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Review

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Do electronic smoking devices impact the risk of dental caries? A systematic review

Os dispositivos eletrônicos para fumar impactam no risco de cáries dentárias? Uma revisão sistemática

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ABSTRACT

Objective: To evaluate the association between the use of electronic smoking devices (ESDs), such as electronic cigarettes, and the risk of developing dental caries. **Material and Methods:** This systematic review included observational studies identified in the electronic databases PubMed, Embase, Scopus, Web of Science, and LILACS/BVS. Cross-sectional and case-control studies that assessed the presence of caries in ESD users compared with non-smokers were included. The Joanna Briggs Institute (JBI) critical appraisal checklist was used for methodological quality assessment. **Results:** Eight studies published between 2018 and 2024 were included, involving populations from different geographic regions and age groups. Most studies demonstrated a higher prevalence of caries and/or higher DMFT indices among ESD users. In six studies, the differences were statistically significant. However, most studies presented methodological limitations, such as lack of data on duration and frequency of ESD use and heterogeneity in outcome measurement. **Conclusion:** The evidence suggests a possible association between the use of ESDs and an increased risk of dental caries. Despite methodological limitations, the findings highlight the need for greater attention from oral health professionals regarding the use of these devices.

KEYWORDS

Dental caries; Electronic cigarettes; Electronic smoking devices; Oral health; Systematic review.

RESUMO

Objetivo: Avaliar a associação entre o uso de dispositivos eletrônicos para fumar (DEFs), como os cigarros eletrônicos, e o risco de desenvolvimento de cárie dentária. **Material e Métodos:** Esta revisão sistemática incluiu estudos observacionais identificados em bases de dados eletrônicas PubMed, Embase, Scopus, Web of Science e LILACS/BVS. Foram incluídos estudos transversais e caso-controle que avaliaram a presença de cárie em usuários de DEFs, comparando-os a não fumantes. A lista de verificação de avaliação crítica do Joanna Briggs Institute (JBI) foi utilizada para avaliação de qualidade metodológica. **Resultados:** Foram incluídos oito estudos, publicados entre 2018 e 2024, com populações de diferentes regiões geográficas e faixas etárias variadas. Os estudos demonstraram, majoritariamente, maior prevalência de cárie e/ou índices de CPO-D mais elevados entre usuários de DEFs. Em seis estudos, as diferenças foram estatisticamente significativas. A maioria dos estudos, no entanto, apresentou limitações metodológicas, como ausência de dados sobre tempo e frequência de uso dos DEFs, além de heterogeneidade na forma de mensuração dos desfechos. **Conclusão:** Os dados sugerem uma possível associação entre o uso de DEFs e o aumento do risco de cárie dentária. Apesar das limitações metodológicas, os achados indicam a necessidade de maior atenção dos profissionais de saúde bucal em relação ao uso desses dispositivos.

PALAVRAS-CHAVE

Cárie dentária; Cigarros eletrônicos; Dispositivos eletrônicos para fumar; Saúde bucal; Revisão sistemática.

INTRODUCTION

In recent decades, electronic smoking devices (ESDs), such as electronic cigarettes and vapes, have emerged as alternatives to conventional cigarettes and have become widely popular, particularly among adolescents and young adults. These devices function by vaporizing liquids that typically contain nicotine, organic solvents such as propylene glycol and vegetable glycerin, as well as flavorings and, often, artificial sweeteners. Although initially promoted as less harmful than combustible tobacco, recent studies have pointed to possible deleterious effects of ESDs on oral health, including increased risk of periodontal diseases, oral mucosa alterations, and, more recently, dental caries [1].

Dental caries is a multifactorial, biofilm-dependent disease associated with the fermentation of carbohydrates by the oral microbiota, resulting in the production of organic acids that promote the demineralization of enamel and dentin [2]. The frequent presence of fermentable substrates and the ecological imbalance of the microbiota are the main factors responsible for its pathogenesis. Several liquids used in ESDs contain sweeteners, such as sucralose and glycerol, which may serve as substrates for cariogenic bacteria such as *Streptococcus mutans* and *Lactobacillus* spp. [3,4]. Moreover, acidic and fruity flavorings commonly used in e-liquids have demonstrated *in vitro* erosive and cariogenic potential [5].

