REVIEW ARTICLE

The Role of Dietary Acids and Acidic Beverages in Dental Enamel Erosion: A Narrative Review

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Abstract

Dental erosion is the dissolution of dental hard tissues by acids of non-bacterial origin and contributes to cumulative erosive tooth wear. This narrative review examines dietary acids and acidic beverages, population-related patterns, biological and behavioral modifiers, and implications for prevention. Evidence from PubMed, Scopus, Google Scholar, and other sources was synthesized qualitatively; no formal risk-of-bias assessment was performed. Laboratory and in situ studies show acid-related mineral loss and surface changes, and observational studies link some acidic-beverage exposure to erosive tooth wear, though findings vary by beverage, exposure pattern, population, and diagnostic method. Erosive potential depends on solution composition and mineral saturation as well as pH. Saliva, intrinsic gastric-acid exposure, and mechanical factors modify the clinical expression of wear. Prevention should prioritize reducing avoidable acidic exposure and behaviors that prolong contact with dental surfaces. Fluoride-containing products may offer additional protection, but experimental findings should not be taken as established long-term clinical effectiveness. Current evidence does not support a universally applicable waiting interval before toothbrushing after acidic exposure, and clinical advice should consider individual risk and fluoride use. Interpretation is limited by heterogeneous evidence and non-systematic source selection; longitudinal clinical studies and more consistent outcome measurement remain necessary.

Keywords: dental enamel erosion, dietary acids, acidic beverages, erosive tooth wear, children, adolescents, prevention.

1 Introduction

Dental erosion is the chemical dissolution of dental hard tissue by acids of non-bacterial origin, and the tissue lost from the softened surface cannot be regained [1]. It is a major component of overall tooth wear and can lead to dentin hypersensitivity, esthetic impairment, and functional problems; patients with tooth wear have been reported to have reduced oral health-related quality of life [2]. Unlike dental caries,

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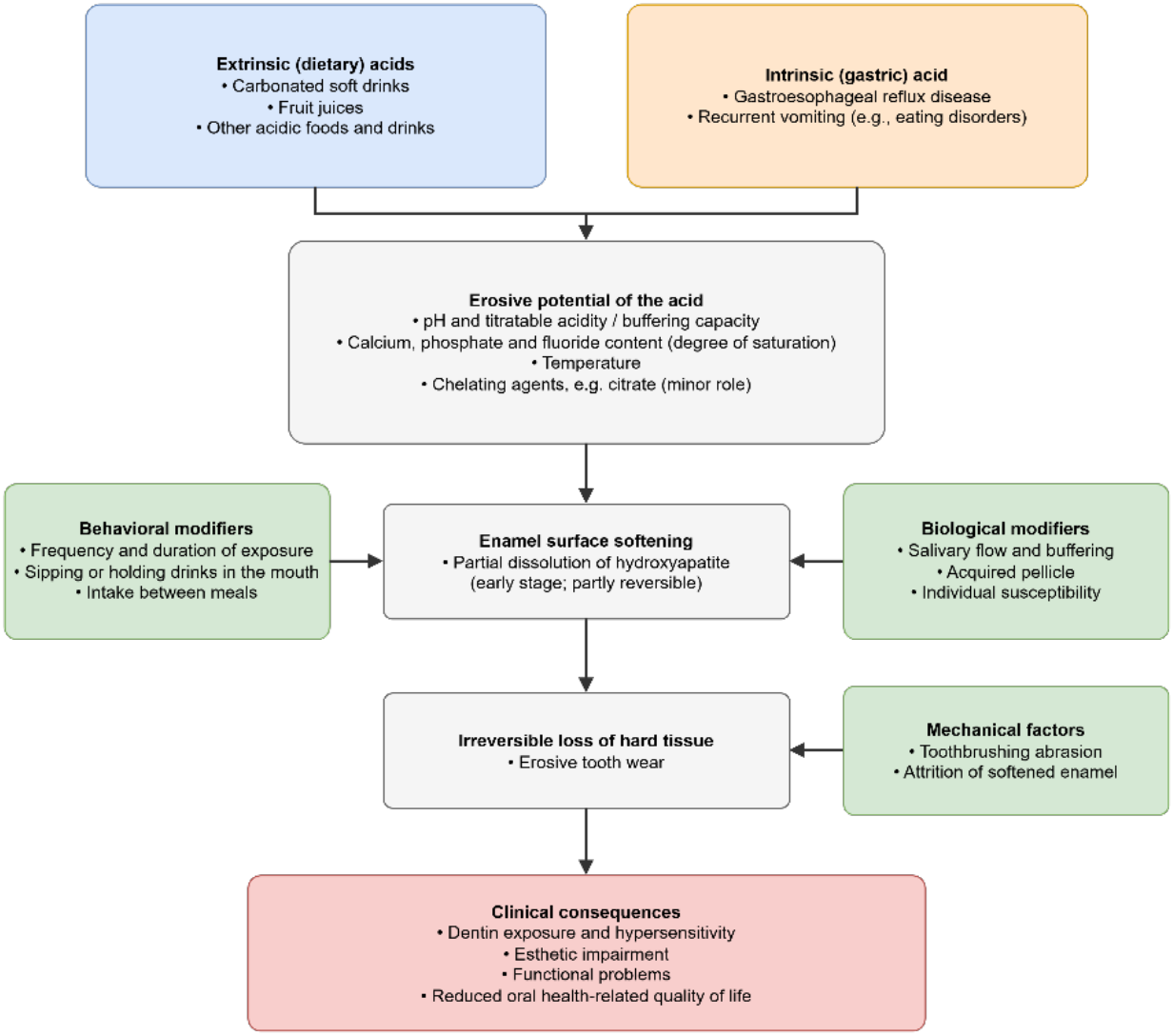


