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Secondary Smoking and Early Childhood Caries: A Systematic Review and Meta-Analysis

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ABSTRACT

Objective: This study aimed to systematically review the relationship between secondary smoking and early childhood caries (ECC) among preschool children.

Method: Two independent reviewers systematically searched English publications with keywords in PubMed, Web of Science, Medline, Scopus, and Embase to identify publications reporting on secondary smoking and ECC for children under 71 months. Observational studies, including cohort studies, case-control studies, and cross-sectional surveys, were included. The reviewers screened the titles and abstracts to remove duplicate records, reviews, and irrelevant studies. They performed meta-analyses to investigate the prevalence of ECC in children exposed to secondary smoking.

Results: This study identified 1243 publications and included 16 publications. Twelve publications were cross-sectional studies. A meta-analysis of 11 of them revealed that children with secondary smoking exposure had an odds ratio of 1.77 in caries risk ($P < .001$), whereas one cross-sectional study found no increase in caries risk without data reporting. Two cohort studies with low and very low quality were combined into a meta-analysis, which found children from infancy with secondary smoking exposure had a relative risk of 1.45 in caries incidence ($P < .001$). Two case-control studies with moderate and low quality were combined into a meta-analysis, which found that children exposed to secondary smoking had an odds ratio of 4.46 in caries prevalence ($P < .001$).

Conclusion: The literature has reported that preschool children with secondary smoking exposure have a higher risk of caries; however, the number and quality of these studies are limited.

Introduction

Dental caries in children have a distinctive pattern and are known as early childhood caries (ECC). It is a common childhood health problem worldwide. Children with dental caries may have discomfort, pain, infection, and functional impairment and are more likely to develop carious lesions in their permanent dentitions.[1,2] ECC affects children's general well-being and quality of life in the long term.[3,4]

Dental caries is an imbalance of numerous risks and protective factors and is the localized destruction of tooth structure by acidic by-products from bacterial fermentation of dietary carbohydrates. The process is mediated by saliva. For caries to occur, there should be a susceptible host tissue (saliva and teeth), cariogenic microflora, and suitable substrate (diet rich in fermentable carbohydrates) that interact for a period.[5]

There are many factors, such as diet, oral health habits, socioeconomic status (SES), parental education level, fluoride use or others, could affect the host tissue, cariogenic microflora, and fermentable carbohydrates, and function on the development of ECC.[6] Lower SES, lower family educational level or poor oral health knowledge increases caries risk in children.[7,8] Lower SES is one of the risk indicators for having dental caries.[9] Meanwhile, people with lower SES are more likely to smoke.[10] Mothers' smoking was found more in lower education family.[11] Children living in these families or communities are more likely to have access to secondary smoking exposure. The relationships among

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lower SES, secondary smoking, and dental caries are interrelated, which can create a vicious cycle. Lower SES can contribute to higher rates of secondary smoking exposure, which in turn can lead to an increased prevalence of dental caries.

Secondary smoking, also known as passive smoking or secondhand smoke, occurs when a person inhales tobacco smoke from the environment rather than directly from a cigarette. Secondary smoking exposure is a common public health problem, especially for children. It is well-established that respiratory and cardiovascular health will have a negative impact with exposure to secondary smoking.[12,13] However, the negative impact of secondary smoking on ECC has arisen and been discussed in recent decades. One study[14] put forward the point that secondary smoking did not directly interfere with the process of dental caries formation, but the smoking chemicals breathed by children may interfere with the development of the teeth and gums, which may lead them to become more susceptible to dental caries. Another study[15] discussed that secondary smoking may directly influence the growth of bacteria and cells, which may imbalance the constitute of microorganisms in the oral cavity and impair the salivary gland function with oral membrane inflammation. However, there is no conclusion on this topic, and researchers hold different views on secondary smoking and ECC.

Few previous studies were performed to systematically review the secondary smoking-related factors and their relationship with dental caries among children. Two studies[14,16] involved a wide age range of children with both permanent and primary teeth. One study[17] focused on the oral health of both infants and preschoolers, no meta-analyses were done to explore the association of secondary smoking and ECC.

Therefore, different from the previous reviews, this study aimed to systematically review and focus on the relationship between secondary smoking and ECC among preschool children.