Evidence suggests that aerosols released by ESDs, upon contact with dental surfaces, can alter the pH of the oral environment and negatively affect the balance of the dental biofilm [6]. Laboratory studies indicate that the use of ESDs may increase the adhesion and metabolism of *S. mutans*, enhancing cariogenic biofilm formation and lactic acid production [7]. Furthermore, the reduction in salivary flow reported by some ESD users, associated with the presence of hygroscopic compounds such as propylene glycol, may impair the protective role of saliva in dental remineralization [8].

Despite the increasing use of ESDs and the growing body of literature on their systemic effects, important gaps remain in the scientific evidence regarding their direct impact on oral health, particularly on the development of carious lesions [9]. However, the accumulated data point to a potentially concerning association that warrants further investigation. In this context, the present study aims to conduct a systematic review of the literature to evaluate the impact of ESDs on the risk of developing dental caries, contributing with scientific evidence for clinical practice and the formulation of public health policies in dentistry.

METHODS

This review was conducted in accordance with the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [10]. The review protocol was registered in PROSPERO (CRD42024490669).

Eligibility criteria

The following guiding question was adopted: "Does the use of electronic cigarettes/vapes increase the risk of dental caries?" The PECO strategy was applied: Adolescents/adults (Population), exposed to electronic cigarettes/vapes (Exposure), compared with non-smokers (Comparison), present an increased risk of dental caries (Outcome).

Inclusion criteria: case-control, cross-sectional, or cohort studies that evaluated caries activity in patients who smoked electronic cigarettes/vapes. Articles published in any language were considered, with no restriction on publication year.

Exclusion criteria: case reports, reviews, dissertations, monographs, letters to the editor, and book chapters.

Information sources

The databases searched were: Medline/PubMed, Embase, Scopus, Web of Science, and LILACS/BVS. Searches were also conducted in the gray literature through Google Scholar and manually in the reference lists of included studies to identify additional potentially relevant articles.

Search strategy

The search strategy was developed using controlled descriptors combined with Boolean operators and applied as follows: ("Adolescent"[Mesh Terms] OR "Adult"[Mesh Terms] OR "Adolescents" OR "Adolescence" OR "Teens" OR "Teen" OR "Teenagers" OR "Teenager" OR "Youth" OR "Youths" OR "Middle Aged" OR "Young Adult") AND ("Vaping"[Mesh Terms] OR "Electronic Nicotine Delivery Systems"[Mesh Terms] OR "Electronic Cigarettes" OR "E-Cigs" OR "E Cigs" OR "E-Cigarettes" OR "E Cigarettes" OR "Cigarettes, Electronic" OR "THC Vaping" OR "Vapes") AND ("Dental Caries"[Mesh Terms] OR "Caries, Dental" OR "Carious Lesions" OR "Carious Lesion" OR "Lesion, Carious" OR "Lesions, Carious" OR "Caries").

No filters were applied for publication year or language. Each strategy was adapted according to the operators of the respective database (Supplementary Material 1).

Study selection

Study selection was carried out independently by two researchers (T.M.O.A. and W.S.L.) and reviewed by two independent reviewers (R.A.C.A and G.A.M.S.) in two stages: screening of titles and abstracts, and full-text reading of selected articles. The process was managed using Rayyan software, which facilitated screening and duplicate removal. Agreement between reviewers was assessed using the kappa coefficient (0.90). Discrepancies were resolved by consensus.

Data collection process

Data extraction from selected studies was also performed independently by the same reviewers using a specific form. Information collected included: year of publication, country, study design, sample size, age and sex of participants, method of exposure assessment (interview or questionnaire), exposure duration, control group, method of caries assessment, and caries outcomes in exposed and control groups.

Methodological quality assessment

Two reviewers (R.A.C.A and G.A.M.S.) independently assessed each study. Inter-observer reliability testing was conducted, yielding a score of 0.62, considered good agreement. Divergences were resolved by consensus.

For cross-sectional studies, the Joanna Briggs Institute (JBI) critical appraisal checklist was used, and a methodological quality graph was constructed using the Rob.vis tool. Studies were assessed based on: (a) inclusion criteria, (b) study subjects and setting, (c) validity and reliability of exposure measurement, (d) objectivity and standardization of outcome measurement criteria, (e) identification of confounding factors, (f) strategies to deal with confounders, (g) validity and reliability of outcome measurement, and (h) appropriateness of statistical analysis.