Figure 1. Etiological factors and mechanisms involved in dental enamel erosion. Created by the authors using draw.io.

which is driven by acids produced by bacterial biofilm, erosion is a chemical process that does not involve bacteria, so it can occur even in individuals who maintain good plaque control [3].

Epidemiological studies show that erosive tooth wear occurs across age groups and geographic regions, although reported prevalence varies considerably with population characteristics and diagnostic criteria [1]. It is frequently reported among children, adolescents, and young adults [4–7], and erosive challenges early in life are thought to contribute to its initiation [1, 8]; longitudinal data show that it can progress during adolescence, with cumulative loss of dental hard tissue [9].

Contemporary dietary patterns are an important modifiable component of erosive risk. Observational studies, systematic reviews, and meta-analyses have associated acidic beverage consumption, particularly of soft drinks, with erosive tooth wear [8, 10–12], but findings differ between beverage types and studies: in a meta-analysis, soft drinks were significantly associated with dental erosion, whereas fruit juice was not [10], and systematic reviews in children and adolescents report heterogeneous findings [8, 12]. The frequency and pattern of exposure are clinically relevant when assessing risk [8, 12].

Figure 1 summarizes how extrinsic and intrinsic acids interact with biological and behavioral modifiers in the development of enamel erosion and its clinical consequences.

Although the erosive potential of acidic beverages has been studied extensively, the evidence is spread across laboratory, in situ, and clinical studies that use different methods and populations, which makes it difficult to apply in clinical practice. This narrative review therefore aims to evaluate the role of dietary acids

and acidic beverages in dental enamel erosion, with particular emphasis on dietary habits among children, adolescents, and young adults, and to discuss intrinsic acid exposure and other modifying factors alongside implications for clinical prevention.

2 Materials and Methods

2.1 Study Design and Search Strategy

This study was conducted as a narrative review. The literature search was performed in PubMed, Scopus, and Google Scholar; the final search was run on 16 January 2026. The core search string was ("dental enamel erosion" OR "erosive tooth wear" OR "tooth erosion") AND ("acidic beverages" OR "dietary acids" OR "lifestyle factors"). In PubMed it was applied to titles and abstracts ([tiab]), in Scopus to titles, abstracts, and keywords (TITLE-ABS-KEY), and in Google Scholar it was run as a full-text query. The exact search string used for each database is provided in Table S1 (Appendix A). Google Scholar results were sorted by relevance and screened by title. No restriction on publication date was applied, because much of the foundational clinical and experimental evidence on erosion predates 2020. The reference lists of included articles were also screened manually, and targeted supplementary searches on erosive tooth wear in adults and in children and adolescents were run in PubMed, Scopus, and Google Scholar to cover topics not captured by the core search string; these searches are described in Table S1.