Material and methods

This systematic review was conducted following the guidelines of the Cochrane Handbook and presented based on the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis statement.[18]

Search strategy

Two reviewers (BWL and IGS) independently performed a systematic search with keywords (child OR child, preschool) AND (smoking OR secondary smoking) AND (dental caries OR childhood caries OR tooth decay) in five electronic databases (PubMed, Web of Science, Medline via Ovid, Scopus, and Embase database via Ovid). The last search was performed on 20 June 2024. We screened publications according to the eligible criteria and selected studies published by 20 June 2024.

Study selection

The title and abstract of the identified publications in English were screened independently by two independent reviewers (BWL and IGS). Reference lists of the related study were screened to identify all possible eligible studies. Full texts of all potentially relevant publications were obtained and read independently after the screening.

The inclusion criteria for selecting studies in this systematic review were:

(1) Study design: observational studies, including cohort studies, case-control studies, and cross-sectional surveys.
(2) Children aged 71 months or younger.
(3) Secondary smoking exposure should be investigated in childhood.
(4) The outcome should be the incidence or prevalence of dental caries in children aged 3 to 6 years.

The exclusion criteria were (1): not separating data for infants, preschool children, and adults (2): smoking exposure was not during childhood.

The final decision about inclusion was made based on the full text of the potentially relevant studies. The consensus was obtained by discussion between the two reviewers or by consulting a third reviewer (CHC). The reasons for exclusions were recorded. Details of the study selection process and elimination of studies are illustrated in Figure 1.

Risk of bias assessment of included studies

For nonrandomized studies, including cohort studies, case-control studies, and cross-sectional studies, Risk Of Bias In Nonrandomized Studies of Exposure[19] was used to assess the risk of bias (risk of bias due to confounding, arising from measurement of the exposure, in selection of participants into the study or into the analysis, postexposure interventions, missing data, arising from measurement of the outcome, in selection of the reported result). Two reviewers (BWL and IGS) independently evaluated the risk of bias in each included study, and the consensus was reached by discussion between the two reviewers or by consulting a third reviewer (CHC). A summary assessment for risk of bias was provided for each included study with classification of very high risk of bias, high risk of bias, some concerns, and low risk of bias.

Data synthesis and outcomes evaluation

The characteristics of the included studies were summarized. Extracted data were compared. The primary endpoints were measured with the prevalence of dental caries for case-control studies and cross-sectional studies, while the incidence of dental caries for cohort studies. For cohort studies, the risk ratio (RR) was used as the measure of treatment effect. For case-control or cross-sectional studies, the odds ratio (OR) was selected. Adjusted or unadjusted estimated ratios were extracted and used in the meta-analysis.

Meta-analysis was conducted for studies reporting the same outcome measures. Data analysis was performed by Review Manager software (RevMan, Version 5.4).[20] The level of significance for all tests was 5%. The random-effect model was used for analysis.

Quality of the evidence

The Cochrane Collaboration's GRADE approach[21] was used to assess the certainty of evidence in this review. Observational studies started with low-quality evidence. The certainty of

