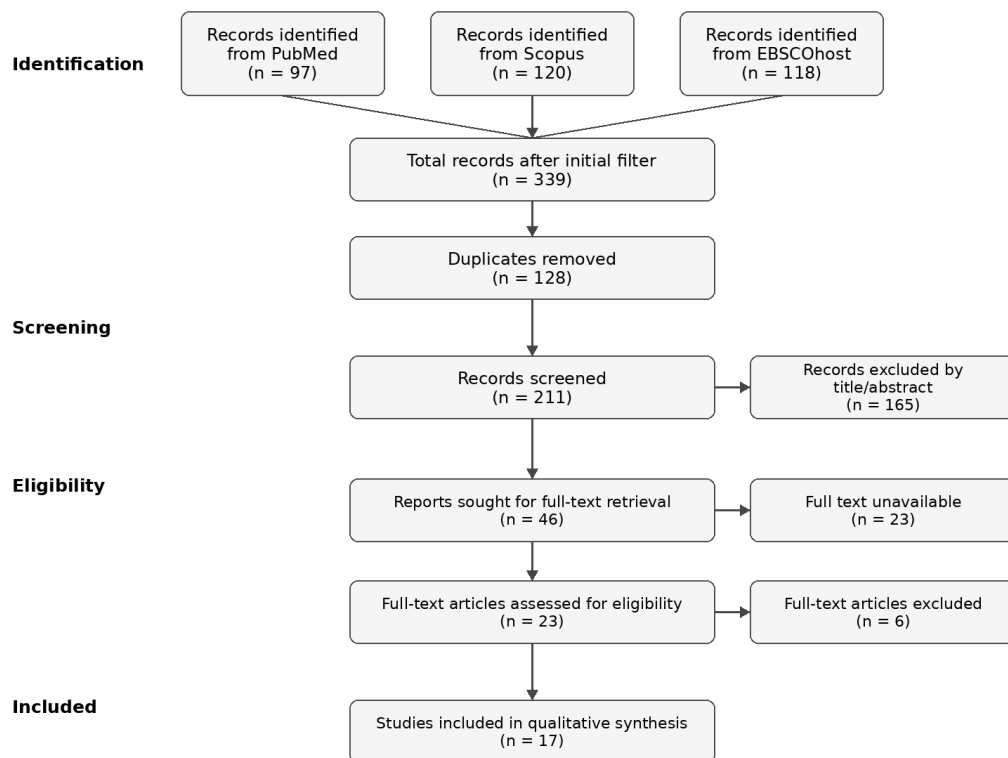


Figure 1. PRISMA flow diagram

Study characteristics

The 17 eligible primary articles consisted of cross-sectional studies, case-control studies, dental plaque microbiological studies, salivary studies, histological studies, ultrastructural studies, and tooth-structure analyses using SEM/EDX. Articles without available full text or articles that were not primary studies were not included in the main synthesis table. The most frequently reported local biological factors were dental caries, plaque, gingivitis, enamel defects, saliva, oral microbiota, dental anomalies, and changes in enamel–dentin structure (Aksakal et al., 2024; Ali et al., 2016; Ali et al., 2017; Bsesa et al., 2023; El-Hawary et al., 2014; Koerdt et al., 2022; Koruyucu et al., 2020; Mahdi & Shihab, 2024; Mohamed Ali et al., 2017; Mohammad et al., 2025; Pourmoghaddas et al., 2018; Raad & Shihab, 2023; Sarac & Derelioglu, 2025; Sarac et al., 2023; Sethi et al., 2025; Tasdemir et al., 2024; Yavsan et al., 2022).

