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An Observed-Variable Socio-Ecological Model Chain Analysis of Socioeconomic Status, Parental Beliefs and Early-Childhood Caries in Chinese

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ABSTRACT

Introduction and Aims: Early childhood caries (ECC) remains widespread in China. Although socioeconomic status (SES) is a recognised driver, its pathway through parental preventive beliefs (BeliefPrev) and child high-risk behaviors (BehaviorRisk) is seldom examined within a single model. This study quantified SES's direct and indirect effects on ECC in preschoolers.
Methods: A cross-sectional survey of 595 children aged 3-6 years and their caregivers was conducted in 10 Nantong kindergartens (2024). Questionnaires captured SES, a 4-item BeliefPrev subscale, BehaviourRisk, and dmft. Scale reliability and factor structure (exploratory factor analysis, EFA) were assessed. Observed-variable SEM specified SES→BeliefPrev→BehaviourRisk→dmft. Coefficients are standardised β with bias-corrected bootstrap mediation. SES was characterised by family socioeconomic index; BeliefPrev was derived from the POHBS; BehaviourRisk combined parent-reported free-sugar exposure frequency and toothbrushing frequency; dmft was recorded using WHO criteria.
Results: SES showed a direct inverse association with dmft after adjusting for BeliefPrev and BehaviourRisk, while indirect paths via BeliefPrev or BehaviourRisk were non-significant. The belief scale showed low reliability (α = 0.18) and 2 factors (professional prevention/misconception and outcome appearance). SES was inversely associated with BehaviourRisk ($\beta = -0.187$, $p < .001$) and retained a direct inverse effect on dmft after adjustment ($\beta = -0.329$, $p = .044$). BehaviourRisk did not predict dmft ($\beta = 0.193$, $p = .233$). Sensitivity analyses with extended behaviour items and sex or age-specific models produced similar patterns.
Conclusion: SES was inversely associated with preschool ECC after accounting for behaviour and beliefs, whereas behaviour showed a modest association and parental beliefs showed none. These findings suggest that knowledge-based interventions are unlikely to overcome the socioeconomic gradient.
Clinical Relevance: Population-level sugar-reduction policies, kindergarten fluoride schemes, and coverage for basic child dental care should be prioritised, with targeted education/behavior coaching as a complement, particularly for low-SES families (SES index Q1–Q2).
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Introduction

Dental caries remains one of the most common chronic conditions in 0-6-year-olds, with early childhood caries (ECC) its initial form. The World Health Organisation classifies ECC as a global public health concern.[1] Over the past 2 decades,

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prevalence among 5-year-olds has fallen below 30% in many European and American nations, mainly owing to fluoridation and wider care access, yet persists at 60-80% in much of Southeast Asia and the Western Pacific, averaging >3 dmft per child.[2,3] The Fourth National Oral Health Epidemiological Survey of China recorded 71.9% prevalence (mean dmft = 4.24) and 10-15-point urban-rural gaps,[4] driven chiefly by socioeconomic status (SES) through differential fluoride access, dental services, and information.[5-7] Behavioural risks-frequent sugars, bedtime sugars, poor brushing-also shape ECC.[8] Our earlier latent class analysis (LCA) identified 3 patterns (high-risk/high-sugar, medium-risk/mixed, low-risk/high-brushing) that unevenly influence caries.[9] However, that study focused solely on behavioural patterns, leaving 2 questions unanswered: (1) How do socioeconomic factors and parental beliefs influence these behavioural subtypes? (2) How can the relationships among SES, parental preventive beliefs (BeliefPrev), and child high-risk behaviours (BehaviourRisk) be quantitatively modelled to inform comprehensive intervention strategies?

Structure-mediator-health theory posits that macrostructural resources shape knowledge, beliefs, and norms, which drive habits and disease.[10-12] Oral-health studies often test only single links, for example, low-income children showing 1.8-2.3-fold higher caries, or Health Belief Model trials lifting twice-daily brushing by 10-15%,[13] leaving the complete SES → belief → behaviour chain under-explored. Hierarchical regression and mediation work (e.g., parental education → supervision → dmft) seldom adjust for income or diet, whereas SEM can estimate multiple direct/indirect paths with error terms.[14-16] Previous latent-variable SEMs suggest 36%-52% of SES impact is indirect via supervision and hygiene, and oral-health literacy can buffer low SES.[17,18] Chinese preschool data are scarce; sample sizes are small, dietary sugar is often ignored, and belief scales are rarely validated, all of which can bias coefficients.[19]

In this study, we operationalised parental beliefs as a 4-item preventive-belief subscale from the POHBS to maximise construct coherence, given the multidimensionality and low overall reliability of the full item pool. Using questionnaires from 3 - 6-year-olds and caregivers, we extend prior LCA work to model SES, BeliefPrev, BehaviourRisk, and dmft. The present study pursued 3 specific aims: (1) to evaluate the factor structure and internal consistency of a 9-item parental oral-health belief scale (POHBS); (2) to quantify the direct effect of SES on dmft and the indirect pathways mediated by BeliefPrev and BehaviourRisk; and (3) to interpret the resulting path coefficients in light of our previously published behavioural latent classes, thereby integrating structural, cognitive, and behavioural perspectives within one analytical framework. The observed-variable socio-ecological model (SEM) will clarify the macrostructure of cognition → behaviour → caries and guide targeted, multilevel interventions.