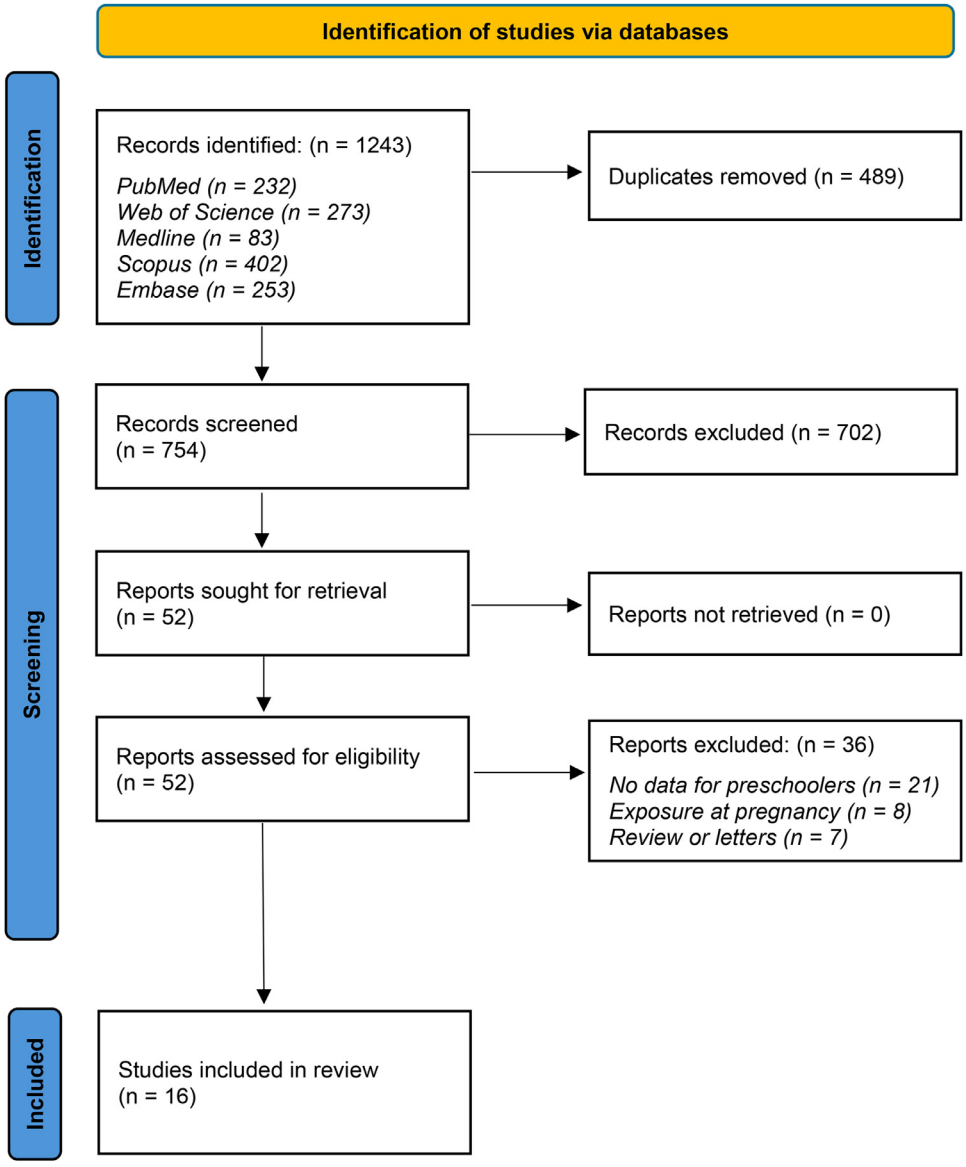

Fig. 1 – PRISMA 2020 flow diagram.

evidence will be downgraded by one level with a high to very high risk of bias or with high heterogeneity (I^2 > 70%), while being upgraded by one level based on the large magnitude of effect with a large OR. The overall certainty of the evidence was evaluated as high, moderate, low, or very low.

Results

Study selection

A total of 1243 studies were identified with MeSH keywords (child OR child, preschool) AND (smoking OR secondary smoking) AND (dental caries OR childhood caries OR tooth decay) in five electronic databases (PubMed, Web of Science, Medline via Ovid, Scopus, and Embase database via Ovid). There were 489 duplicates. The study flow diagram is shown in Figure 1. After screening the titles and abstracts, 52 studies were identified and processed to assess full-text for eligibility. Among the remaining 52 studies, 36 studies were excluded for reasons. The reasons for exclusion included being reviews or letters, the smoking exposure being before children's birth, and not separating data for infants, preschool children, and adults in the reporting. Finally, 16 studies were identified to be eligible and included in the review. There were two cohort studies, two case-control studies, and 12 cross-sectional studies.

Characteristics of included studies

All the included were synthesized and summarized. The cross-sectional and case-control studies are in Table 1 and cohort studies are in Table 2.

Across the two cohort studies, two case-control studies, and 12 cross-sectional surveys, a total of 124,179 participants

Table 1 – Quality of evidence and main findings of the cross-sectional and case-control studies (*n* = 14).