Table 2. Basic characteristics of the included primary articles

Author, year	Country	Study design	Population/sample	Local biological factor/oral outcome	Main findings of the article	Synthesis meaning for the review
El-Hawary et al., 2014	Egypt	Laboratory study: ultrastructure and microanalysis	Primary teeth from children with CHD	Enamel-dentin structure and mineral composition	Primary teeth of children with CHD showed ultrastructural and microanalytical alterations in dental hard tissues.	Altered enamel-dentin structure supports the concept that tooth-tissue quality may be a local biological factor influencing caries susceptibility in children with CHD.
Ali et al., 2016	Sudan	Cross-sectional comparative study	Children with and without congenital heart defects	Dental caries, gingivitis, oral health behavior, dental service utilization	Children with CHD had poorer oral health behavior and lower dental service utilization; the odds of dental caries and gingivitis were higher after adjustment for background factors.	Dental caries and gingivitis in children with CHD are influenced not only by local biological factors but also by oral behavior and access to care.
Ali et al., 2017	Sudan	Observational comparative study	Children with congenital heart defects and controls	Plaque, gingivitis, dental caries	Plaque, gingivitis, and caries were clinically assessed in CHD and control groups.	Dental plaque and biofilm and gingival inflammation are indicators of local imbalance and should be targets for prevention in children with CHD.
Mohamed Ali et al., 2017	Sudan	Plaque microbiological study	Children with congenital heart defects	Dental plaque microbial profile	Dental plaque microbial profiles of children with CHD were analyzed to describe the composition of oral bacteria associated with biofilm.	Plaque microbiota is an important local factor linking plaque, gingivitis, dental caries, and potential transient bacteremia.

Author, year	Country	Study design	Population/sample	Local biological factor/oral outcome	Main findings of the article	Synthesis meaning for the review
Pourmoghadam et al., 2018	Iran	Case-control study	Children with CHD and healthy controls	Dental caries, gingival status, salivary microorganisms	Streptococcus mutans colony counts were not higher in children with CHD; Lactobacilli tended to be higher in children with CHD but not significantly. Dental caries and gingival status were also evaluated.	Salivary microorganisms are not the sole determinants of caries; diet, gingival status, plaque, saliva, and other local factors may interact.
Koruyucu et al., 2020	Turkey	Cross-sectional study	Children with CHD and controls	Salivary pH, flow rate, buffering capacity, oxidative stress, dental caries	Salivary flow rate did not differ significantly, but children with CHD had lower pH and buffering capacity and higher salivary oxidative stress markers.	Salivary problems in children with CHD appear more prominently as changes in salivary quality, which may reduce buffering ability and support demineralization.
Koerdt et al., 2022	Germany	Observational study	Children with CHD	Dental caries and dental rehabilitation needs	More than one-third of the examined children required dental rehabilitation.	Dental caries is an important clinical outcome of interactions between local and external factors; prevention should begin early.
Yavsan et al., 2022	Turkey	Case-control study	Preschool children with CHD and controls	Dental caries, plaque, gingivitis, oral health-related quality of life	Clinical oral variables and oral health-related quality of life were compared between children with CHD and controls.	Plaque, dental caries, and gingivitis affect not only clinical status but also children's quality of life.
Sarac et al., 2023	Turkey	Cross-sectional	Children with CHD	Oral condition, dental treatment, enamel defects	Oral-dental care variables and enamel defects	Enamel defects and dental treatment needs

Author, year	Country	Study design	Population/sample	Local biological factor/oral outcome	Main findings of the article	Synthesis meaning for the review
		comparative study	and controls		were evaluated in children with CHD and controls.	should be mapped as local risk factors in children with CHD.
Bsesa et al., 2023	Syria	Case-control study	Children with CHD and controls	Dental caries, plaque, gingivitis, enamel opacity/defect, quality of life	Children with CHD showed poorer oral manifestations and oral health-related quality of life.	Enamel defects, plaque, and gingivitis contribute to poor oral conditions and functional/psychosocial impacts.
Raad & Shihab, 2023	Iraq	Histological study	Primary teeth from children with CHD	Enamel thickness, dentin thickness, odontoblastic layer	Reduced thickness and integrity of primary tooth structures were reported.	Alterations in dental hard tissues provide direct biological evidence explaining the susceptibility of primary teeth in children with CHD.
Tasdemir et al., 2024	Turkey	Cross-sectional study	Children with congenital and acquired heart disease	Dental caries, plaque, gingiva, DDE, MIH, treatment needs	Oral health status, treatment needs, DDE, and MIH were evaluated; DDE was reported in some children and was associated with the severity of heart disease.	Clinical local factors and developmental enamel defects should be assessed together because they may aggravate caries risk and treatment needs.
Aksakal et al., 2024	Turkey	Case-control microbiological study	Children with CHD and controls	Oral bacteria, saliva, dental caries, gingival index	Selected oral bacteria and clinical indices were assessed; bacterial counts were not always significantly different, but the gingival index was higher in children with CHD.	Oral microbiota and saliva should be interpreted together with clinical conditions, especially gingivitis and oral hygiene.
Mahdi & Shihab, 2024	Iraq	SEM/EDX laboratory study	Primary teeth from children with VSD	Chemical composition of enamel and dentin	SEM/EDX analysis showed differences in enamel-dentin	Mineral alterations in dental hard tissues strengthen the