Materials and methods

Research design and sample

This study adopts an observed-variable SEM approach, grounded in the integrated social-behaviour-disease framework, to investigate the hypothesised pathway associations among SES, BeliefPrev, BehaviourRisk, and dmft. Based on this framework, specific hypotheses were formulated with anticipated relationships indicated (Table 1).

The outlined hypotheses systematically assess each component's relative influence and sequential roles within the structure-cognition-behaviour-disease pathway. Comparing hypotheses H4 and H5 clarifies the relative contributions of structural residual and chain-mediated effects. Confirmation of these hypotheses would inform evidence-based interventions targeting caries among children from low-SES backgrounds. Specifically, it evaluates whether traditional health education alone is sufficient to reduce social disparities in oral health, or whether macrostructural resource allocation, such as improved access to preventive services and economic subsidies, is required to achieve equitable oral health outcomes.

A stratified cluster survey was conducted in Nantong City, Jiangsu Province. Kindergartens were first stratified into urban and suburban strata; within each stratum, 2 public and 2 private schools were randomly selected (6 public, 4 private). All classes-small, middle, and large-were invited, and oral examinations plus questionnaires were completed for 612 children; 595 usable records yielded a 97.2% response. The instrument, adapted from a pre-tested preschool oral health questionnaire, covered demographics and SES (parental education, household income), a nine-item POHBS with 5-point Likert and 3 reverse-scored items, children's brushing and sugar intake habits, and dmft recorded to WHO 2013 standards. Two calibrated dentists conducted exams (inter-examiner κ = 0.92). School doctors reviewed forms on site,

Table 1 – Research hypotheses within the SES-BeliefPrev-BehaviourRisk-dmft pathway model

Code	Path	Hypothesis	Expected
H1	SES→BeliefPrev	Higher SES is associated with stronger BeliefPrev	$\beta > 0$
H2	BeliefPrev→BehaviourRisk	Stronger BeliefPrev are associated with lower BehaviourRisk (high-sugar intake and missed night-time brushing	$\beta < 0$
H3	BehaviourRisk→dmft	Higher child BehaviourRisk is associated with higher dmft	$\beta > 0$
H4	SES→dmft	After controlling for BeliefPrev and BehaviourRisk, SES retains a direct negative effect on dmft	$\beta < 0$
H5	SES→BeliefPrev→ BehaviourRisk→dmft	SES affects dmft indirectly through sequential mediation by BeliefPrev and BehaviourRisk	indirect effect < 0

Note: β denotes the standardised regression coefficient. $\beta > 0$ indicates a positive association, $\beta < 0$ a negative association, and $\beta = 0$ no linear relationship between the variables.

eliminating missing data. Ethical approval was granted by the Biomedical Ethics Committee of Nantong Stomatological Hospital (PJ 2021-002-01) in line with the Declaration of Helsinki. Parents received written study information and gave informed consent; withdrawal was permitted at any time. Examinations were non-invasive (visual inspection and probing only), and data were stored confidentially for research and policy use. The same approval covers secondary analyses.

Questionnaire structure and data processing

The questionnaire contains 34 items, developed according to Kline's principles and organised into 5 modules: demographic information, SES, parental oral health beliefs, children's oral health behaviours, and oral clinical examination findings. Variable names, coding methods, and descriptions are summarised in Table 2, providing essential metadata for data replication, re-analysis, and model interpretation. Derived variables standardised by Z-transformation for regression analyses and path modelling are indicated by the suffix "_z". Given the brevity of the items, BehaviourRisk may under-capture diet timing/stickiness and supervised brushing; future work will incorporate objective logs and plaque indices to improve measurement precision.

The nine-item POHBS uses a 5-point Likert format. Exploratory factor analysis of the 9-item belief pool yielded 2 correlated factors: the professional prevention (PP) and outcome appearance (OA) domains. PP comprises 4 positively worded statements; OA contains 2 positive and 3 reverse-coded items. Because α assumes unidimensionality, this multidimensionality likely contributed to the low POHBS α. We therefore analysed a 4-item preventive-belief subscale to improve coherence, noting its still-modest reliability. Internal consistency was poor (α total = 0.18; PP = 0.40; OA = 0.08), indicating marked item heterogeneity. Exploratory factor analysis of the polychoric matrix (KMO = 0.70; Bartlett $\chi^2(36) = 684.5$; $p < .001$) revealed 2 factors explaining 61% of the variance. After rotation, the 4 positive PP items-regular check-ups, pit-and-fissure sealants, protecting 6-year molars,