For case-control studies, the JBI critical appraisal checklist was also applied, and a methodological quality graph was constructed using Rob.vis [11]. Studies were assessed based on: (a) definition of groups, (b) representativeness of cases, (c) selection of controls, (d) validity and reliability of exposure measurement, (e) consistency of exposure measurement across groups, (f) identification of confounding factors, (g) strategies to deal with confounders, (h) validity and reliability of outcome measurement, and (i) appropriateness of statistical analysis.

Synthesis methods

Due to methodological heterogeneity, meta-analysis was not feasible. Results were presented in summary tables and descriptive narrative form.

RESULTS

Study selection

The search strategy retrieved 150 articles (32 from PubMed, 59 from Scopus, 28 from Web of Science, 31 from Embase, and 0 from LILACS). After removing 74 duplicates found across databases, 76 titles and abstracts were screened. Of these, 11 studies were selected for full-text review, and 8 met the inclusion criteria. No studies were included through manual searching. The Google Scholar search retrieved 6 studies, but none were included. Figure 1 illustrates the search and study selection process.

Methodological quality assessment

According to the JBI critical appraisal checklist for cross-sectional studies, the risk of bias across all studies was classified as low for the domains "description of participants and study setting," "measurement criteria," "reliability of outcome measurement," and "appropriateness of statistical analysis". For the domain "definition of inclusion criteria," only the study by Lisetska and Rozhko [12] did not clearly report inclusion criteria. For the domain "exposure measurement," only Abdul-Jabbar and Mohammed Hoobi [13] quantified e-cigarette use based on daily frequency and duration, and it was classified as low risk of bias. For the domains "identification of confounding factors" and "measures to address confounders," only three studies were rated as low risk of bias [12,13] (Figure 2).

For case-control studies, the JBI checklist classified the risk of bias as low in the domains "definition of groups," "consistency in exposure measurement across groups," "validity and reliability of outcome measurement," and "appropriateness

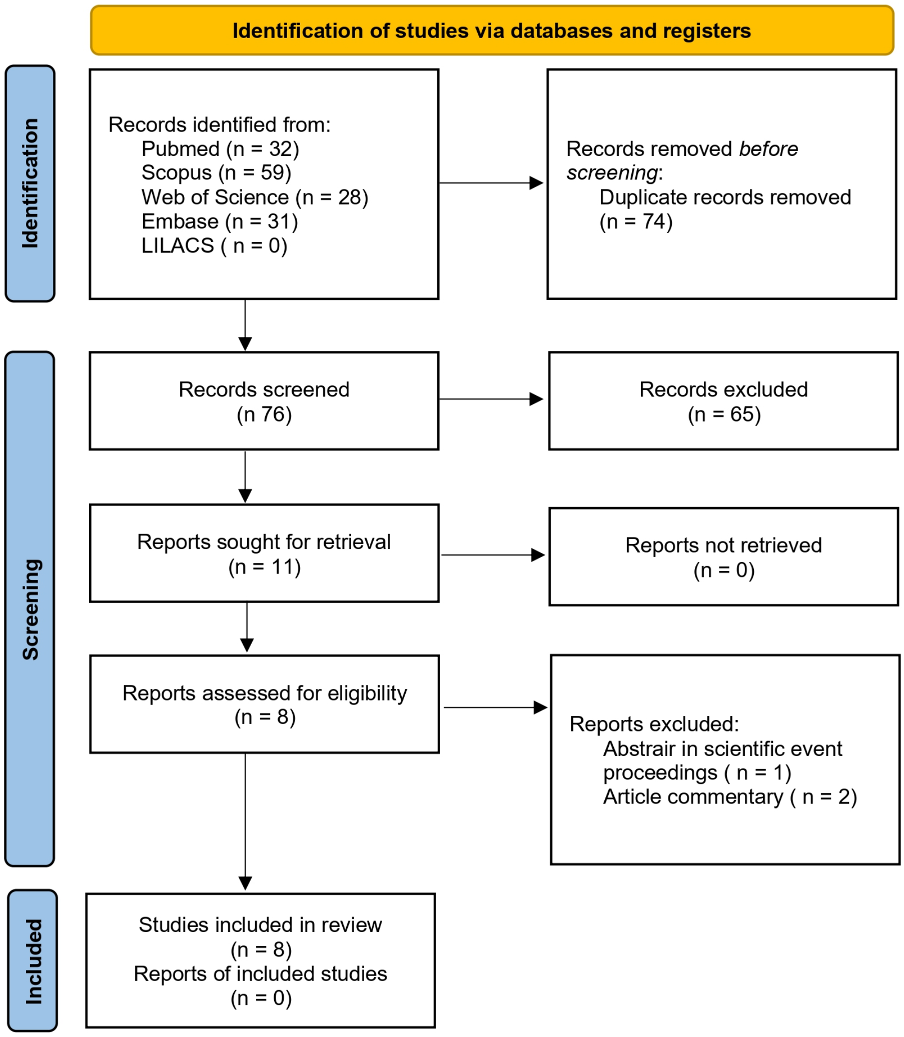

Figure 1 - Flowchart detailing the steps of article search and selection.