Author, year	Country	Study design	Population/sample	Local biological factor/oral outcome	Main findings of the article	Synthesis meaning for the review
			and controls		mineral composition in primary teeth of children with VSD.	hypothesis that CHD subgroups may have different enamel-dentin quality.
Sethi et al., 2025	India	Cross-sectional study	300 children aged 2-16 years with CHD	Dental caries, OHI, debris, calculus, dental anomalies, enamel opacities/hypoplasia	Caries prevalence was 56.7%, dental anomalies 9%, and enamel opacities/hypoplasia 8%. Mean dmft and calculus index were higher in cyanotic CHD, whereas caries prevalence was higher in acyanotic CHD.	Dental caries, calculus, and enamel defects are interrelated local outcomes; CHD type may be considered a systemic factor, but it is not the only determinant.
Sarac & Derelioglu, 2025	Turkey	Cross-sectional comparative study	Children with CHD and controls	Dental age, dental development, dental caries	Dental age was lower in children with CHD than in controls; differences between cyanotic and acyanotic types were not always significant.	Dental development may reflect systemic-local interactions and is important for preventive, restorative, and orthodontic planning.
Mohammad et al., 2025	Malaysia	Cross-sectional comparative study	Children with CHD and controls	Oral health needs, gingivitis, barriers to care	Children with CHD showed significant oral health needs, gingivitis, and access/behavioral barriers.	Although not purely biological, access and behavioral barriers can aggravate biofilm, gingivitis, and caries in children with CHD.

Source: Authors' synthesis based on included primary studies retrieved from PubMed, Scopus, and EBSCOhost (2014–2025).

Table 3. Data synthesis based on primary articles meeting the eligibility criteria

Synthesis domain	Supporting primary articles	Main evidence	Interpretation
Dental hard-tissue structure	El-Hawary et al., 2014; Raad & Shihab, 2023; Mahdi & Shihab, 2024	Histological, ultrastructural, microanalytical, and SEM/EDX studies showed alterations in	Enamel-dentin structure is a core local biological factor. Poor tissue quality may