Table 2 – Core variable dictionary of the questionnaire

Variable name	Module	Coding	Meaning
Sex	Basic info	1 = male; 2 = female	Child sex
Age		3-6 years (integer)	Child age
Height		Continuous, cm	Measured height
Weight		Continuous, kg	Measured weight
BMI		Continuous, kg/m^2	Body mass index
FatherEdu	SES	1 = primary or below;	Father's highest education
MotherEdu		2 = junior high; 3 = senior high / vocational; 4 = associate degree; 5 = bachelor's or above	Mother's highest education
IncomeLevel		1 = <50 k; 2 = 50-100 k; 3 = 100-200 k; 4 = 200-300 k; 5 = >300 k (CNY)	Household annual-income quintile
IncomeGroup		Low / Middle / High	Household income category
Feeding_6m		1 = breastfeeding; 2 = formula; 3 = mixed	Feeding mode for the first 6 months
OralStatusSelf	Clinical examination	Likert scale 1-5	Parent-rated oral health
NutritionStatus		Likert scale 1-5	Parent-rated nutrition status
dmft		Count 0-20	Decayed-missing-filled primary teeth
ToothacheYear		0 = no; 1 = yes	Toothache/discomfort in the past year
DentalVisit		0 = no; 1 = yes	Visited a dental specialist hospital
SweetSnackFreq	Child oral health behaviour	0-7 times/wk	Sweet-snack intake
SSB_Freq		0-7 times/wk	Sugar-sweetened beverage intake
DairyDrinkFreq		0-7 times/wk	Dairy-drink intake
FastFoodFreq		0-7 times/wk	Fast-food intake
FriedFreq		0-7 times/wk	Fried-food intake
PackSnackFreq		0-7 times/wk	Packaged-snack intake
NightSugar		0-3 times/night	Bedtime sweet snack/drink
NightMilk		0-3 times/night	Bedtime formula-milk
NightBrushFreq		0-7 times/wk	Brushing before bedtime
FluoridePaste		1 = yes; 2 = no; 3=unknown	Use of fluoride toothpaste
Belief_Check	Parental oral health beliefs	Likert 1-5	Regular dental check-ups are essential
Belief_FirstMolar		Likert 1-5	Protect the first permanent molar is important.
Belief_Bacteria		Likert 1-5	Bacteria can cause gingival inflammation.
Belief_Sealant		Likert 1-5	Pit-and-fissure sealing can prevent caries.
Belief_Innate_R		Likert 1-5 (reverse-scored)	Teeth are innate and unrelated to self-care
Belief_Bleed_R		Likert 1-5 (reverse-scored)	Gum bleeding during brushing is normal
Belief_Fluoride_R		Likert 1-5 (reverse-scored)	Fluoride is useless for protecting teeth
Belief_MotherInflu		Likert 1-5	The mother's poor teeth affect the child's teeth.
Belief_Appearance		Likert 1-5	Tooth decay affects a child's appearance.

and “bacteria cause gingival inflammation”-loaded 0.46-0.71 on Factor 1, while the 3 reverse PP items loaded −0.42 to −0.67. The 2 OA items loaded 0.64 and 0.68 on Factor 2, matching expectations. To enhance reliability, only the 4 high-loading PP items (≥ 0.35) were averaged and standardised to form BeliefPrev_z, focusing analyses on the intervention-relevant prevention construct and minimising measurement error.

All continuous or semi-continuous variables were z-standardised. SES was the mean of three 1-5 items (father’s education, mother’s education, and annual income). Three misconception statements were reverse-coded in the nine-item POralHBS (6-x); only 4 professional-prevention items with factor loadings ≥ 0.35 were averaged and standardised as BeliefPrev_z. Misconception and appearance items were excluded to reduce error. BehaviourRisk combined indicators of inadequate plaque removal and free-sugar exposure. Nightly toothbrushing frequency (1 = 0 times to 5 = ≥3 times) was reverse-coded to InvBrush. The weekly frequencies of sweets and sugar-sweetened drinks (0-7) were averaged with InvBrush; all components were z-standardised and signs aligned so that higher scores reflect higher risk, yielding BehaviourRisk_z. A sensitivity variant (BehaviourRisk_alt_z) additionally included snack and fried-food frequency; inferences were unchanged. This work conducted stratified models by sex (boys/girls) and single-year age groups (3, 4, 5, 6 years) as pre-specified sensitivity analyses. Caries were recorded according to the WHO 2013 criteria; teeth with caries and fillings were counted as carious. Despite positive skew, dmft was entered into linear models; a binary dmft_01 (0 vs ≥ 1) was used for sensitivity analyses. All indicators conformed to model assumptions.

Statistical analysis

This work used an observed-variable SEM chain to decompose total effects into direct and indirect components and to test mediation with bias-corrected bootstrap 95% CIs, reporting standardised β for within-model comparison. A latent-variable SEM was not pursued because the belief item pool showed low internal consistency (POHBS $\alpha \approx 0.18$; BeliefPrev $\alpha \approx 0.40$), raising risks of unstable factor solutions and biased paths. This transparent observed-variable framework, therefore, best matched the measurement properties of the present data.

Standardised path coefficients β are reported to convey the expected change in the outcome per 1 SD change in the predictor, conditional on other variables. Statistical significance was judged by bias-corrected bootstrap 95% CIs (2000 resamples) and 2-sided p-values; CIs excluding zero indicate significance. While β facilitates within-model comparisons of relative pathways, cross-study comparisons of β should be made cautiously, as standardisation depends on sample-specific variances and measurement reliability. As contextual guidance (not rigid thresholds), β values of about 0.10, 0.30, and ≥0.50 can be viewed as small, moderate, and large effects, respectively. While dmft is a count outcome, we used chained OLS for transparency; future work will consider generalised SEM with count links to address zero-inflation and non-normality. Indirect (mediated) effects were assessed with bias-corrected bootstrap 95% CIs. Given the modest reliability of the belief scale and the cross-sectional design, small mediations may be downward-biased and should be interpreted cautiously. The statistical analysis process is as follows:

Stage 1: Reliability/validity. Cronbach’s α was calculated for the nine items and subscales. Scales with $\alpha < 0.70$ underwent exploratory factor analysis (polychoric matrix, multiple imputation, principal-axis factoring). Factor number was set by parallel analysis and eigenvalues > 1, followed by Varimax rotation; loadings ≥ 0.35 were retained. If α stayed low, BeliefPrev was recomputed from high-loading items;

Stage 2: Path modelling. Chained OLS regressions estimated: (a) SES → BeliefPrev; (b, c′) SES + BeliefPrev → BehaviourRisk; (d-f) SES + BeliefPrev + BehaviourRisk → dmft. BehaviourRisk_alt_z tested sensitivity. Gender- and age-stratified models compared standardised coefficients (95% CI);

Stage 3: Indirect effects. Bias-corrected bootstrapping (2000 resamples) quantified mediation; paths were significant when the 95% CI excluded zero. Analyses used Python 3.11 (pandas 2.2, matplotlib 3.8), R 4.3.2 (psych 2.3.6, GPArotation 2023.9), and statsmodels 0.14/scikit-learn 1.4 with a fixed seed (2025).