Study	Country	Children		Caries prevalence		Odds ratio	*P* value	Exposure measurement
		Number	Age (years)	Exposure	Control			
Cross-sectional studies (n = 12)								
Leroy[35,*]	Belgium	1,038	3	Not reported		1.98	.210	Family smoking
Leroy[35,*]	Belgium	1,093	5	Not reported		3.36	.004	Family smoking
Ogawa[30]	Japan	3,320	3-6	31%	11%	3.91	.002	Parental smoking
Lee[31]	Malaysia	396	3-6	Not reported		1.16	.005	Household smoking
Tang[28]	China	283	3	Not reported		1.03	.940	Household smoking
Goto[32]	Japan	405	3-6	38%	24%	1.72	.019	Family smoking
Nakayama[33]	Japan	2,825	3	25%	14%	1.74	<.001	Family smoking
Kato[29]	Japan	6,315	3	Not reported		Not reported	>.05	Household smoking
Nakayama[34]	Japan	1,801	3	37%	15%	2.15	<.001	Parental smoking
Songo[36]	Congo	158	4-6	Not reported		2.02	>.05	Father smoking
Tanaka[37]	Japan	2,015	4-6	25%	18%	1.53	<.001	Household smoking
Hanioka[26]	Japan	711	3	41%	26%	1.99	<.001	Parental smoking
Williams[27]	UK	749	3-4	Not reported		1.54	<.05	Mother smoking
Case-control studies (age and gender-matched, n = 2)								
Avsar[25]	Turkey	180	4-6	90%	66%	4.86	<.001	Household smoking
Mohammed[24]	Iraq	60	5	100%	87%	10.36	>.05	Household smoking

* The same publication.

Table 2 – Quality of evidence and main findings of the cohort studies (*n* = 2).

Study	Country	Children		Follow-up	Caries prevalence		Risk ratio	*P* value	Exposure measurement
		Number	Age		Exposure	Control			
Tanaka[22]	Japan	71,652	4 mo	3 y	19%	13%	1.54	<.01	Household smoking
Watanabe[23]	Japan	31,178	1.5 y	1.5 y	20%	14%	1.47	<.01	Family smoking

aged from 4 months to 6 years were included. Most of the studies were conducted in Asia (75%, 12/16), while the remaining were conducted in Europe (19%, 3/16) and Africa (6%, 1/16). More than half of them (69%, 11/16) were published in the last 10 years. The two cohort studies[22,23] were birth cohort studies recording the conditions of children exposed to secondary smoking from birth to 3 years old. In the two case-control studies,[24,25] a control was matched by gender and age in a one-to-one ratio, a case was defined as a child living with a regular smoker or smoker who smoked more than 20 cigarettes per day for at least 5 years. In the remaining 12[26-37] cross-sectional studies, the conditions of children exposed to father smoking, mother smoking, both parental smoking, family smoking, or duration of being exposed to have been recorded through the questionnaire.

For confounding factors such as diet, oral health habits, SES, parental education level, fluoride use, and so on, all the 16 included studies have considered, controlled some of them in the study design, or adjusted in the data reporting. Regarding SES, seven studies considered this, controlled in the study design[25,28,35] or adjusted it[30,31,33,36] in the data reporting. The other nine studies[22-24,26,27,29,32,34,37] did not record the SES of participants.

Data synthesis

In this review, data from all included studies were categorized according to the different study designs.

Among the 16 studies, 15 of them could be extracted and categorized into three meta-analyses:

- Cross-sectional survey: Children exposed to secondary smoking (Yes vs No)
- Cohort study: Children exposed to secondary smoking from infancy (Yes vs No)
- Case-control study: Children exposed to secondary smoking (Yes vs No)

In all three meta-analyses, children who were exposed to secondary smoking at a young age had a higher risk of having dental caries during 3 to 6 years old compared to those who were not exposed to ($P < .001$).

Only one cross-sectional study[29] with limited data could not be combined into a meta-analysis, which reported no difference in the prevalence of ECC at 3-year-old between children who were exposed to secondary smoking or not exposed to it.

Meta-analysis

Cross-sectional survey: Children exposed to secondary smoking (Yes vs No) (Figure 2)

A total of 11 cross-sectional surveys[26-37] reported secondary smoking conditions in children. Children who were exposed to secondary smoking had a higher risk of having dental caries at 3 years old compared to those who were not exposed to it (OR = 1.77 [1.57, 2.01], $P < .001$).

