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Review Article

Salivary Lactate Alterations Associated with Early Childhood Caries: A Systematic Review

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Abstract

Background: Early Childhood Caries (ECC) is a highly prevalent chronic disease affecting children under six years of age and is associated with pain, infection and impaired quality of life. Conventional diagnostic methods detect disease only after irreversible structural damage has occurred. Salivary metabolomics offers a non-invasive approach for identifying early biochemical alterations, with lactate emerging as a key metabolite involved in the cariogenic process.

Methods: This systematic review was conducted in accordance with the PRISMA 2020 guidelines and registered in PROSPERO (CRD420261304626). Electronic searches of PubMed, Scopus, Google Scholar and the TRIP Database were performed for studies published between 2010 and 2025. Observational studies evaluating salivary lactate levels in children aged ≤6 years with ECC using metabolomic techniques were included. Risk of bias was assessed using the modified Newcastle-Ottawa Scale.

Results: A total of 583 records were identified, of which three cross-sectional studies met the inclusion criteria. Two studies reported significantly higher salivary lactate levels in children with ECC than in caries-free controls, while one study found no statistically significant independent association. Overall, the available evidence indicates a trend toward elevated salivary lactate concentrations in children with ECC.

Conclusion: The available evidence supports the biological relevance of salivary lactate as a biomarker associated with Early Childhood Caries. However, current evidence remains limited and salivary lactate should be interpreted as part of a broader metabolomic profile rather than as a stand-alone biomarker.

Keywords: Early Childhood Caries; Saliva; Lactic Acid; Metabolomics; Preschool Child

Abbreviations

ECC: Early Childhood Caries; AAPD: American Academy of Pediatric Dentistry; WHO: World Health Organization; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PROSPERO: International Prospective Register of Systematic Reviews; NOS: Newcastle-Ottawa Scale; LC-MS: Liquid Chromatography-Mass Spectrometry; GC-MS: Gas Chromatography-Mass Spectrometry; NMR: Nuclear Magnetic Resonance; CE-MS: Capillary Electrophoresis-Mass Spectrometry.

Introduction

Early Childhood Caries (ECC) is one of the most prevalent chronic diseases affecting children under six years of age. It is characterized by its early onset and rapid progression, frequently resulting in pain, infection, impaired mastication and speech, poor nutritional status and a reduced quality of life [1-3]. According to the Global Burden of Disease Study, untreated dental caries in primary teeth affects approximately 530 million children worldwide, representing a substantial public health burden [4]. Recent updates from the Global Burden of Disease framework reinforce that untreated primary dentition caries remains a critical unmet health need globally, showing minimal decline in absolute prevalence over the past decade [5-18]. The diagnosis of ECC is conventionally based on visual-tactile examination and radiographic assessment [2,5].

However, these methods generally detect the disease only after irreversible structural changes have occurred in enamel or dentin, thereby limiting opportunities for early intervention [5,6]. Consequently, there is increasing interest in identifying sensitive biomarkers capable of detecting biochemical alterations that precede clinically detectable disease [19,20].

Metabolites are low-molecular-weight molecules produced as intermediates or end products of metabolic processes within both the host and the resident oral microbiota [7]. Salivary metabolites originate from salivary glands, oral tissues, dietary intake and microbial metabolism, providing real-time insights into the biochemical status of the oral environment [7,8]. Because saliva can be collected non-invasively, easily and with excellent acceptance among young children, it has emerged as an ideal diagnostic biofluid for pediatric oral diseases [8,9].

Advances in salivary metabolomics have enabled the identification of metabolic alterations that distinguish children with ECC from caries-free individuals [10-12]. Previous studies have demonstrated significant changes in amino acids, carbohydrates and organic acids in children with ECC, reflecting alterations in microbial ecology and host-microbial interactions associated with disease progression [10-13].

Among these altered metabolites, lactate has attracted particular interest because it is the principal end product of dietary carbohydrate fermentation by acidogenic oral bacteria and plays a central role in the cariogenic process [6,13]. As a direct indicator of bacterial glycolytic activity and acid production, salivary lactate represents a biologically plausible biomarker for assessing disease activity. Compared with broad metabolomic profiling,evaluating a single mechanistically relevant metabolite such as lactate may facilitate clinical interpretation and improve comparability across studies. However, the available evidence regarding salivary lactate alterations in children with ECC remains fragmented and has not been comprehensively synthesized. Therefore, this systematic review aims to synthesize the existing evidence regarding salivary lactate alterations associated with Early Childhood Caries and to evaluate its consistency and potential role as a salivary biomarker for distinguishing children with ECC from caries-free controls.