2.2 Selection Criteria

Studies were selected based on their relevance to the multifactorial etiology of dental enamel erosion, including dietary acids, acidic beverages, intrinsic acid exposure, biological modifiers, and preventive approaches. Experimental, in situ, clinical, observational, and review evidence was considered when directly relevant to erosion or when it provided clearly identified mechanistic context. The inclusion and exclusion criteria applied in the study selection are presented below.

Inclusion criteria. Studies were considered eligible for inclusion if they met the following criteria:

- Peer-reviewed articles and book chapters published in English;
- Studies evaluating enamel or dentin surfaces experimentally, or clinical/observational studies assessing erosive tooth wear in human populations;
- Studies focusing on dietary acids, acidic beverages, and intrinsic factors related to enamel erosion;
- Articles addressing the etiology, risk factors, physicochemical properties, mechanisms, clinical implications, or prevention of enamel erosion; review articles were included when they provided directly relevant contextual or mechanistic background.

Exclusion criteria. Studies were excluded if they met any of the following criteria:

- Studies without a clear description of the erosive exposure or the outcome measure;
- Studies focusing exclusively on dental caries, plaque-related disease, or broader oral-health outcomes without a direct and clearly stated relevance to erosive tooth wear;
- Case reports, short communications, editorials, and conference abstracts;
- Studies not directly related to enamel erosion or its associated risk factors.

2.3 Study Selection

Records retrieved by the database searches were screened by title and abstract, and potentially relevant articles were read in full and assessed against the eligibility criteria in Section 2.2. Screening was performed by A.K., with uncertain cases discussed with A.S. Further sources were identified from the reference lists of included articles, from the targeted supplementary searches (Section 2.1), and from AI-assisted suggestions (see AI Use Statement); each was read in full by the authors and assessed against the same eligibility criteria before inclusion. In total, 35 sources met the eligibility criteria and informed this narrative synthesis, and all are cited in the reference list. Record-level documentation of the searches and screening is not available; the number of records at each stage of selection and the identification route of individual sources therefore cannot be reported. As this is a narrative review, no systematic review protocol was used and no PRISMA flow diagram was produced.

2.4 Data Extraction and Synthesis

Data were extracted by A.K. and checked by A.S., recording for each study its design, population or model, exposure, and erosion-related outcome. The extracted information was qualitatively synthesized, focusing on acid characteristics, exposure patterns, and reported effects on enamel structure and integrity. No

formal quality appraisal or risk-of-bias assessment was performed, and studies were not weighted or excluded on the basis of methodological quality; instead, the text distinguishes experimental, in situ, observational, and clinical evidence so that the type of evidence behind each statement is clear.

Table 1 presents selected representative studies discussed within this narrative review. Each entry identifies the study design, population or model, exposure, and erosion-specific outcome or focus; the studies were chosen to illustrate the main study designs (longitudinal, systematic review, laboratory, in situ, and observational), and the table is not exhaustive.

3 Discussion

Across the studies reviewed, dietary acids and acidic beverages emerge as consistent contributors to the initiation and progression of dental enamel erosion. Experimental and in situ studies show that acidic exposure can soften enamel and cause mineral loss and structural change [13–16], a hydroxyapatite-crystal model shows rapid mineral dissolution by acidic beverages [17], and a meta-analysis and systematic reviews of observational studies associate frequent consumption of acidic beverages, particularly soft drinks, with erosive tooth wear [8, 10, 12]. These findings support the characterization of erosive tooth wear as a chemically mediated process distinct from caries-related demineralization.

3.1 Physicochemical Determinants

The erosive potential of an acidic beverage is influenced by chemical factors, including its pH, buffering, degree of saturation with respect to tooth mineral, and fluoride content, and by physical factors such as temperature and flow rate [3]. Low pH favors demineralization, but pH alone does not fully characterize erosive potential [3].