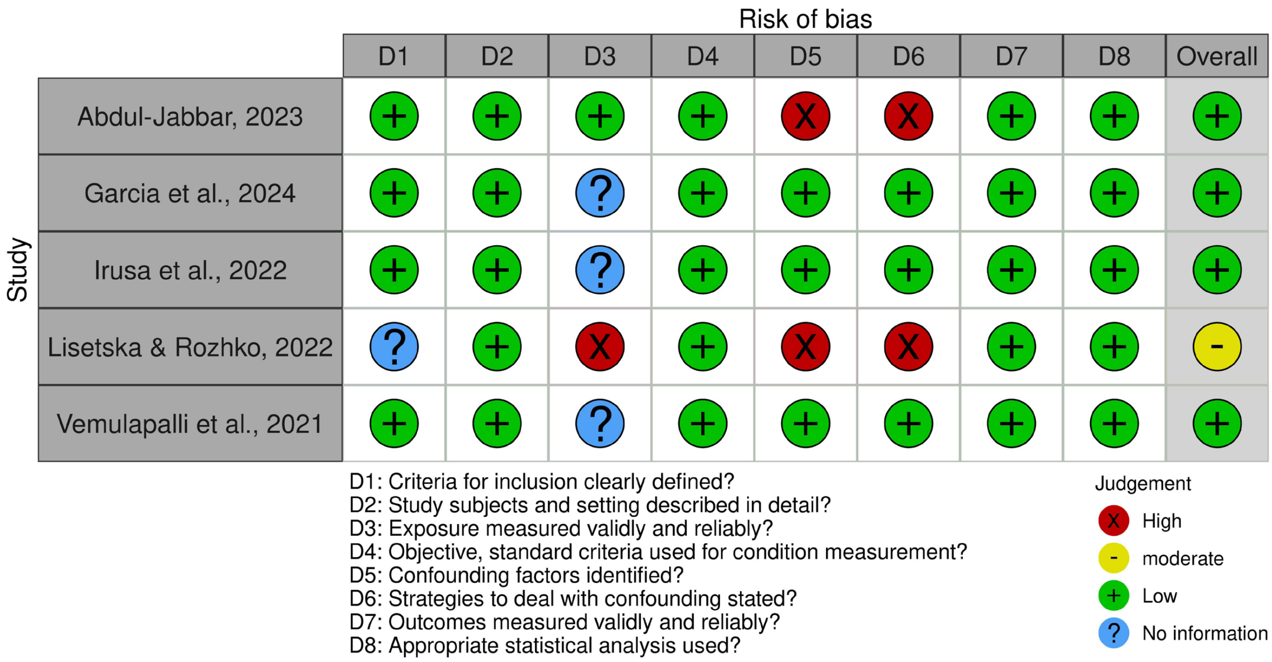

Figure 2 - Methodological quality and risk of bias assessment of cross-sectional studies according to the JBI critical appraisal checklist.