Methodology

Study Design and Protocol Registration

This systematic review was conducted to evaluate alterations in salivary lactate levels associated with Early Childhood Caries (ECC) in children. The methodology was developed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Fig. 1).

The review protocol was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD420261304626, thereby minimizing the risk of selective reporting and methodological bias.

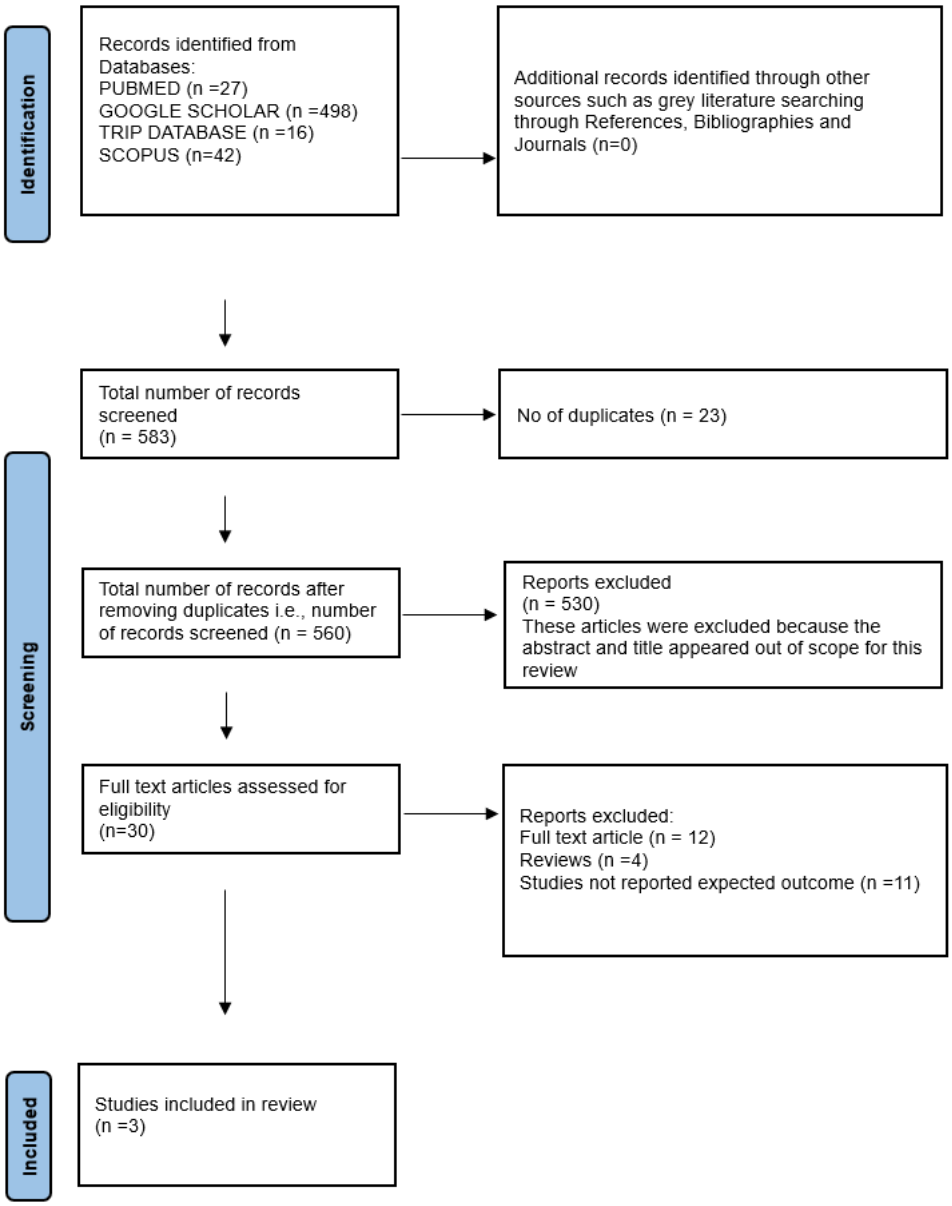


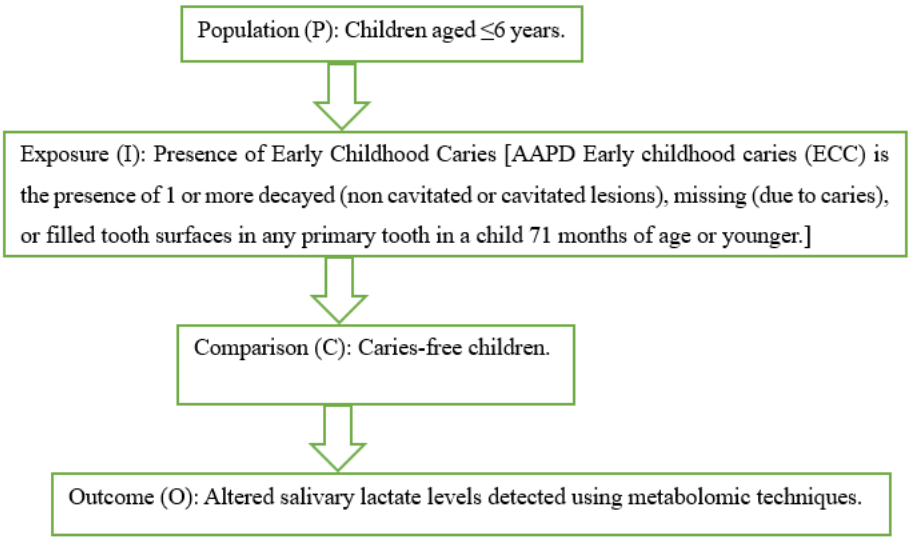
Figure 1: PRISMA 2020 flow diagram.

Study Selection

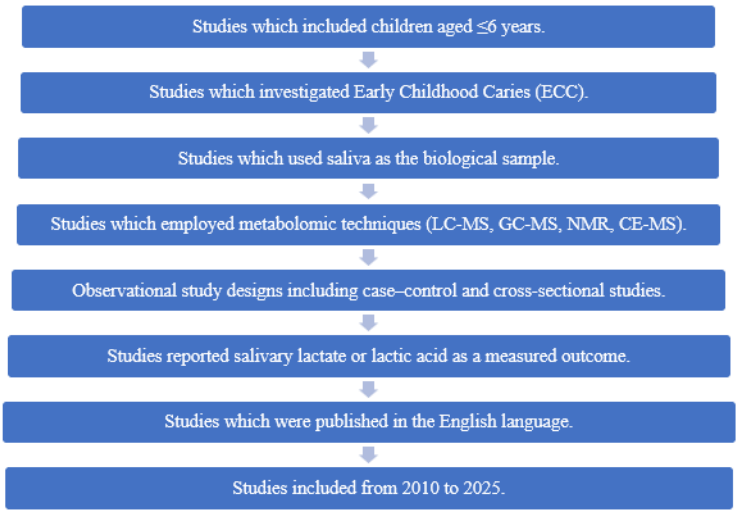
A comprehensive electronic search was conducted across four databases: PubMed (n = 27), Google Scholar (n =498), TRIP Database (n = 16) and Scopus (n = 42), yielding a total of 583 records. No additional records were identified through other sources. All retrieved references were imported into Zotero reference management software and 23 duplicate records were identified and removed. Following duplicate removal, 560 unique records remained for title and abstract screening.

Titles and abstracts of the 560 records were independently screened by two reviewers according to the predefined inclusion and exclusion criteria. During this stage, 530 records were excluded as they were deemed out of scope for the review. Thirty full-text articles were subsequently retrieved and assessed for eligibility. Of the 30 full-text articles evaluated, 27 were excluded for the following reasons: failure to meet eligibility criteria upon detailed assessment (n = 12), scoping reviews (n = 4) and studies that did not report the primary outcome of interest—salivary lactate levels (n = 11). Ultimately, three studies fulfilled all eligibility criteria and were included in the qualitative synthesis. Any disagreements that arose during the screening or eligibility assessment stages were resolved through discussion and consensus between the reviewers. The study selection process was conducted and reported in accordance with the PRISMA 2020 guidelines and is illustrated using the PRISMA 2020 flow diagram.