Unlike caries, erosion has no fixed critical pH: whether enamel dissolves depends on the degree of saturation of the acidic solution with respect to tooth mineral, which is determined by its pH together with its calcium, phosphate, and fluoride concentrations [3]. Buffering is one of the solution properties that influence the rate of dissolution [3]; however, in a hydroxyapatite-crystal model, the erosive potential of cola drinks and orange juices within the first minutes of exposure was determined by pH alone [17]. Citric acid can also bind calcium, but in vitro evidence indicates that this chelating effect contributes little to enamel erosion compared with the effect of the acid itself [18].

3.2 Evidence from Experimental and In Situ Studies

Laboratory studies at the nanoscale have shown that both acid pH and acid concentration influence early-stage changes in enamel and dentin [13]. Even short exposures to acidic solutions produce measurable surface softening in vitro [13, 16]; whether frequent low-level challenges are more damaging than fewer high-intensity exposures has not been established by the studies reviewed here.

In vitro and in situ investigations report reductions in enamel surface hardness and structural alterations after exposure to acidic conditions [13–16]. Enamel and dentin also respond differently to acid challenge because of differences in their mineral content and structure [19]. In an in vitro study on enamel specimens, diet cola reduced enamel microhardness more than regular cola, whereas beverage temperature (2 °C vs. 20 °C) had no statistically significant effect [14]. In a model using hydroxyapatite crystals rather than enamel specimens, the immediate erosive potential of cola drinks was about ten times that of orange juices, and a salivary-protein coating reduced the erosive potential of cola drinks by up to 50% [17]. These models are useful for mechanistic interpretation but do not provide direct estimates of clinical disease frequency.

3.3 Clinical Evidence in Adult Populations

Observational studies in adult populations have reported associations between acidic beverage consumption and erosive tooth wear, although findings vary according to population and exposure assessment [1, 20]. In a multicenter study of 3,187 adults aged 18–35 years in seven European countries, 29% had distinct tooth wear (Basic Erosive Wear Examination (BEWE) score of 2 or 3), and wear was associated with heartburn or acid reflux, repeated vomiting, and higher intake of fresh fruit and fruit juice [7]. In a review of prevalence studies, Jaeggi and Lussi reported that the prevalence of erosion in adults aged 18–88 years ranged from 4% to 100% across studies, with a tendency towards more erosive lesions with increasing age [21]. Erosive lesions may affect facial (buccal), palatal, and occlusal surfaces depending on the source and pattern of acid exposure [1, 22].

Table 1. Representative studies on dietary acids and enamel erosion.

Study	Design & population/model	Exposure	Erosion-specific outcome or focus
El Aidi et al., 2010 [9]	3-year longitudinal study; adolescents	Age, sex, and socio-economic status	Followed the dynamics/progression of tooth erosion over three years.
Casaña Ruiz et al., 2023 [8]	Systematic review; children and adolescents	Dietary habits/dietary acids	Synthesized evidence on dietary habits in relation to dental erosion in pediatric populations.
Pattem et al., 2022 [13]	Experimental laboratory study; enamel and dentin specimens	Acid pH and concentration	Assessed nanoscale erosion-related changes associated with acid pH and concentration.
Khamverdi et al., 2013 [14]	In vitro study; enamel specimens	Regular and diet cola at 2 °C and 20 °C	Diet cola reduced enamel microhardness more than regular cola; beverage temperature had no significant effect.
Ablal et al., 2017 [15]	In situ study; human enamel specimens on removable intraoral appliances	Orange juice, 5 min three times daily	Characterized in situ erosion lesions and tongue abrasion of acid-softened enamel.
Mafla et al., 2017 [5]	Observational prevalence/risk-factor study; adolescents	Extrinsic risk factors	Reported dental erosion prevalence and evaluated extrinsic risk factors in an adolescent population.

3.4 Erosive Challenges in Children and Adolescents

Studies in children and adolescents report erosive tooth wear across diverse populations [4–6, 9, 11], but prevalence estimates vary substantially because of differences in age, geography, diagnostic criteria, and study design [21, 23]. Behavioral factors, including frequent or prolonged acidic beverage exposure, are commonly evaluated as modifiable risk factors in this age group [5, 8, 11, 24].

Children and adolescents are frequent consumers of acidic beverages [8, 12]. Systematic reviews and observational studies suggest that frequent intake of acidic beverages is associated with a higher prevalence of dental erosion in these age groups, although findings differ between beverage types and studies [8, 12, 24]. A study in preschool children also examined the influence of frequently consumed beverages and snacks on dental erosion [25].