Results

Demographic and socioeconomic status distribution

This study encompassed 595 children aged 3 to 6 years and their respective caregivers. The cohort consisted of 326 males and 269 females, yielding a male-to-female ratio of approximately 1.21:1, which aligns with the findings of the Fourth National Oral Health Epidemiological Survey of China. The age distribution among the participating children approximated a normal distribution, with a mean age of 4.5 years (SD = 1.0). The sample sizes across the different age groups were relatively evenly distributed, with the proportions of children aged 3, 4, 5, and 6 years being 23.7%, 27.2%, 26.4%, and 22.7%, respectively. This balanced distribution satisfies the statistical requirements necessary for detailed age-stratified analyses.

SES was constructed from the average of three 1-5 scale indicators: father’s education, mother’s education, and annual family income, and divided into quintiles based on the 20%, 40%, 60%, and 80% percentiles, as shown in Table 3. In this study, low-SES families refer to the lowest 2 quintiles (Q1-Q2) of the SES index. The lowest 2 quintiles comprised 296 cases (49.8%). In contrast, the highest quintile comprised only 75 cases (12.6%), showing a slight left skew, with a clear concentration of children with low SES, indicating that economically disadvantaged groups in the study area still bear

Table 3 – Distribution of SES quintiles

SES Quintile	Count	Percentage (%)
1 (lowest)	136	22.9
2	160	26.9
3	151	25.4
4	73	12.3
5 (highest)	75	12.6

the brunt of oral health inequalities, and also providing sufficient variation for subsequent SES gradient analysis.

Figure 1 summarises night-time brushing, fluoride toothpaste use, and sugar intake among 595 preschoolers. Nightly brushing was everyday: 62.7% brushed every night, 34.8% brushed 3-6 times/wk, and 2.5% brushed ≤2 times/wk. Fluoride use lagged brushing: 53.6% of caregivers reported fluoride toothpaste, 22.2% did not, and 24.2% were unsure, signalling information gaps that may limit fluoride's preventive benefit.

Sugar exposure was skewed toward snacks. While 24.7% of children ate sweets ≥3 times/wk, only 4.8% drank sugary beverages > 3 times/wk; 79.2% consumed sweet drinks once weekly. High-frequency intake of fried or puffed snacks was rare (3.7% and 5.0%, respectively), suggesting that these are minor sources of sucrose. No sex differences emerged in any indicator (e.g., sugary drinks $\chi^2 = 0.27$, $p = .60$). A behavioural risk index combined 3 standardised components: infrequent night-time brushing (≤2 times/wk), sweet-snack frequency, and sweet-drink frequency. Standardisation prevented any single item from dominating the score. The index captures the 2 principal caries risks-limited plaque removal and dietary sugars-and will be used in subsequent path models to test behaviour as a mediator between SES and dmft.

Validation

Cronbach's α for the POHBS is summarised in Table 4. The nine-item α was 0.175, far below the conventional 0.70, indicating marked item heterogeneity. Subscale reliabilities were also low: professional-prevention (six forward-phrased items) $\alpha = 0.401$ and misconceptions/negative beliefs (3 reverse-phrased items) $\alpha = 0.084$, both <0.50. The low consistency stems from reverse items differing in difficulty and wording, and from image-related statements that are loosely aligned with the core prevention construct, thereby inflating measurement error.

Table 4 – Cronbach's α reliability for the parental oral-health beliefs scale

Scale	Items	Cronbach α
Full scale	9	0.175
Professional prevention subscale	6	0.401
Misconception subscale	3	0.084

Given these results, 4 forward-phrased professional-prevention items-regular check-ups, pit-and-fissure sealants, protection of 6-year molars, and bacterial-caries were retained to form the BeliefPrev composite score, reducing error variance and preserving content most relevant to preventive practice for subsequent path analyses. After standardising reverse-coded items, EFA revealed a clear 2-factor solution (Table 5). Factor 1 combined 4 strongly loaded prevention items: pit-and-fissure sealants (0.505), bacteria cause gingivitis (0.311), protecting deciduous teeth (0.436), and regular check-ups (0.354)- with 3 misconception statements with small positive loadings (e.g., "good teeth are innate," 0.173). Thus, parents' rejection of misconceptions and endorsement of professional prevention skills form a single latent construct accounting for 41% of the variance.