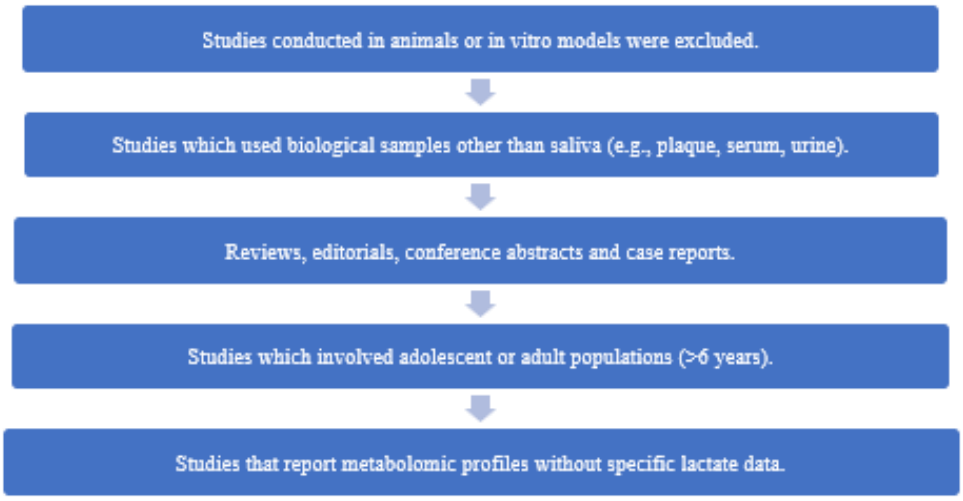
Eligibility Criteria



Inclusion Criteria



Exclusion Criteria



Search Strategy

A comprehensive literature search was conducted in PubMed, Google Scholar, TRIP Database and Scopus to identify relevant studies evaluating salivary lactate alterations associated with Early Childhood Caries (ECC) in children. The search was limited to studies published between 2010 and 2025 and restricted to the English language. Additionally, a manual bibliographic search of the reference lists of all included studies was performed to identify any further relevant articles; however, no additional eligible studies were found. The detailed search strategies for each database are presented in Table 1.

SI No	Database	Search Strategy
1	PUBMED	(Dental Caries[MeSH Terms] OR early childhood caries[tiab] OR severe early childhood caries[tiab] OR ECC[tiab]) AND (Saliva[MeSH Terms] OR saliva[tiab] OR salivary[tiab]) AND (Metabolomics[MeSH Terms] OR Metabolome[MeSH Terms] OR metabolomics[tiab] OR metabolome[tiab] OR Lactic Acid[MeSH Terms] OR lactate[tiab] OR lactic acid[tiab]) AND (Child[MeSH Terms] OR Child, Preschool[MeSH Terms] OR Infant[MeSH Terms] OR child[tiab] OR children[tiab] OR preschool children[tiab] OR infant*[tiab] OR toddler*[tiab])
2	GOOGLE SCHOLAR	("early childhood caries" OR ECC)AND(saliva OR salivary)AND(lactate OR "lactic acid")AND (metabolomics OR metabolomic OR "LC-MS" OR "GC-MS" OR NMR)AND(child* OR preschool* OR infant* OR toddler*)
3	TRIP DATABASE	("early childhood caries" OR ECC OR "severe early childhood caries") AND (saliva OR salivary) AND (lactate OR "lactic acid" OR metabolomics OR metabolome OR "LC-MS" OR "GC-MS" OR NMR) AND (child OR children OR preschool OR infant OR toddler)
4	SCOPUS	("early childhood caries" OR ECC) AND (saliva OR salivary) AND (lactate OR "lactic acid") AND (metabolomics)

Table 1: Search patterns for various databases.

Data Extraction

Data extraction was performed using a standardized data extraction form. Extracted information included author details, year of publication, study design, metabolomic platforms used, summary and lactate-related outcomes relevant to ECC (Table 2).

SI NO	AUTHOR (YEAR)	STUDY DESIGN	AIM OF THE STUDY	STUDY SUMMARY	RESULT (SALIVARY LACTATE)
1	Schulz, et al., 2020	Cross-sectional observational study	To quantitatively analyze salivary and acquired pellicle metabolites in children with varying caries activity	Targeted metabolomic analysis using LC-MS and GC-MS was performed to compare metabolite profiles among caries-active, caries-inactive and caries-free children	Higher mean salivary lactate levels observed in caries-active children, suggesting increased acidogenic activity
2	Kim, et al., 2023	Cross Sectional study	To identify salivary metabolite biomarkers associated with early childhood caries	Untargeted salivary metabolomics was used to differentiate children with ECC from caries-free controls and to develop a diagnostic metabolite biomarker panel	Salivary lactate was significantly elevated in ECC and included in the optimal biomarker panel

3	Li, et al., 2023	Cross-sectional study	To explore salivary metabolomic and microbiome alterations in severe early childhood caries	LC-MS-based untargeted metabolomics combined with oral microbiome profiling identified altered metabolic pathways in severe ECC	No statistically significant difference in salivary lactate levels as an individual metabolite

Table 2: Data extraction table.