3.5 Role of Intrinsic Acid Exposure

Beyond dietary acids, intrinsic gastric-acid exposure represents an additional pathway in erosive tooth wear. Reviews and clinical guidance recognize recurrent contact with gastric acid, for example in gastroesophageal reflux disease or recurrent vomiting associated with eating disorders, as relevant to the etiology and distribution of erosive lesions, although the magnitude of risk varies with the underlying condition and exposure pattern [1, 22]. Erosion from intrinsic acid characteristically affects the palatal surfaces of the maxillary teeth [22].

3.6 Salivary Protection and Mechanical Interaction

Saliva protects against erosion by diluting and clearing acids, buffering pH changes, supplying calcium and phosphate for remineralization, and forming the acquired pellicle on tooth surfaces [26]. An in vitro study that simulated different salivary flow conditions assessed erosion of enamel and dentine adjacent to restorations, treating salivary flow as a variable that may modify erosion [27], and susceptibility to erosion differs between individuals [28].

Chemical erosion also interacts with mechanical factors. Acid-softened enamel is more susceptible to abrasion and attrition, and laboratory studies show that toothbrushing after an erosive challenge can increase enamel loss [29]; in situ evidence further suggests that abrasion by the tongue can remove acid-softened enamel [15]. Whether delaying toothbrushing reduces this effect is discussed in Section 3.7.

3.7 Preventive and Clinical Implications

Preventive strategies emphasize modifying dietary behavior: reducing the frequency of acidic beverage intake, avoiding prolonged sipping or holding drinks in the mouth, and consuming acidic drinks with meals rather than between meals [22]. Advice on the timing of toothbrushing is less certain. Recent reviews have re-examined the common advice to delay toothbrushing for 30–60 min after acidic intake [30, 31]: a systematic review of in vitro and in situ studies found that delayed brushing did not demonstrate a statistically significant reduction in erosive wear of human enamel compared with immediate brushing [30], and a scoping review concluded that brushing with fluoride toothpaste immediately after an erosive challenge does not appear to increase erosive tooth wear [31]. Because this evidence comes mainly from laboratory and in situ models and robust clinical studies are lacking, toothbrushing advice should be individualized rather than based on a fixed waiting interval [29–31].

Fluoride-containing products may provide additional protection. In a meta-analysis, stannous fluoride (SnF_2) dentifrices reduced erosive tooth wear more than sodium fluoride (NaF) dentifrices in in vitro studies but not in in situ studies, and the authors judged the evidence insufficient for clinical conclusions [32]. In vitro, a casein phosphopeptide–amorphous calcium phosphate (CPP-ACP) paste increased the surface hardness of bovine enamel previously softened by a cola drink [16]. In view of the limited clinical evidence, these products should be regarded as adjuncts to, not substitutes for, reducing erosive exposure.

Early erosive lesions can be subtle and may be overlooked, particularly when they overlap with other forms of tooth wear [33]. Current consensus therefore recommends screening for early signs of erosive tooth wear and evaluating all etiological factors [33], and the BEWE provides a standardized index for recording erosive wear in clinical practice and research [33, 34]. Early detection and risk assessment may help reduce irreversible tissue loss and its functional and esthetic consequences.

4 Limitations and Future Perspectives

4.1 Limitations

This narrative review is limited by heterogeneity among included studies, variability in experimental designs, and differences in outcome measures used to assess enamel erosion. Furthermore, reliance on in vitro and in situ models may not fully replicate the complexity of the oral environment, including salivary dynamics and individual behavioral factors. In addition, because study selection was non-systematic and no formal risk-of-bias assessment was performed, the synthesis may be affected by selection bias. Restricting the search to English-language publications, and the limited reproducibility of Google Scholar searches, may also have caused relevant studies to be missed. Finally, because record-level documentation of the searches and screening is not available, the number of records at each stage of selection, the identification route of individual sources, and the exact strategies of the targeted supplementary searches cannot be reported, which limits the reproducibility of the selection process.