Factor 2 was supported mainly by perception items; caries affects appearance (0.311), and a mother's teeth influence her child's (0.363), which explains ~20% of the variance. Loadings were lower than those in Factor 1, indicating that appearance-related concerns are mainly independent of professional-prevention beliefs; misconception items showed negligible loadings here. The scale's low overall α reflects heterogeneity between these 2 dimensions and the small item set for Factor 2. To improve measurement reliability, 4 high-loading items from Factor 1 (sealants, bacteria, deciduous-tooth protection, check-ups) were retained to construct BeliefPrev, while Factor 2 was used descriptively only. This

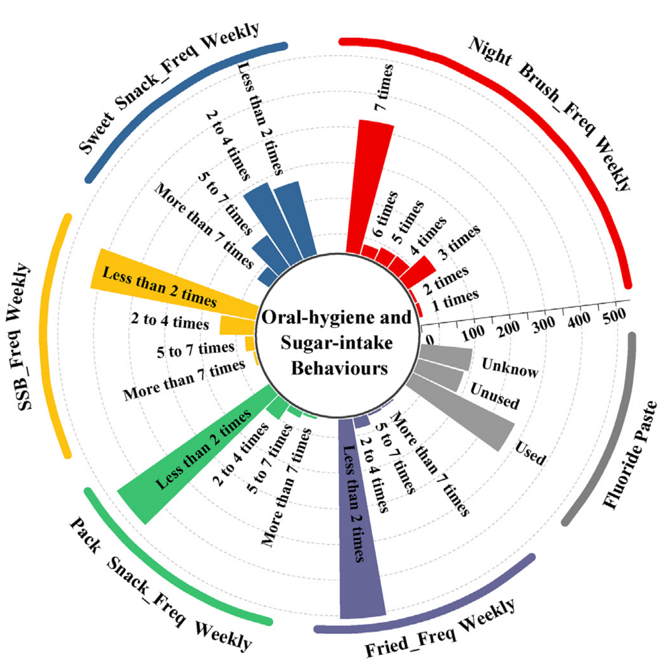

Fig. 1 – Descriptive statistics of oral-hygiene and sugar-intake behaviours in preschoolers.

Table 5 – Two-factor EFA loading matrix of the POHBS

	Factor1 (Professional prevention dimension)	Factor2 (Result-image dimension)
Fluoride does not protect teeth	−0.517	0.078
Pit and fissure sealant can prevent childhood caries	0.505	0.15
Protecting deciduous teeth is very important	0.436	−0.118
Regular dental check-ups are essential	0.354	−0.208
Bacteria can cause gingivitis	0.311	−0.071
Bleeding gums while brushing is normal	−0.280	−0.004
Dental caries affects children's appearance	0.274	0.311
Mother's poor teeth will affect her child's teeth	0.176	0.363
Teeth are innate and unrelated to self-care	0.173	−0.265

strategy enhances reliability and theoretical focus, providing a stable base for subsequent path models.

Model estimation

The SES→BeliefPrev path was small and non-significant. The inverse SES→BehaviourRisk association refers to the composite index, not a single item; results were similar using an expanded behaviour index.

(1) SES → BehaviourRisk

Table 6 summarises the OLS model with SES_z and BeliefPrev_z predicting BehaviourRisk_z. The model was significant (F = 11.01, df = 2, 592; $p < .001$) but explained slight variance (adjusted $R^2 = 0.033$), a pattern typical of complex social behaviours. SES_z showed a significant inverse association with BehaviourRisk_z ($\beta = -0.187$, $p <.001$): a 1-SD increase in SES corresponded to a 0.19-SD decrease in combined brushing and sugar-exposure risk. BeliefPrev_z was negligible ($\beta = 0.012$, $p = .769$), likely dampened by measurement error and social-desirability bias noted earlier.

These findings support the structure-first hypothesis: SES affects BehaviourRisk, whereas belief scores add little. Although the model explains only 3.3% of variance, this fraction can mediate part of the SES-dmft link in subsequent analyses. Public health efforts should therefore prioritise removing structural barriers that limit low-SES families' access to preventive resources, while supplementing these efforts with high-fidelity educational strategies.

(2) BehaviourRisk → dmft and SES residual effects

Table 7 presents the multivariable model with BehaviourRisk_z, BeliefPrev_z, and SES_z predicting dmft. SES_z remained the sole significant predictor ($\beta = -0.329$; $p = .044$; 95% CI: −0.649 to −0.009). Thus, a one-SD decline in SES corresponded to an average increase of 0.33 carious teeth. By contrast, BehaviourRisk_z ($\beta = 0.193$; $p = .233$) and BeliefPrev_z ($\beta = 0.022$; $p = .890$) were insignificant, their CIs spanning zero.

Although the 3 predictors accounted for 5.8% of the variance (adjusted $R^2 = 0.058$), the SES effect persisted after accounting for behaviour and cognition, indicating a residual structural influence on caries. The regression intercept (2.575) aligns with the sample mean dmft (2.58), underscoring satisfactory prediction at average covariate levels. These findings mirror the small effect pattern typical in oral health epidemiology, yet clearly demonstrate that socioeconomic gradients outweigh short-term self-reported behaviours and parental beliefs in preschool caries. Consequently, interventions should prioritise reducing structural barriers, such as costs and geographic access to fluoride and professional care, while supplementing these efforts with evidence-based education using high-reliability tools.

(3) Standardised path diagram

Figure 2 displays direct and indirect links among SES, BeliefPrev, BehaviourRisk, and dmft within the SEM. Significant paths are drawn as black solid lines; non-significant ones as grey dashed lines. SES directly affected dmft ($\beta = -0.329$, $p = .044$), indicating higher caries risk in lower SES children. SES also negatively affected BehaviourRisk ($\beta = -0.187$, $p < .001$), showing that limited economic and educational resources are associated with poorer brushing and dietary habits, raising caries risk. This dual pathway supports the structure− priority model: structural resources directly shape disease prevalence, and behavioural risk is shaped indirectly.