Synthesis domain	Supporting primary articles	Main evidence	Interpretation
Enamel defects and dental anomalies	Sarac et al., 2023; Bsesa et al., 2023; Tasdemir et al., 2024; Sethi et al., 2025	enamel, dentin, the odontoblastic layer, and mineral composition of primary teeth in children with CHD or VSD. Enamel defects, enamel opacities/hypoplasia, developmental defects of enamel, MIH, and dental anomalies were reported in several clinical studies. Sethi et al. reported enamel opacities/hypoplasia in 8% and dental anomalies in 9%. Tasdemir et al. included DDE and MIH in oral status evaluation.	reduce resistance to cariogenic challenges and accelerate the destruction of primary teeth. Enamel defects may increase plaque retention, sensitivity, and the risk of demineralization. In children with CHD, these defects should be considered markers of caries risk and early preventive treatment needs.
Saliva and the chemical oral environment	Pourmoghaddas et al., 2018; Koruyucu et al., 2020	Pourmoghaddas et al. showed that S. mutans was not higher in children with CHD and Lactobacilli tended to be higher but not significantly. Koruyucu et al. showed that salivary flow rate did not differ, whereas pH and buffering capacity were lower and oxidative stress markers were higher in children with CHD.	Saliva can act as either a protective factor or a risk factor. Altered salivary profiles in children with CHD may create a more cariogenic environment and exacerbate gingival inflammation.
Oral microbiota and dental plaque biofilm	Mohamed Ali et al., 2017; Ali et al., 2017; Aksakal et al., 2024	Plaque microbial profiles and selected oral bacteria were evaluated together with plaque, caries, oral hygiene, and gingival status. Aksakal et al. showed that bacterial counts were not always significantly different, but the gingival index was higher in children with CHD.	Oral microbiota links changes in the local environment with clinical manifestations such as dental caries and gingivitis. In children with CHD, biofilm control is important because biofilm may also be a source of transient bacteremia.
Gingivitis and local inflammation	Ali et al., 2016; Ali et al., 2017; Yavsan et al., 2022; Bsesa et al., 2023; Mohammad et al., 2025	Gingivitis was frequently reported together with dental caries, plaque, access barriers, and poorer quality of life. Ali et al. reported higher odds of gingivitis in children with CHD than in controls.	Gingivitis is a clinical marker of local biological imbalance. It reflects biofilm burden and should be a routine preventive target, especially in children with CHD who are at risk of systemic infection.
Dental caries as the final clinical manifestation	Ali et al., 2016; Pourmoghaddas et al., 2018; Koerdt et al., 2022; Yavsan et al., 2022; Sarac et al.,	The caries burden was reported in many studies, but its magnitude varied by age, setting, diagnostic method, and comparator group. Koerdt et al. reported dental rehabilitation	Dental caries is best understood as the final manifestation of interactions among tooth structure, enamel defects, saliva, microbiota, plaque, behavior,

Synthesis domain	Supporting primary articles	Main evidence	Interpretation
	2023; Tasdemir et al., 2024; Sethi et al., 2025	needs in more than one-third of children; Sethi et al. reported a caries prevalence of 56.7%.	diet, medication, and access to care.
Dental development and dental age	Sarac & Derelioglu, 2025	Children with CHD showed lower dental age than controls, although differences between cyanotic and acyanotic types were inconsistent.	Dental development may reflect interactions between systemic and local factors. Dental age information is important for preventive, restorative, and orthodontic treatment planning in children with CHD.

Source: Developed by the authors based on the synthesis of included primary studies.

Note: CHD = congenital heart disease; VSD = ventricular septal defect; DDE = developmental defects of enamel; MIH = molar-incisor hypomineralization; OHI = oral hygiene index; SEM/EDX = scanning electron microscopy/energy-dispersive X-ray spectroscopy.

Synthesis of local biological factors

The synthesis showed that local oral biological factors in children with CHD can be grouped into seven main domains: dental hard-tissue structure, enamel defects and dental anomalies, saliva, oral microbiota and dental plaque biofilm, gingivitis and local inflammation, dental caries as the final clinical manifestation, and dental development. Alterations in enamel–dentin structure represent one of the most direct biological findings because they are supported by histological, ultrastructural, and SEM/EDX studies (El-Hawary et al., 2014; Mahdi & Shihab, 2024; Raad & Shihab, 2023).

Enamel defects and dental anomalies were reported in several clinical studies. Enamel opacities, enamel hypoplasia, developmental defects of enamel, and MIH can increase plaque retention, complicate oral hygiene, and accelerate the risk of demineralization. Sethi et al. (2025) reported a caries prevalence of 56.7%, dental anomalies of 9%, and enamel opacities/hypoplasia of 8% among 300 children with CHD (Bsesa et al., 2023; Sarac et al., 2023; Sethi et al., 2025; Tasdemir et al., 2024).

Saliva and oral microbiota serve as links between systemic conditions and local clinical manifestations. Changes in pH, buffering capacity, flow rate, oxidative stress, salivary microorganisms, and plaque bacterial profiles may affect the demineralization–remineralization balance and gingival inflammation (Aksakal et al., 2024; Koruyucu et al., 2020; Mohamed Ali et al., 2017; Pourmoghaddas et al., 2018).