Qualitative Assessment of Included Studies

The methodological quality and risk of bias of the included studies were assessed using a modified Newcastle-Ottawa Scale (NOS) adapted for cross-sectional and case-control studies. This classification approach was adopted to provide a standardized interpretation of study quality and is consistent with previously published systematic reviews that have used NOS adaptations, where higher cut-off scores reflect better methodological rigor and lower risk of bias. The thresholds were applied to ensure uniformity in study appraisal and to facilitate comparison across included studies. The scale evaluated three domains: selection of the study sample, comparability of study groups (control of confounding) and assessment of exposure/outcome (Table 3). Based on the total NOS score, studies were classified as having a low (7-9 stars), moderate (4-6 stars) or high (0-3 stars) risk of bias (Table 4).

Study (Author, Year)	Representativeness (1★)	Sample Size (1★)	Exposure Assessment (2★)	Outcome Assessment (2★)	Adjustment for Confounders (2★)	Assessment of Confounders (1★)	Total (/9)	Risk of Bias
Kim, et al., 2023	★	★	★★	★★	★	★	8 / 9	Low
Li, et al., 2023	★	★	★★	★★	★	★	8 / 9	Low
Schulz, et al., 2020	★	-	★★	★★	-	★	6 / 9	Moderate

Table 3: The risk of bias of the included studies was evaluated using a modified Newcastle-Ottawa Scale (NOS).

Total Score (out of 9)	Risk of Bias Category
7 - 9	Low risk of bias
4 - 6	Moderate risk of bias
0 - 3	High risk of bias

Table 4: Interpretation for modified Newcastle-Ottawa Scale.

Results

Search Results

583 entries were found by the electronic search throughout PubMed, Google Scholar, TRIP Database and Scopus.560 titles and abstracts were evaluated after 23 duplicates were eliminated. 530 of these records were eliminated because they did not fit the requirements for eligibility. Twenty-seven of the thirty full-text papers that were evaluated for eligibility were eliminated because of the scoping review design, the lack of salivary lactate reporting or the absence of pertinent results. Three papers were ultimately included in the qualitative synthesis after meeting all inclusion criteria [14-16].

Outcome Synthesis

The key findings, analytical characteristics for the included investigations have been compiled and structured into Table 2.

Discussion

The elevated salivary lactate concentrations observed in children with ECC are biologically plausible. Frequent exposure to fermentable carbohydrates promotes the proliferation of acidogenic and aciduric microorganisms, particularly *Streptococcus mutans* and *Lactobacillus* species, which metabolize dietary sugars through glycolysis and produce lactate as the principal organic acid. The accumulation of lactate lowers plaque pH below the critical threshold for enamel demineralization, thereby initiating and accelerating the caries process [5,6,14].

The findings of the present review indicate a consistent trend toward higher salivary lactate concentrations in children with Early Childhood Caries (ECC) than in caries-free controls, although statistically significant differences were not observed across all included studies. Despite this variability, the overall evidence supports the biological association between salivary lactate and cariogenic activity.

These findings are consistent with evidence from untargeted salivary metabolomic studies, which have demonstrated alterations in amino acid, carbohydrate, energy and organic acid metabolism in children with ECC compared with caries-free controls [10-12,23-25]. Stage-specific metabolomic analyses have identified distinct metabolic signatures associated with different stages of ECC, suggesting progressive metabolic dysregulation during disease development [10]. Furthermore, integrated microbiome-metabolome investigations have demonstrated significant associations between altered salivary metabolites and cariogenic bacterial communities, highlighting the complex host-microbial interactions underlying ECC [12,25].

Among the identified metabolites, organic acids including lactate, acetate, propionate and formate play important roles in caries pathogenesis. Lactate is the predominant end product of bacterial carbohydrate fermentation and has a well-established mechanistic role in plaque acidification and enamel demineralization [5,6]. Consequently, elevated salivary lactate concentrations may serve as an indirect indicator of increased bacterial glycolytic activity and active cariogenic biofilms. Compared with comprehensive metabolomic profiling, evaluating a single mechanistically important metabolite such as lactate offers greater analytical simplicity, improved reproducibility, enhanced clinical interpretability and easier comparison across studies.