BeliefPrev showed no significant impact. The direct path to dmft ($\beta = 0.022$, $p = .890$) and the indirect path via BehaviourRisk ($\beta = 0.012$, $p = .769$) were non-significant, indicating that stronger parental beliefs alone do not translate into better habits or fewer caries in this cross-sectional sample. This pattern matches the scale's modest reliability and the lag between cognitive change and behavioural adoption. The

Table 6 – Multiple regression of SES and BeliefPrev on BehaviourRisk

	β	Std. Err.	t	p	Lower 95% CI	Upper 95% CI
const	0.000	0.041	0.000	.991	−0.079	0.079
BeliefPrev_z	0.012	0.041	0.294	.769	−0.068	0.092
SES_z	−0.187	0.041	−4.587	<.001	−0.267	−0.107

Table 7 – Multiple regression of BehaviourRisk, BeliefPrev, and SES on dmft

	β	Std. Err.	t	p	Lower 95% CI	Upper 95% CI
const	2.575	0.158	16.27	.000	2.264	2.886
BehaviourRisk_z	0.193	0.161	1.19	.233	−0.124	0.510
BeliefPrev_z	0.022	0.16	0.14	.890	−0.292	0.337
SES_z	−0.329	0.163	−2.02	.044	−0.649	−0.009

BehaviourRisk → dmft link was positive but still non-significant, likely reflecting the short observational window and social-desirability under-reporting of sugar intake. Moreover, the small coefficients are similar to those observed in previous behavioural studies in oral epidemiology, where significant residual variance is common. Together with Figure 2, these findings confirm SES as the dominant determinant of preschool caries and show that educational programmes must be paired with broad, community-wide structural policies-subsidised fluoride supplies and improved service access-to secure practical, sustainable oral-health gains.

Sensitivity and Robustness

Figure 3 contrasts 2 dmft models that differ only in the BehaviourRisk index. The original index includes night-time brushing, sweet-snack, and sweet-drink frequency; the extended index adds snack and fried-food frequency (5 items total). Both models control for BeliefPrev_z and SES_z. SES_z remained influential: $\beta = -0.329$ ($p = .044$) in the 3-item model and $\beta = -0.310$ ($p = .057$) in the 5-item model, slightly attenuated yet directionally stable, indicating that socioeconomic gradients persist after accounting for extra behaviour items. BehaviourRisk lost strength after extension ($\beta = 0.193 \rightarrow 0.176$), and both 95% CIs crossed zero, confirming limited predictive value. BeliefPrev_z stayed negligible ($\beta \approx 0.02$; $p > .8$). Adding snacks and fried-food frequency did not improve model fit, likely because these variables are collinear with sugary-snack and sweet-drink intake, while omitting critical aspects such as food stickiness and postmeal brushing. Consequently, the behavioural pathway contribution to caries remains understated, whereas the structural SES effect endures across specifications.

Figure 4 plots β (95% CI) for SES_z, BehaviourRisk_z, and BeliefPrev_z against dmft separately for boys and girls. SES_z showed a stronger negative link in boys ($\beta = -0.16$; CI excludes 0) than in girls ($\beta = -0.08$; CI touches 0), suggesting greater socioeconomic vulnerability among boys. BehaviourRisk_z and BeliefPrev_z were near zero in both sexes, with CIs spanning 0, indicating no independent or gender-specific effects. Thus, the structure-dominant, weak behaviour-belief pattern remains consistent after gender stratification.

Figure 5 traces SES effects on dmft across ages 3 - 6. The SES β became more negative from −0.06 (age 3) to −0.13 (age 5), then eased to −0.03 (age 6). A linear trend (≈ −0.03 per year; $p < .05$) supports the cumulative disadvantage hypothesis: low SES children experience prolonged exposure to sugary diets and limited resources once primary molars erupt, with disparities peaking at ages 4-5. The attenuated effect at age 6 may reflect fewer cases and earlier school-based fluoride programmes, suggesting that intervention should begin around 4-5 years via subsidies, fluoride toothpaste distribution, and routine screenings.

BehaviourRisk_z β values rose slightly with age but remained non-significant (CIs straddling 0), implying a biological lag between high sugar exposure / skipped brushing and observable enamel loss, compounded by parental under-reporting and omission of factors such as food stickiness or post-meal cleaning. BeliefPrev_z showed unstable, non-significant effects ($\beta = -0.13$ at 4 years; $\beta = 0.08$ at 6 years), likely due to scale unreliability and potential reverse causation (parents heighten beliefs after noticing caries). Future work should use objective methods, such as 24-hour dietary recall, plaque biomarkers, and longitudinal follow-up to capture delayed behavioural impacts. Validated scales are also needed to track links between beliefs, behaviour, and caries at different ages, forming the evidence base for phased, precise interventions.

Discussion

Main findings

Using cross-sectional data from 595 preschoolers, this observed-variable SEM showed that SES retained a significant negative link with dmft after controlling for beliefs and behaviours. The SES effect intensified with age, peaking at $\beta = -0.13$ at 5 years, then easing, likely due to a smaller six-year subsample and school fluoride programme. This trend supports cumulative disadvantage theory and identifies ages 4-5 as a key intervention window. Compared with earlier reports (OR: 0.65 - 0.80; unstandardised $\beta \approx -0.20$), our age-specific β values allow finer cross-study comparisons.