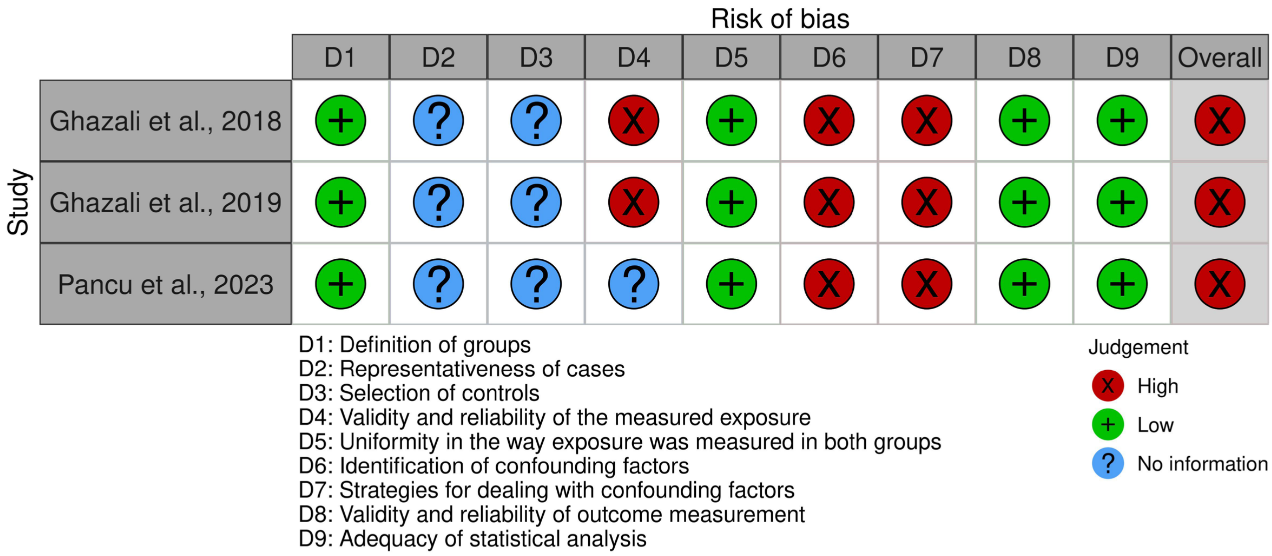

Figure 3 - Methodological quality and risk of bias assessment of case-control studies according to the JBI critical appraisal checklist.

Table I – Methodological characteristics of included studies

Author and year	Country	Type of study	Age	Sex	Exposure assessment	Exposure time	Control	Measurement of caries activity
Abdur-Jabbar and Mohammed Hoobi, 2023 [13]	Iraq	Cross-Sectional	18 to 25 years old	80 (100%) M	Interview	60 min/day for 1 year	Non-smokers	Intraoral examination (DMFT)
Garcia et al., 2024 [18]	Brazil	Cross-Sectional	Over 18 Years	95 (31.67%) M 205 (68.33%) F	Electronic Questionnaire	-	Non-smokers and smokers of traditional cigarettes	Intraoral examination (Presence of untreated caries)
Ghazali et al., 2019 [15]	Malaysia	Case-Control	20 to 64 years old	103 (76.3%) M 32 (23.7%) F	Questionnaire	1 to 25 years	Non-smokers and smokers of traditional cigarettes	Intraoral examination (DMFT)
Ghazali et al., 2018 [14]	Malaysia	Case-Control	20 to 64 years old	89 (74.2%) M 31 (25.8%) F	Questionnaire	-	Non-smokers and smokers of traditional cigarettes	Intraoral examination (DMFT)
Irusa et al., 2022 [16]	USA	Cross-Sectional	Over 16 Years	6,274 (47.9%) M 6,824 (52.1%) F	Questionnaire	-	Non-smokers	Intraoral examination (Cavity risk)
Lisetska and Rozhko, 2022 [12]	Ukraine	Cross-Sectional	15 to 24 years old	-	Interview	-	Non-smokers and smokers of traditional cigarettes	Intraoral examination (Caries prevalence and DMFT)
Pancu et al., 2023 [19]	Romania	Case-Control	19 to 35 years old	-	Interview	-	Non-smokers and smokers of traditional cigarettes	Intraoral examination (DMFT)
Vemulapalli et al., 2021 [17]	USA	Cross-Sectional	Over 18 Years	2,234 (48.11%) M 2,384 (51.89%) F	Questionnaire	used e-cigarettes within the past 30 days	Non-smokers and smokers of traditional cigarettes	Intraoral examination (Presence of untreated caries)

of statistical analysis." None of the three studies clearly reported on the domains "representativeness of cases" and "selection of controls." Regarding "validity and reliability of exposure measurement," all studies determined exposure (use of cigarettes or e-cigarettes) based on self-report, without standardized criteria such as frequency, duration, type, or intensity of use, and were therefore classified as high risk of bias for this domain. Finally, for "identification of confounding factors" and "strategies to address confounders," all studies were classified as high risk of bias (Figure 3).

Methodological characteristics of the studies

The included studies were published between 2018 and 2024. Four studies were conducted in Asian countries (Iraq, Malaysia, and Ukraine) [12-15], two in the United States [16,17], one in Brazil [18], and one in Romania [19]. Five were cross-sectional [12,13,16-18] and three were case-control studies [14,15,19] (Table I).