4.2 Future Research Directions

Future research should prioritize long-term, longitudinal clinical studies that reflect real-life exposure to dietary acids across different life stages, particularly from childhood to early adulthood. Greater standardization of diagnostic criteria and outcome measures, including harmonized clinical erosion indices such as the BEWE [34] and comparable laboratory measurement methods (for example, contact and non-contact profilometry and confocal laser scanning microscopy, which have been compared for measuring enamel erosion [35]), is needed to improve comparability across studies and support evidence-based clinical guidelines. Preventive research should further explore targeted dietary and behavioral interventions for high-risk populations, alongside population-level public health strategies aimed at reducing acidic beverage consumption. Clinical trials are also needed to establish whether, and for whom, the timing of toothbrushing after acidic exposure matters. In patients with gastroesophageal reflux disease or eating disorders, collaboration between dental and medical teams would allow intrinsic and extrinsic acid exposure to be assessed together.

5 Conclusions

Dental enamel erosion is a multifactorial condition influenced by extrinsic acid exposure, particularly dietary acids and acidic beverages, together with intrinsic gastric acid exposure and biological and behavioral modifiers. Epidemiological evidence documents erosive tooth wear in children, adolescents,

and adults, but prevalence estimates vary substantially across populations and diagnostic methods. Accordingly, population-specific findings should not be generalized beyond the settings in which they were measured.

Prevention of erosive tooth wear should focus primarily on reducing avoidable acidic exposure and modifying behaviors that prolong contact between acids and dental surfaces. Fluoride-based products, and possibly calcium-phosphate-based products, may provide additional protection, although clinical evidence for both is limited, and dietary and behavioral measures remain central to prevention. Toothbrushing advice should be individualized, because the evidence does not support a fixed waiting interval after acidic exposure.

Early identification of erosive changes is important because initial lesions may be subtle. Routine use of a standardized index such as the BEWE, combined with a review of dietary and medical risk factors, offers a practical way to detect such changes and to monitor them over time.

Data Availability Statement

No new data were created or analyzed in this study. All data discussed are available in the cited publications.

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This research received no external funding.

Conflicts of Interest

The authors declare no conflicts of interest.

AI Use Statement

During the preparation of this manuscript, the authors used Claude (Anthropic) for language editing and text formatting, to assist in revising the manuscript text in response to peer review, and to suggest potentially relevant literature (Section 2.3). All AI-suggested sources were retrieved, read in full, and assessed by the authors against the same eligibility criteria as the database records. All content was written, reviewed, and verified by the authors, who take full responsibility for the manuscript. The tool was used in accordance with its terms of use.

Ethical Approval and Consent to Participate

Not applicable. This narrative review is based solely on previously published studies and did not involve human participants or animals.

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Appendix

Database-Specific Search Strategies

Table S1. Database-specific search strategies.

Database	Search string	Fields, filters and settings
PubMed	(“dental enamel erosion”[tiab] OR “erosive tooth wear”[tiab] OR “tooth erosion”[tiab]) AND (“acidic beverages”[tiab] OR “dietary acids”[tiab] OR “lifestyle factors”[tiab])	Core string applied to titles and abstracts ([tiab]). No publication-date limit.
Scopus	TITLE-ABS-KEY ((“dental enamel erosion” OR “erosive tooth wear” OR “tooth erosion”) AND (“acidic beverages” OR “dietary acids” OR “lifestyle factors”))	Core string applied to title, abstract and keywords. No publication-date limit.
Google Scholar	(“dental enamel erosion” OR “erosive tooth wear” OR “tooth erosion”) AND (“acidic beverages” OR “dietary acids” OR “lifestyle factors”)	Full-text query. Results were sorted by relevance and screened by title.
PubMed, Scopus, Google Scholar (targeted supplementary searches)	Topic-specific searches on erosive tooth wear in adults and on erosive tooth wear in children and adolescents, run to cover topics not captured by the core search string. The exact search strings are not available.	Records were assessed against the same eligibility criteria and read in full.

Final search date for all databases: 16 January 2026. Further sources were identified from the reference lists of included articles, from the targeted supplementary searches, and from AI-assisted suggestions; all were read in full and assessed against the same eligibility criteria. In total, 35 sources informed the narrative synthesis. Record-level documentation of the searches and screening is not available; the numbers of records retrieved and screened therefore cannot be reported. Only English-language publications were eligible (see Section 2.2).



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