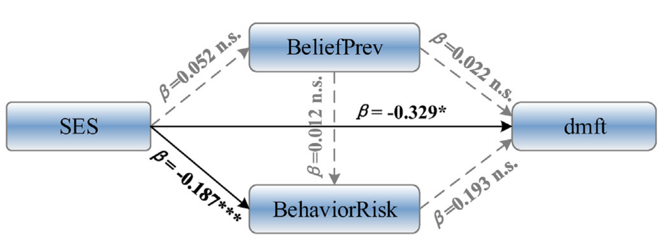

Fig. 2 – Path relationships among SES, BeliefPrev, BehaviourRisk, and dmft.

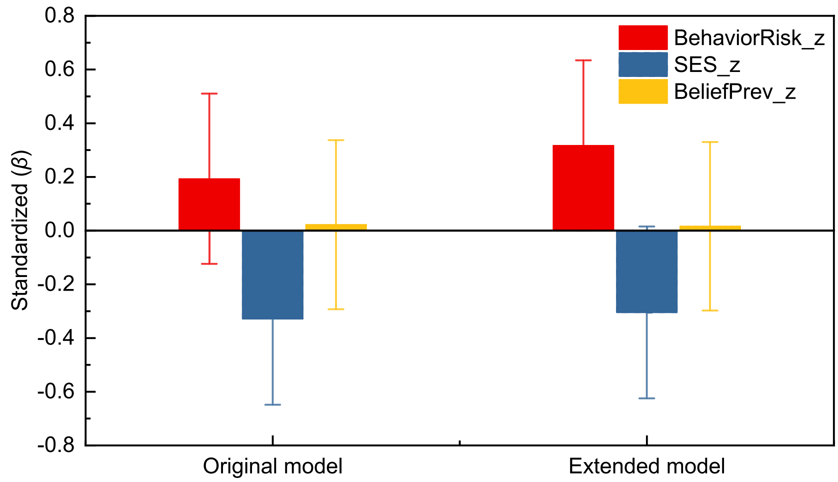

Fig. 3 – Sensitivity analysis with alternative behaviour-risk definition.

Relative to other structural markers, the SES β mirrors the dmft coefficient reported in the Basque region ($\beta = -0.14$) but is weaker than community dentist density in the US Head-Start cohort ($\beta = -0.22$).[20,21] In urban settings where access is generally good, economic advantage alone may not capture the full gradient; neighbourhood dentist distribution and social capital likely interact with SES. Multilevel models incorporating public service density alongside SES could more precisely disentangle economic versus neighbourhood residual effects. Relating these paths to our prior LCA-derived groups—high-risk/high-sugar, medium-risk/mixed, low-risk/high-brushing—shows that even low-risk children remain exposed when SES is low, while the null Belief → Behaviour path implies education alone cannot shift high-risk profiles without simultaneous structural support. Thus, structural measures plus targeted coaching are required; knowledge-only programmes are unlikely to close the SES gap. Because β is sample-standardised, effect significance rests on CIs/p-values, whereas practical importance should additionally consider estimate precision, construct reliability, and policy relevance. Accordingly, our conclusions emphasise direction, statistical evidence, and measurement limitations, rather than β magnitude alone.

Behavior and and belief pathways: Lag, measurement, age differences

The standardised coefficient for BehaviourRisk rose from 0.06 at age 3 to 0.16 at age 6, yet all 95% CIs crossed zero. This suggests a biological or reporting lag between high sugar / missed brushing and observable caries, consistent with STRIP-cohort evidence that sugar at age 5 predicts molar lesions only 18-24 months later.[22,23] Self-report bias further weakens the signal: questionnaires omit stickiness, timing, and post-meal cleaning, and parents often mis-recall bottle-feeding or bedtime drinks.[24] Objective tools, multi-day diet logs, plaque ATP fluorescence, and pre-sleep plaque photos could more accurately capture behaviour in future work. The 4-item BeliefPrev composite showed modest internal consistency (Cronbach's $\alpha = 0.40$). Such low reliability attenuates regression coefficients, so the near-zero BeliefPrev → Behaviour and BeliefPrev → dmft paths cannot be taken as evidence that parental beliefs are unimportant. Social-desirability bias and potential reverse causation (heightened beliefs after caries onset) may also mask actual effects. Reverse-coded items comprised 33% of the original scale, exceeding the WHO <20% recommendation, and likely depressed α, echoing

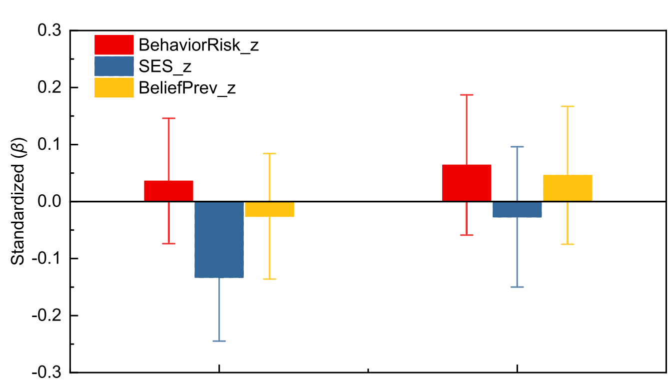

Fig. 4 – Sex-stratified β with 95 % CI predicting dmft.