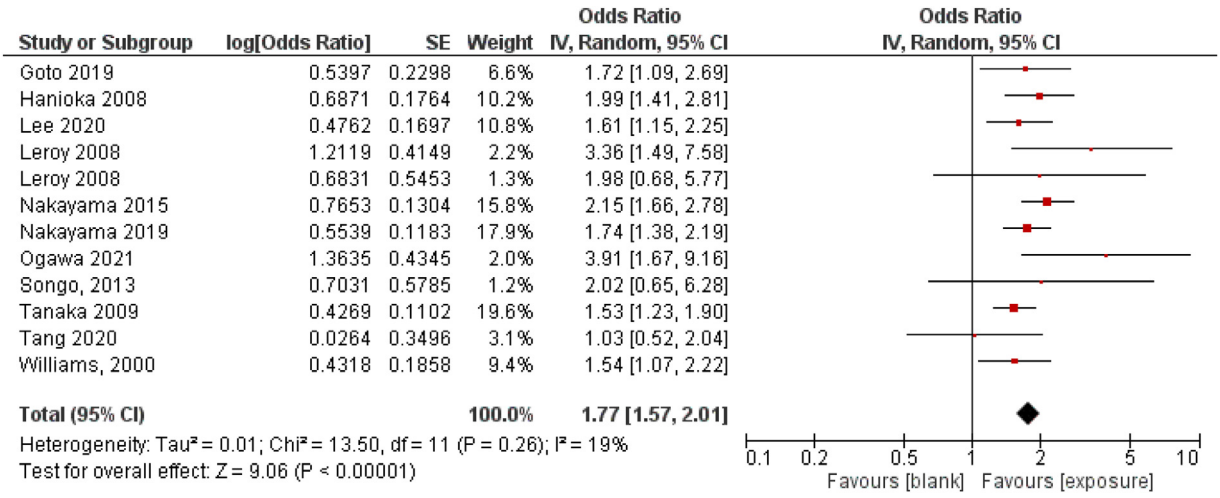

Fig. 2 – Cross-sectional study: odds ratio of caries prevalence in children exposed to secondary smoking (Yes vs No).

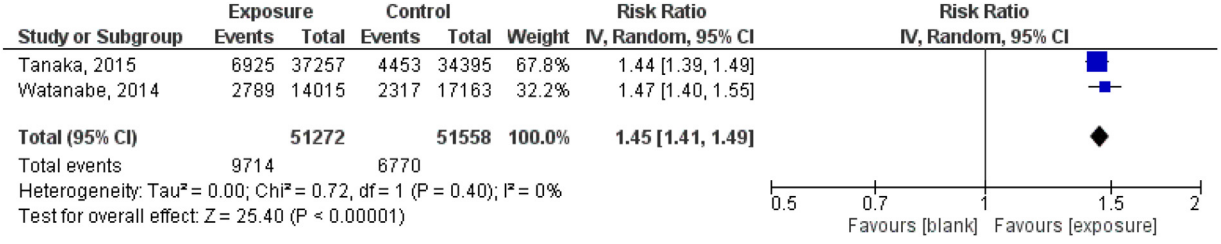

Fig. 3 – Cohort study: risk ratio of caries incidence in children exposed to secondary smoking (Yes vs No).

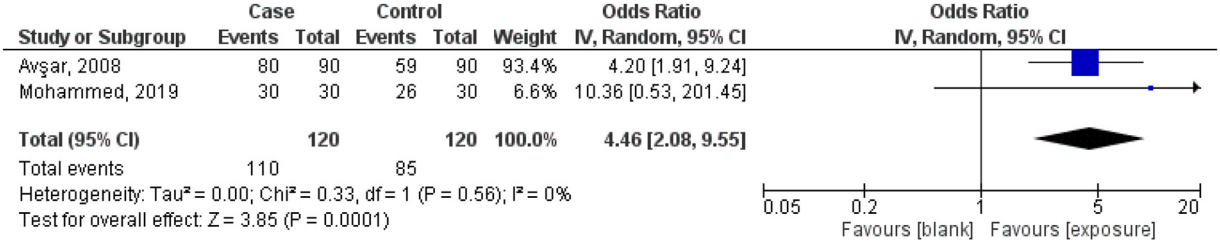

Fig. 4 – Case-control study: odds ratio of caries prevalence in children exposed to secondary smoking (Yes vs No).

Cohort study: Children exposed to secondary smoking from infancy (Yes vs No) (Figure 3)

Two cohort studies[22,23] reported children's caries incidence at the age of 3 years with exposure to secondary smoking from the age of 4 or 18 months. Children who were exposed to secondary smoking at a young age had a higher risk of having dental caries at 3 years old compared to those who were not exposed to it (RR = 1.49 [1.45, 1.54], $P < .001$).

Case-control study: Children exposed to secondary smoking (Yes vs No) (Figure 4)

Two case-control studies[24,25] found that children exposed to secondary smoking had a higher risk of having dental caries during the age of 4 to 6 years compared to those who did not expose to (OR = 4.46 [2.08, 9.55], $P < .001$).