Dental caries and gingivitis were the most frequently reported clinical outcomes. Both conditions do not stand alone; rather, they result from interactions between local biological factors and external factors such as toothbrushing frequency, fluoride use, diet, parental knowledge, long-term medication, behavioral barriers, and access to dental care (Ali et al., 2016; Ali et al., 2017; Koerdt et al., 2022; Mohammad et al., 2025; Yavsan et al., 2022).

Discussion

The findings of this review indicate that oral conditions in children with CHD cannot be explained solely by the cardiological diagnosis or CHD type. Oral susceptibility appears to result from interactions among local biological factors, systemic factors, family behavior, and

access to care. Focusing on local biological factors provides a more applicable understanding for pediatric dentistry because these factors can be assessed directly during clinical visits through examination of caries, plaque, gingiva, enamel defects, and, when available, salivary or microbiological evaluation (Aksakal et al., 2024; Ali et al., 2016; Ali et al., 2017; Bsesa et al., 2023; El-Hawary et al., 2014; Koerdt et al., 2022; Koruyucu et al., 2020; Mahdi & Shihab, 2024; Mohamed Ali et al., 2017; Mohammad et al., 2025; Pourmoghaddas et al., 2018; Raad & Shihab, 2023; Sarac & Derelioglu, 2025; Sarac et al., 2023; Tasdemir et al., 2024; Yavsan et al., 2022).

When viewed according to the strength and proximity of evidence to local biological factors, the findings in this review can be distinguished as direct and indirect factors. The most direct evidence comes from histological, ultrastructural, and SEM/EDX studies showing alterations in enamel–dentin structure, the odontoblastic layer, and mineral composition of primary teeth in children with CHD (El-Hawary et al., 2014; Mahdi & Shihab, 2024; Raad & Shihab, 2023). These findings differ from clinical studies of dental caries or gingivitis, which describe final manifestations. Thus, alterations in dental hard-tissue structure can be positioned as primary local biological factors, whereas dental caries and gingivitis are clinical outcomes arising from interactions among dental tissues, saliva, microbiota, dental plaque biofilm, behavior, and access to care.

Altered enamel–dentin structure is the most direct evidence of local biological involvement. Studies by El-Hawary et al. (2014), Raad and Shihab (2023), and Mahdi and Shihab (2024) showed that primary teeth of children with CHD may exhibit changes in ultrastructure, enamel–dentin thickness, the odontoblastic layer, and mineral composition. This is important because primary teeth have relatively thinner enamel and dentin than permanent teeth; therefore, changes in tissue quality may accelerate caries progression and increase the need for early restorative care (El-Hawary et al., 2014; Mahdi & Shihab, 2024; Raad & Shihab, 2023).

Enamel defects and dental anomalies can be understood as local predisposing factors. Hypoplastic or hypomineralized enamel surfaces are rougher, more retentive to biofilm, and more susceptible to demineralization. In children with CHD, enamel defects may also be associated with systemic disturbances during tooth formation, such as hypoxia, failure to thrive, suboptimal nutritional status, or a history of intensive medical care. However, this relationship cannot yet be considered causal because most studies are cross-sectional (Bsesa et al., 2023; Sarac et al., 2023; Seow, 2014; Sethi et al., 2025; Tasdemir et al., 2024).

Saliva is a highly important local biological component because it regulates pH, buffering capacity, lubrication, remineralization, and microbial balance. Salivary findings should be interpreted cautiously because results across studies are not entirely uniform. Pourmoghaddas et al. (2018) evaluated salivary microorganisms, dental caries, and gingival status, but did not show that children with CHD always had higher *Streptococcus mutans* counts than controls. Conversely, Koruyucu et al. (2020) demonstrated clearer changes in salivary quality, including lower pH and buffering capacity and increased oxidative stress parameters in children with CHD. This suggests that the role of saliva in children with CHD may not be determined solely by microbial counts but also by the ability of saliva to neutralize acid, maintain remineralization, and preserve the oral environmental balance. Salivary changes may increase caries risk, especially when children also have cariogenic diets, long-term medication use, or

suboptimal oral hygiene habits (Dodds et al., 2005; Koruyucu et al., 2020; Pourmoghaddas et al., 2018).