However, evidence suggests that salivary lactate demonstrates greater diagnostic utility when interpreted as part of a metabolite panel rather than as an isolated biomarker. NMR-based metabolomic studies have shown that combinations of lactate, formate, proline and glycine provide superior discrimination between children with ECC and healthy controls than individual metabolites alone [14]. These findings suggest that lactate contributes to a broader metabolic fingerprint characteristic of ECC. Interpretation of the available evidence should consider the methodological heterogeneity among studies.Variations in saliva collection procedures, sample processing, analytical platforms (LC-MS, GC-MS and NMR)and metabolite quantification methods may substantially influence measured lactate concentrations.(11,15) In addition, salivary lactate levels are affected by salivary flow rate, buffering capacity, dietary intake, oral hygiene practices and circadian variation, factors that were not consistently controlled across the included studies [16].

From a clinical perspective, salivary lactate is an attractive biomarker because saliva collection is non-invasive,inexpensive and well accepted by young children [8,9]. Although current evidence does not support its use as a stand-alone diagnostic marker, salivary lactate may complement conventional clinical examination and contribute to future biomarker-based or point-of-care diagnostic approaches, particularly when incorporated into multiplex metabolomic panels [14,17,26]. Future multicenter longitudinal studies using standardized saliva collection protocols, validated analytical methodologies and uniform diagnostic criteria are required to establish clinically applicable reference values and determine the predictive value of salivary lactate for the early detection and monitoring of ECC [22].

Limitations

1. A limited number of eligible studies were included
2. Most included studies were cross-sectional, limiting causal inference
3. Methodological heterogeneity in saliva collection, analytical techniques and metabolite quantification reduced comparability across studies

Conclusion

Salivary lactate appears to be a biologically relevant biomarker associated with Early Childhood Caries, reflecting increased acidogenic microbial activity and metabolic changes linked to the cariogenic process. Although the current evidence supports its potential role in biomarker-based caries assessment, salivary lactate is best interpreted as part of a broader metabolomic profile rather than as a stand-alone marker.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethical Statement

The project did not meet the definition of human subject research under the preview of the IRB according to federal regulations and therefore was exempt.

Informed Consent Statement

Not applicable.

Authors' Contributions

Dr. Sedhu Bharath S: Conceptualization and study design; data acquisition.

Dr. Savitha S: Data analysis and interpretation; manuscript drafting; critical revision of the manuscript.

Dr. Aparna Sukumaran: Critical revision of the manuscript for important intellectual content; final approval of the version to be published.

Dr. P. D. Madankumar: Critical revision of the manuscript for important intellectual content; final approval of the version to be published.

Equal Contribution: Dr. Savitha S, Dr. Aparna Sukumaran, and Dr. P. D. Madankumar contributed equally to this work.

Author Approval: All authors have read and approved the final manuscript. All authors meet the criteria for authorship and confirm that the work is original, has not been published elsewhere, and represents an accurate and honest account of the research conducted.

References

1. American Academy of Pediatric Dentistry. Policy on early childhood caries (ECC): classifications, consequences and preventive strategies. In: *The Reference Manual of Pediatric Dentistry*. Chicago (IL): American Academy of Pediatric Dentistry; 2023. p. 79-82.
2. Pitts NB, Zero DT, Marsh PD, Ekstrand KR, Weintraub JA, Ramos-Gomez FJ, et al. Dental caries. Nat Rev Dis Primers. 2017;3:17030.
3. World Health Organization. Ending Childhood Dental Caries: WHO Implementation Manual. Geneva: World Health Organization; 2019.
4. Kassebaum NJ, Smith AGC, Bernabé E, Fleming TD, Reynolds AE, Vos T, et al. Global, regional and national prevalence, incidence and disability-adjusted life years for oral conditions for 195 countries, 1990-2015: A systematic analysis for the Global Burden of Disease Study 2015. J Dent Res. 2017;96(4):380-387.
5. Featherstone JDB. The continuum of dental caries evidence for a dynamic disease process. J Dent Res. 2004;83:C39-C42.
6. Takahashi N, Nyvad B. The role of bacteria in the caries process: Ecological perspectives. J Dent Res. 2011;90(3):294-303.