Risk of bias assessment

The risk of bias assessment of included studies is presented in Table 3. Two cross-sectional studies[29,37] were judged to be at very high risk of bias due to the high risk of bias in three domains. Eight cross-sectional studies[26-28,30,32-34,36] one cohort study[23] and one case-control study[24] were judged to be at high risk of bias. One cohort study[22] was judged to have some concerns about the risk of bias. One case-control study[25] and two cross-sectional studies[31,35] were judged to be at low risk of bias.

Quality of evidence

The quality of the evidence is presented in Table 4. The heterogeneity was all acceptable in three meta-analyses (cross-sectional: 19%; cohort: 0%; and case-control: 0%). The meta-analysis of cross-sectional studies was downgraded in total 2 levels to have very low certainty of evidence. The meta-analyses of cohort studies and case-control studies were downgraded 1 level and upgraded 1 level respectively, and have low certainty of evidence overall.

Table 3 – Risk of bias assessment of included studies (*n* = 16).

First author, Year	Confounding factors	Exposure measurement	Participants selection	Post-exposure intervention	Missing data	Outcome measurement	Result reporting	Overall judgement
Cross-sectional studies (n=12)								
Kato, 2017	+	+	X	+	X	X	+	!
Tanaka, 2009	+	+	X	+	X	X	+	!
Ogawa, 2021	+	+	X	+	+	X	+	X
Nakayama, 2019	+	+	X	+	+	X	+	X
Williams, 2000	+	+	X	+	+	X	+	X
Songo, 2013	+	+	X	+	-	+	+	X
Hanioka, 2008	+	+	X	+	+	-	+	X
Goto, 2019	+	+	X	+	+	-	+	X
Tang, 2020	+	+	-	+	+	X	+	X
Nakayama, 2015	+	+	+	+	+	X	+	X
Lee, 2020	+	+	+	+	+	+	+	+
Leroy, 2008	+	+	+	+	+	+	+	+
Cohort studies (n=2)								
Watanabe, 2014	+	+	X	+	+	-	+	X
Tanaka, 2015	+	+	+	+	+	-	+	-
Case-control studies (n=2)								
Mohammed, 2019	+	+	+	+	+	X	+	X
Avşar, 2008	+	+	+	+	+	+	+	+

! Very high: the study is very problematic in this domain: characteristics of the study give rise to a very high risk of bias.

X High: the study has some important problems in this domain: characteristics of the study give rise to a high risk of bias.

- Some concerns: there is some concern about bias with regard to this domain, although it is not clear that there is an important risk of bias.

+ Low: there is little or no concern about bias with regard to this domain.

Discussion

Secondary smoking refers to the inhalation of other people's smoke, which is nearly equivalent to that of active smoking. Secondary smoking has been extensively researched regarding its negative impact on general health and oral health. Our findings with evidence support that secondary smoking can have negative effects on children's oral health and lead to an increased risk of dental caries. Our findings align with the previous systematic reviews[14,16] that secondary smoking exhibited the potential to infer a causal association with ECC. Even though there may be a difference in inclusion criteria. Different from ours, these two reviews conducted in 2011[14] and 2020[16] have investigated the relationship between dental caries and secondary smoking among other age groups with both primary teeth and permanent teeth.

All these included studies were published after 2000, and most (69%) were in the last 10 years. Researchers become more interested in this topic. The categories and terms that measured the condition of children exposed to secondary smoking were different across these included studies, such as father smoking,[36] mother smoking,[27] parental smoking,[30] household smoking,[29] or family smoking.[32] All of these terms' data were considered and grouped into secondary smoking comparisons with 'Yes' or 'No' groups.

Besides the biological factors that directly impact ECC, behavioural factors and environmental factors could affect

Table 4 – Summary of findings.

Study design	Outcome	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)‡
		Assumed risk (Control)	Corresponding risk (Exposure)			
Cross-sectional	Caries prevalence	See comment†	See comment†	OR 1.77 (1.57-2.01)	14,794 (11)	Very low§
Case-control		0.71	0.92 (0.90-0.97)	OR 4.46 (2.08-9.55)	240 (2)	Low¶,‖
Cohort	Caries incidence	0.13	0.40 (0.40-0.41)	RR 1.45 (1.41-1.49)	102,830 (2)	Low#,**

CI, confidence interval; OR, odds risk; RR, risk ratio.