Oral microbiota and dental plaque biofilm link local factors and systemic risk. Mohamed Ali et al. (2017) and Aksakal et al. (2024) showed that plaque microbial profiles and oral bacteria can be evaluated in children with CHD. In the context of CHD, biofilm is relevant not only to dental caries and gingivitis but also because the oral cavity can serve as a source of transient bacteremia. This reinforces the urgency of intensive plaque control and regular dental visits before odontogenic infection develops into a more severe problem. Oral microbiota and plaque biofilm have an important position because they connect local and systemic risks. On one hand, biofilm contributes to the pathogenesis of dental caries and gingivitis; on the other hand, plaque accumulation and gingival inflammation may increase the likelihood of transient bacteremia from daily activities such as toothbrushing or mastication (Aksakal et al., 2024; Lockhart et al., 2008; Mohamed Ali et al., 2017; Wilson et al., 2021). Therefore, plaque control in children with CHD is not only intended to reduce caries risk but is also part of an oral infection prevention strategy with potential systemic implications.

Dental caries in this review is best understood as a final clinical manifestation rather than a single factor. Several studies reported a high caries burden, but the magnitude varied across countries, age groups, recruitment settings, and measurement methods. This variation explains why previous systematic reviews found heterogeneous results. Therefore, a more useful approach is not merely to ask whether children with CHD have higher caries experience, but to identify which local biological factors increase caries risk in a given child (Ali et al., 2016; Karikoski et al., 2021; Koerdt et al., 2022; Moussa et al., 2024; Pourmoghaddas et al., 2018; Sethi et al., 2025; Tasdemir et al., 2024; Yavsan et al., 2022).

Gingivitis also has important clinical meaning. Gingival inflammation indicates an imbalance between biofilm and the local tissue response. In children with CHD, gingivitis should not be regarded merely as a mild periodontal problem, but also as an indicator of poor plaque control and a potential source of daily bacteremia. Therefore, parental education on oral hygiene, use of fluoridated toothpaste, limitation of sugar exposure, and preventive recall schedules should be emphasized from the time a child is diagnosed with CHD (Ali et al., 2016; Ali et al., 2017; Bsesa et al., 2023; Mohammad et al., 2025; Wilson et al., 2021; Yavsan et al., 2022).

Findings on dental age and dental development suggest that CHD may be associated with aspects of dental growth. Sarac and Derelioglu (2025) reported lower dental age in children with CHD than in controls, although differences between cyanotic and acyanotic types were inconsistent. This information is important for pediatric dental treatment planning, including eruption timing, caries prevention in young permanent teeth, and considerations for interceptive orthodontics (Sarac & Derelioglu, 2025).

The implication of this review is the need for a risk-based preventive approach. Children with CHD should receive early dental examination, screening for enamel defects, periodic caries and gingival assessment, intensive plaque control, topical fluoride application, consideration of sealants in young permanent teeth, and salivary evaluation when available. Parental education is essential because parents often prioritize cardiac problems, resulting in delayed dental care (Ali et al., 2016; American Academy of Pediatric Dentistry, 2024; Koerdt et al., 2022; Mohammad et al., 2025; Sethi et al., 2025).

Academically, this review highlights clear research gaps. Future studies should use longitudinal designs, standardized outcome definitions, and more comprehensive measurement of local biological factors, such as salivary pH, buffering capacity, microbiota, enamel defects, and caries indices simultaneously. Grouping according to CHD type, disease severity, surgical history, oxygen saturation, and medication use is also important so that the relationship between systemic conditions and local oral factors can be better understood (Aksakal et al., 2024; Sarac & Derelioglu, 2025; Sethi et al., 2025; Tasdemir et al., 2024).

Several studies reported differences between cyanotic and acyanotic CHD; however, the available evidence is not sufficiently consistent to establish CHD type as the main determinant of oral conditions. Sethi et al. (2025) reported that mean dmft and calculus index were higher in the cyanotic group, whereas caries prevalence was higher in the acyanotic group. Meanwhile, Sarac and Derelioglu (2025) showed that dental age was lower in children with CHD than in controls, but differences between cyanotic and acyanotic types were not always significant. These findings support recording CHD type as a clinical variable, but oral conditions in children with CHD are more appropriately understood as the result of multifactorial interactions among local biological factors, systemic conditions, behavior, and access to care.