The age of participants varied, with minimum limits between 15 and 20 years and maximum limits ranging from 24 to over 65 years. Regarding sex

Table II – Caries activity data in different groups of included studies

Author and year	Total sample	Exposed group	Control group (non-smokers)	Control group (cigarette smokers)	Type of variable	Caries Activity in the Exposed Group	Caries Activity in the Control Group
Abdur-Jabbar and Mohammed Hoobi, 2023 [13]	80	40	40	-	Continuous	DMFT – 9.7	DMFT – 7.6
Garcia et al., 2024 [18]	300	54	135	11	Dichotomous	Caries with cavitation: 7.41% White spot lesions: 12.96%	Caries with cavitation: 8.89% White spot lesions: 3.7%
Ghazali et al., 2019 [15]	90	45	45	45	Continuous	DMFT - 3.13	DMFT – 3.51
Ghazali et al., 2018 [14]	120	40	40	40	Continuous	DMFT – 3.05	DMFT - 3.65
Irusa et al., 2022 [16]	13,098	91 (0.07%)	13,007 (99.3%)	-	Dichotomous	High or moderate risk - 85 (93.4%)	High or moderate risk – 11,119 (85.5%)
Lisetska and Rozhko, 2022 [12]	114	22	43	49	Dichotomousand Continuous	Caries prevalence 20 (90.4%) DMFT - 5.88	Caries prevalence 36 (84.5%) DMFT - 4.78
Pancu et al., 2023 [19]	50	10	10	30	Continuous	DMFT - 19.80	DMFT D - 6.7
Vemulapalli et al., 2021 [17]	4,618	947 (20.5%)	3.671 (79.5%)	681 (14.7%)	Dichotomous	Untreated cavities 254 (26.8%)	Untreated cavities 674 (18.3%)

distribution, in three studies most participants were female (51.89% to 68.33%) [16-18]; in two studies, most were male (74.2% and 76.3%) [14,15]; one study included only male participants [13], and two studies did not report participants' sex [12,19] (Table I).

Exposure assessment (e-cigarette use) was collected via questionnaires in five studies [14-18], while the others used structured interviews [12,13,19]. Most studies did not collect data on total duration, intensity, or daily frequency of use (Table I).

Regarding control groups, six studies compared exposed groups (e-cigarette users) with both non-smokers and conventional cigarette smokers [12,14,15,17-19], while two compared only with non-smokers [13,16] (Table I). Total sample sizes ranged from 50 [19] to 13,098 [15] (Table II).

All studies used intraoral examination as the method for caries assessment; however, outcome presentation varied. Five articles reported continuous variables using DMFT indices [12-15,19]. In one of these, caries prevalence was also calculated [12]. The other studies used dichotomous outcomes: untreated caries [17,18] or caries risk assessment [16] (Table I).

For studies reporting DMFT, scores ranged from 3.05 [15] to 19.8 [19] in exposed groups, and from 3.51 [14] to 7.6 [13] in controls, with statistically significant differences in three studies [13,14,19]. For dichotomous outcomes: Irusa et al. [16] found a higher percentage of participants at moderate-to-high caries risk in exposed groups (93.4%) compared with controls (85.5%). Vemulapalli et al. [17] reported untreated caries in 26.8% of exposed versus 18.3% of controls, a significant association. Garcia et al. [18] found cavitated caries lesions in 7.41% of exposed versus 8.89% of controls, and active white spot lesions in 12.96% of exposed versus 3.7% of controls, with a significant difference only for active white spot lesions (Table II).

DISCUSSION

The findings of this systematic review suggest a possible association between the use of electronic smoking devices (ESDs), such as electronic cigarettes and vapes, and an increased risk of developing dental caries. This relationship was primarily demonstrated through higher DMFT indices and greater prevalence of active carious lesions among ESD users compared with non-smokers.

Studies that used the DMFT index as an outcome measure generally reported higher values in exposed groups, ranging from 3.05 to 19.8, compared with 3.51 to 7.6 in control groups. These findings align with growing evidence in the literature indicating the cariogenic potential of ESDs, owing to substances such as propylene glycol, vegetable glycerin, and flavorings, which can alter the oral microbiota and decrease salivary pH, thereby favoring enamel demineralization [17,20,21].