Title: The caries risk of children exposed to secondary smoking. Population: Children aged 4 months to 6 years. Settings: Dental examination with no restriction. Exposure: Exposed to secondary smoking. Control: Not exposed to secondary smoking.

* The basis for the assumed risk is provided in footnotes. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the intervention group and the relative effect of the intervention (and its 95% CI).

† Comment: some studies did not report the outcomes, and the assumed risk cannot be calculated.

‡ GRADE Working Group grades of evidence. High certainty: we are very confident that the true effect lies close to that of the estimate of the effect. Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different. Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect. Very low certainty: we have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect.

§ Downgraded 2 levels for study limitations (very high in 1 study and high overall risk of bias in 8 studies).

¶ Downgraded 1 level for study limitations (high overall risk of bias 1 study).

‖ Upgraded 1 level for a large magnitude of effect.

Downgraded 1 level for study limitations (high overall risk of bias 1 study).

** Upgraded 1 level for a large number of participants (>100,000).

these biological factors and indirectly impact the development of ECC.[38,39] The intricacy of interventions, particularly other confounding factors, such as sugar intake, fluoride use, diet habits, SES, parental education level and so on, may make it challenging to separate the risks of secondary smoking from other factors influencing caries risk. Those potential confounding factors should be controlled in the study design or adjusted in data reporting. In this review, all of the included studies have considered some confounding factors, which contributed to the robustness of the evidence. It should be noted that researchers should try to adjust confounding factors as much as possible in further research.

SES is one of the most important confounding factors because people with lower SES are more likely to smoke.[10] Smoking is closely related to SES as is dental caries.[40] It is possible that what is being observed in these studies is the confounding effect of economic and material circumstances rather than any direct relationship between secondary smoking and dental caries. Researchers should evaluate SES as a potentially confounding factor in their studies on ECC prevalence. In this review, less than half (44%) of the included studies evaluated SES as effect modifiers. We recommend future studies should measure the effects of SES on ECC as one of the most important confounding factors.

The strength of this study stems from it being the inaugural systematic review that evaluated the relationships between secondary smoking and ECC. In contrast to earlier reviews that primarily concentrated on all age groups including both primary teeth and permanent teeth, our analysis distinguishes itself by performing an extensive search through five databases and applying rigorous selection criteria. A binary approach to the presence/absence of dental caries was used in this review. All the dental caries conditions focused on children aged 3 to 6 years. Available RR and OR were extracted or calculated based on the data provided by these included studies. The heterogeneity (I^2 < 30%) was low indicating the results of meta-analysis might be more certainty of evidence to apply broadly. However, most of the included studies were cross-sectional studies, the evidence contributing to this systematic review is of low to very low quality with the limitations of observational studies in the study design. The quality of evidence has been downgraded based on the high to very high risk of bias.

Nonetheless, it is essential to recognize certain constraints. A language bias may be present, as we only considered studies published in English, which could potentially introduce bias. There may also be publication bias, resulting in an overestimation of the effectiveness of the intervention. The variability among studies in terms of methodology, populations, and interventions makes it difficult to consolidate meta-analysis outcomes. These limitations ought to be taken into account while interpreting the results.

Despite the study's limitations, this systematic review still provides valuable results for researchers, the public, dentists, and parents. For researchers, further observational studies will be undertaken on this topic, but the quality should be improved. No randomised clinical trials could be taken on this topic due to the ethical issue. In addition, randomised clinical trials cannot determine the cause of disease. Disease causality can only be determined from case-control and cohort studies. For the public and parents, the provided information can be advantageous, as it may be a warning that guides them in fostering good oral health for their children.

Conclusion

The literature has reported that preschool children with secondary smoking exposure have a higher risk of caries; however, the number and quality of these studies are limited.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

CRediT authorship contribution statement

Bella Weijia Luo: Conceptualization, Methodology, Visualization, Software, Formal analysis, Data curation, Writing – original draft, Writing – review & editing. **Ivy Guofang Sun:** Conceptualization, Methodology, Formal analysis, Data curation, Writing – review & editing. **Sophia Siu Chee Chan:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Chun Hung Chu:** Conceptualization, Methodology, Visualization, Formal analysis, Data curation, Writing – review & editing.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.identj.2024.08.013.

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