This review has limitations. First, the synthesis was performed narratively because study designs, outcomes, and measurement methods were highly heterogeneous. Second, most studies were cross-sectional, so causal relationships cannot be concluded. Third, relevant articles without available full text were not included in the main synthesis, meaning that additional evidence may not have been captured. Fourth, several studies reported clinical oral conditions but did not always measure local biological mechanisms directly.

CONCLUSION

Local oral biological factors associated with oral conditions in children with CHD include alterations in enamel–dentin structure, enamel defects, dental anomalies, salivary changes, oral microbiota, dental plaque biofilm, gingivitis, calculus, dental caries, and delayed dental development. Based on 17 eligible primary studies, the most direct evidence was identified in alterations of dental hard tissues through histological, ultrastructural, and SEM/EDX investigations, whereas the most frequently reported clinical findings included dental caries, plaque accumulation, gingivitis, enamel defects, and dental treatment needs. Dental caries and gingivitis should be understood as final clinical manifestations resulting from interactions among tooth structure, enamel defects, saliva, microbiota, dental plaque biofilm, behavioral factors, diet, medication use, and access to care, rather than as direct consequences of CHD diagnosis alone. Preventive dental care for children with CHD should begin early through enamel defect detection, plaque control, fluoride application, consideration of sealant placement, caries and gingival risk assessment, and interdisciplinary collaboration with pediatricians and cardiologists. Future research should employ longitudinal designs and standardized measurements of local biological factors, including salivary pH, buffering capacity, oral microbiota, enamel defects, dental age, and classification of CHD type and severity.

REFERENCES

- Aksakal, S. D., Guven, Y., Topcuoglu, N., Kulekci, G., & Aktoren, O. (2024). Assessment of oral bacteria potentially associated with the mobile microbiome in children with congenital heart disease. *Journal of Clinical Pediatric Dentistry*, 48(2), 47–56. <https://doi.org/10.22514/jocpd.2024.026>
- Bsesa, S. S., Srour, S., & Dashash, M. (2023). Oral health-related quality of life and oral manifestations of Syrian children with congenital heart disease: A case-control study. *BMC Oral Health*, 23, 316. <https://doi.org/10.1186/s12903-023-03017-8>
- Dodds, M. W. J., Johnson, D. A., & Yeh, C. K. (2005). Health benefits of saliva: A review. *Journal of Dentistry*, 33(3), 223–233. <https://doi.org/10.1016/j.jdent.2004.10.009>
- El-Hawary, Y. M., El-Sayed, B., Abd-Alhakem, G., & Ibrahim, F. M. (2014). Deciduous teeth structure changes in congenital heart disease: Ultrastructure and microanalysis. *Interventional Medicine & Applied Science*, 6(3), 111–117. <https://doi.org/10.1556/IMAS.6.2014.3.3>
- Karikoski, E., Sarkola, T., & Blomqvist, M. (2021). Dental caries prevalence in children with congenital heart disease: A systematic review. *Acta Odontologica Scandinavica*, 79(3), 232–240. <https://doi.org/10.1080/00016357.2020.1849792>
- Koerdt, S., Hartz, J., Hollatz, S., Heiland, M., Neckel, N., Ewert, P., et al. (2022). Prevalence of dental caries in children with congenital heart disease. *BMC Pediatrics*, 22, 711. <https://doi.org/10.1186/s12887-022-03769-2>
- Koruyucu, M., Batu, S., Bayram, M., Uslu, F. E., Guven, Y., & Seymen, F. (2020). Saliva profiles in children with congenital heart disease. *European Oral Research*, 54(1), 48–54. <https://doi.org/10.26650/eor.20200087>
- Lockhart, P. B., Brennan, M. T., Sasser, H. C., Fox, P. C., Paster, B. J., & Bahrani-Mougeot, F. K. (2008). Bacteremia associated with toothbrushing and dental extraction. *Circulation*, 117(24), 3118–3125. <https://doi.org/10.1161/CIRCULATIONAHA.107.758524>
- Mahdi, H. R., & Shihab, O. I. (2024). Teeth structure analysis of primary teeth in children with congenital heart disease (ventricular septal defect) in Erbil City. *Erbil Dental Journal*, 7(2), 200–207. <https://doi.org/10.15218/edj.2024.22>
- Mohamed Ali, H., Berggreen, E., Nguyen, D., Ali, R. W., Van Dyke, T. E., Hasturk, H., et al. (2017). Dental plaque microbial profiles of children from Khartoum, Sudan, with congenital heart defects. *Journal of Oral Microbiology*, 9(1), 1281556. <https://doi.org/10.1080/20002297.2017.1281556>
- Mohammad, H., Shoaib, L. A., Dzaruddin, N., & Zahari, N. (2025). Oral health needs and barriers to care in children with congenital heart disease. *Journal of Clinical Pediatric Dentistry*, 49(6), 82–92. <https://doi.org/10.22514/jocpd.2025.129>
- Moussa, C., Savard, G., Estrade, L., Bourgi, R., Kharouf, N., Denis, F., et al. (2024). Dental health in children with congenital heart defects: A systematic review and meta-analysis. *Journal of Clinical Medicine*, 13(23), 7022. <https://doi.org/10.3390/jcm13237022>
- Pourmoghaddas, Z., Meskin, M., Sabri, M., Norousali Tehrani, M. H., & Najafi, T. (2018). Dental caries and gingival evaluation in children with congenital heart disease. *International Journal of Preventive Medicine*, 9, 52. https://doi.org/10.4103/ijpvm.IJPVM_401_15
- Raad, H., & Shihab, O. (2023). The impact of pediatric congenital heart disease on primary teeth structure: A histological study. *Acta Biomed*, 94(6), e2023260. <https://doi.org/10.23750/abm.v94i6.14567>
- Sarac, F., Derelioglu, S. S. (2025). Assessment of growth and development, dental caries, and dental development in children with congenital heart disease. *Journal of Clinical Pediatric Dentistry*, 49(3), 107–114. <https://doi.org/10.22514/jocpd.2025.056>
- Sarac, F., Derelioglu, S. S., Sengul, F., Laloglu, F., & Ceviz, N. (2023). The evaluation of oral