Recent studies suggest that e-cigarette use (vaping) may have significant cariogenic potential.

E-liquids containing propylene glycol, glycerin, nicotine, and sweet flavors may alter the oral microbiota and increase the risk of dental caries [16,22]. Exposure to e-cigarette aerosols has been shown to increase microbial adhesion to enamel, enhance biofilm formation, and reduce enamel hardness. In addition, the viscosity of e-liquids facilitates the adherence of cariogenic bacteria such as S. mutans to pits and fissures, potentially accelerating demineralization [22,23]. Vaping can also induce dysbiosis of the oral microbiota, favoring the growth of cariogenic bacterial strains and creating an acidic environment conducive to enamel demineralization [24]. These findings suggest that vaping may have effects comparable to, or even more detrimental than, conventional cigarettes on oral health, underscoring the need for further clinical investigation and patient education.

The study by Irusa et al. [16] highlighted a significantly higher percentage of ESD users classified at moderate-to-high caries risk (93.4%) compared with the control group (85.5%). Similarly, Vemulapalli et al. [17] demonstrated that participants who used e-cigarettes were more likely to present untreated caries than those who had never smoked. These findings indicate that even in the absence of combustion tobacco, the chemical components of inhaled vapors may contribute to a more cariogenic oral environment, potentially through reduced salivary flow or adverse effects on saliva composition [5,6].

Another relevant finding was the greater prevalence of early carious lesions, such as active white spot lesions, among ESD users. Garcia et al. [18] identified a statistically significant difference in the presence of these lesions (12.96% among ESD users versus 3.7% among non-smokers), underscoring the importance of early detection and monitoring in this population.

Nonetheless, some methodological limitations must be acknowledged. Most studies collected exposure data via self-reported questionnaires or structured interviews, without precise measurement of duration, frequency, or intensity of device use. Moreover, lack of standardization in outcome reporting makes comparisons across studies challenging. These limitations increase the risk of information bias and may compromise internal validity. The diversity of study populations, both geographically and demographically, may also influence findings. Differences in diet, access to dental care, and oral hygiene practices could act as confounders, limiting the strength of observed associations [25].

Caries assessment was predominantly performed through intraoral examination, but the way results were reported varied considerably. Some studies used DMFT indices, while others reported dichotomous outcomes such as untreated caries or caries risk. This heterogeneity in outcome presentation hinders direct comparison and generalizability of results. Future research with longitudinal designs, representative samples, and rigorous control of confounding factors is essential to better elucidate the mechanisms involved and the actual magnitude of caries risk associated with ESDs.

Despite these limitations, the findings of this systematic review emphasize the need for increased attention to the oral health impacts of ESD use, particularly among adolescents and young adults, who represent the largest proportion of users [26]. Therefore, it is critical that dental professionals remain vigilant about this potential association and include ESD use as a relevant variable in medical history and preventive strategies. The need for training of these professionals is also emphasized, since dentists generally exhibit a positive attitude toward tobacco cessation counseling; however, a lack of formal training significantly impedes their ability to effectively implement such interventions [27].

CONCLUSIONS

This systematic review indicates a trend toward an association between the use of electronic smoking devices and an increased risk of dental caries. Although the current literature still presents methodological limitations and heterogeneity in data collection and analysis methods, the results highlight the need for caution regarding the use of these devices, particularly among young people and adults.

Data availability

Research data is only available upon request.

Author's Contributions

GAMS: Conceptualization. TMOA, WSL: Data Curation. RACA: Formal Analysis. GAMS: Funding Acquisition. TMOA, WSL: Investigation. TMOA, WSL: Methodology. GAMS: Project Administration.

RACA, GAMS: Supervision. RACA: Validation. TMOA, WSL: Writing – Original Draft Preparation. RACA, GAMS: Writing – Review & Editing.

Conflict of Interest

No conflicts of interest declared concerning the publication of this article.

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Regulatory Statement

Ethical Oversight: The review protocol was registered in PROSPERO (CRD42024490669).

Compliance with Reporting Guidelines: This review was conducted in accordance with the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).

Data transparency: The data extraction forms, analytical code, and datasets used in the review are available as supplementary material to this article.

Ethical Considerations for Included Studies: Ethical approval and informed consent were obtained for all primary studies included in the review.

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Supplementary Material

Supplementary material accompanies this paper.

Supplementary File 1. Assessment of the certainty of evidence for the three meta-analyses

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