7. Dame ZT, Aziat F, Mandal R, Krishnamurthy R, Bouatra S, Borzouie S, et al. The human saliva metabolome. Metabolomics. 2015;11:1864-1883.
8. Humphrey SP, Williamson RT. A review of saliva: Normal composition, flow and function. J Prosthet Dent. 2001;85(2):162-169.
9. Javaid MA, Ahmed AS, Durand R, Tran SD. Saliva as a diagnostic tool for oral and systemic diseases. J Oral Biol Craniofac Res. 2016;6(1):66-75.
10. Washio J, Takahashi N. Metabolomic studies of oral biofilm and dental caries. J Oral Biosci. 2016;58(2):45-52.
11. Sakanaka A, Kuboniwa M, Takeuchi H, Hashino E, Amano A. Salivary metabolomics for oral disease biomarker discovery. J Oral Biosci. 2022;64(2):123-131.
12. Liu Y, Zhang Y, Wang L, Guo Y, Xiao S. Salivary metabolomics in early childhood caries: a systematic review. Metabolites. 2023;13:1006.
13. Marsh PD. Microbial ecology of dental plaque and its significance in health and disease. Adv Dent Res. 1994;8(2):263-271.
14. Kim S, Park J, Lee J, Kim J. Evaluation of salivary lactate levels in preschool children with severe early childhood caries using NMR-based metabolomics. J Clin Pediatr Dent. 2023;47(4):215-223.
15. Schulz S, Schaller HG, Sefat S, Hieke C, Gernhardt CR. Salivary metabolomics in children with early childhood caries determined by gas chromatography-mass spectrometry. Clin Oral Investig. 2020;24(9):3125-3134.
16. Li X, Wang Y, Zhang Z, Liu Y. Comparison of liquid chromatography-mass spectrometry-based salivary metabolic profiles between caries-free children and children with active early childhood caries. BMC Oral Health. 2023;23(1):412.
17. Fidalgo TK, Freitas-Fernandes LB, Ammari MM, Mattos CT, de Souza IP, Maia LC. The metabolic profile of saliva in children with early childhood caries: A systematic look at prospective validation. Metabolomics. 2024;20(2):45.
18. GBD 2019 Oral Disorders Collaborators. Global, regional and national burden of untreated dental caries, severe periodontitis and total tooth loss in 204 countries and territories, 1990-2019: A systematic analysis for the Global Burden of Disease Study 2019. J Dent Res. 2020;99(12):1333-1343.
19. Hajishengallis E, Parsaei R, Klein MI, Koo H. Advances in the microbial pathogenesis and treatment of early childhood caries. Periodontol 2000. 2017;74(1):153-172.
20. Schwendicke F, Frencken JE, Bjørndal L, Maltz M, Manton DJ, Ricketts D, et al. Managing carious lesions: Consensus recommendations on carious tissue removal. Adv Dent Res. 2016;28(2):58-67.
21. Gardner A, Park KC, Woods A, Chapple ILC, Grant MM, Gross R, et al. Collection, storage and processing of saliva samples for metabolomic applications: A consensus statement. Metabolomics. 2020;16(5):59.
22. Pitts NB, Baez RJ, Diaz Guillory C, Donly KJ, Feldens CA, McGrath C, et al. Early childhood caries: IADR policy statement on global prevention and management. JDR Clin Trans Res. 2021;6(2):124-127.
23. Grier A, Myers JA, O'Connor TG, Quivey RG, Gill SR, Kopycka-Kedzierawski DT. Oral microbiota and metabolite profiles in dynamic progression of early childhood caries. Microbiome. 2021;9(1):118.
24. Zhang Q, Yin X, Wang C, Wang J, Farook AA, Zhou Y, et al. Untargeted metabolomic analysis reveals biochemical changes in saliva associated with severe early childhood caries. J Proteome Res. 2024;23(3):845-854.
25. Ribeiro AA, Azcarate-Peril MA, Cadenas MB, Butz N, Paster BJ, Chen T, et al. The oral microbiome and metabolome of children with severe early childhood caries. Clin Oral Investig. 2021;25(8):4915-4926.
26. Twetman S. Prevention of early childhood caries (ECC) through biomarker-driven risk assessment: A review of current clinical evidence. Eur Arch Paediatr Dent. 2023;24(1):15-22.

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