- health condition and oral and dental care in children with congenital heart disease. *Journal of Clinical Medicine*, 12(11), 3674. <https://doi.org/10.3390/jcm12113674>
- Seow, W. K. (2014). Developmental defects of enamel and dentine: Challenges for basic science research and clinical management. *Australian Dental Journal*, 59(Suppl. 1), 143–154. <https://doi.org/10.1111/adj.12104>
- Sethi, M., Sood, S., Sharma, N., Singh, A., Sharma, P., & Kukshal, P. (2025). Oral health status and dental anomalies among children with congenital heart disease in contemporary times. *Special Care in Dentistry*, 45, 160–167. <https://doi.org/10.1111/scd.12815>
- Tasdemir, T., Erbas Unverdi, G., Ballikaya, E., Aypar, E., Aykan, H. H., Karagoz, T., & Uzamis Tekcicek, M. (2024). Evaluation of oral health status and treatment needs of children with congenital and acquired heart disease. *Journal of Clinical Medicine*, 13(14), 4060. <https://doi.org/10.3390/jcm13144060>
- Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., et al. (2018). PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Annals of Internal Medicine*, 169(7), 467–473. <https://doi.org/10.7326/M18-0850>
- Wilson, W. R., Gewitz, M., Lockhart, P. B., Bolger, A. F., DeSimone, D. C., Kazi, D. S., et al. (2021). Prevention of viridans group streptococcal infective endocarditis: A scientific statement from the American Heart Association. *Circulation*, 143(20), e963–e978. <https://doi.org/10.1161/CIR.0000000000000969>
- Yavsan, Z. S., Tosun, G., & Sert, A. (2022). Oral health-related quality of life of preschool-aged Turkish children with congenital heart disease. *Dental and Medical Problems*, 59(4), 503–508. <https://doi.org/10.17219/dmp/143581>