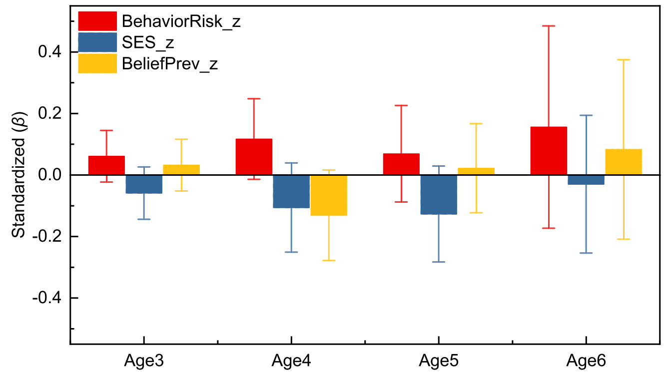

Fig. 5 – Age-stratified β with 95 % CI predicting dmft.

misclassification seen in Korean and Japanese adaptations.[25] Future studies should adopt higher-fidelity instruments, for example, IRT-calibrated items, cognitive interviews for cultural clarity, situational-judgement tests, and, where possible, corroborate parental reports with objective markers of home care.

Model optimisation and measurement priorities. The non-significant BehaviourRisk→dmft path likely reflects under-reporting in self-reports and latency between exposures and clinical caries. Future analyses could employ generalised SEM using a negative-binomial or zero-inflated link for the dmft path, test non-linearities and interactions (e.g., SES × BehaviourRisk), and include richer indicators: diet timing and stickiness (bedtime sugars, retentive snacks), supervised bedtime brushing and fluoride exposure (toothpaste strength, varnish/sealants), objective plaque status (visible plaque or photographic indices; optional plaque ATP fluorescence), and contextual access (kindergarten fluoride programmes; neighbourhood service density). These enhancements may reduce attenuation, improve model fit, and better capture behaviour-to-caries translation.

Interpretation of null mediation. The non-significant indirect paths via BeliefPrev and BehaviourRisk do not imply that beliefs or behaviours are irrelevant to ECC. First, the BeliefPrev subscale showed modest internal consistency (Cronbach's $\alpha \approx 0.40$; POHBS $\alpha \approx 0.18$), suggesting attenuation of mediated effects. Second, our cross-sectional design cannot establish temporality and is vulnerable to reverse causality (e.g., existing caries may heighten parental concern and reported behaviours). Third, brief self-reports under-capture diet timing/stickiness and supervised bedtime brushing, and behaviour-to-caries translation may require 18–24 months to manifest clinically. Consequently, we interpret the null mediation as a measurement/timing limitation, while the direct SES association remained detectable under these conditions. Prospective studies using validated belief instruments, objective behaviour metrics (multi-day diet logs, fluoride exposure, visible/plaque photographic indices), and longitudinal mediation within generalised SEM for count outcomes are warranted.

Public health and clinical implications

The results point to 2 priorities. First, the cumulative SES effect argues for early structural action-free fluoridated toothpaste, economic subsidies, and mobile clinics aimed at 4-5-year-olds, before habits rigidify and caries accelerate. Second, although BehaviourRisk was insignificant, its age-linked rise suggests age 6 is an opportune moment for dietary counselling and reinforced bedtime brushing. Objective indicators (detailed sugar logs, plaque biomarkers) should track programmed impact. The Australian School Dental Service shows that coupling toothpaste distribution, sealants, nutrition monitoring, and one-off subsidies for low-SES kindergartens reduces mean dmft by 0.5-0.8 within 2 years, underscoring the synergy of structural and behavioural measures.[24]

Consistent with the observed SES–dmft gradient and attenuated belief/behaviour paths, structural supports should accompany education, especially for families with constrained resources. Priority options include coverage and co-payment waivers for fluoride varnish and sealants, subsidised distribution of fluoride toothpaste to households with preschoolers, and the integration of preventive care with routine child health contacts (e.g., immunisation visits, kindergarten health checks). At the service/environment level, kindergarten-based supervised toothbrushing and school food standards that limit free sugars reduce reliance on parental knowledge alone. For underserved neighbourhoods, mobile/community dental teams and tracking of service density and fluoride-programme participation can better target resources. Where feasible, earmarked revenues from sugar-sweetened beverage policies can finance preschool prevention. In light of our age-stratified results, targeting ages 4–5 may maximise yield. These recommendations are presented as policy-relevant associations rather than causal claims and should be evaluated prospectively.

This work emphasises harmonised indicators and structural supports, consistent with Broomhead et al.,[26] which demonstrate how standardised international oral-health datasets enable equity monitoring and cross-country comparability in service and outcome measures. In parallel, the 2-year longitudinal study by Chou shows that parental health beliefs prospectively predict ECC, indicating that our cross-sectional null mediation is likely influenced by measurement reliability and temporality, rather than the true absence of effect.[27]

Limitations and future research

The non-significant BehaviourRisk→dmft path likely reflects under-measurement of key behaviours and latency between exposures and manifest caries. Brief self-reports omit diet timing and stickiness (e.g., bedtime sugars, retentive snacks) and post-meal/brushing supervision, which can attenuate path estimates. It should incorporate multi-day 24-hour diet logs with timing/frequency/stickiness, together with bed-time-brushing supervision logs and fluoride exposure (tooth-paste concentration, varnish/sealants), together with objective plaque indices (visible or photographic; optionally plaque ATP fluorescence) to reduce measurement error and better capture behaviour-to-caries translation.

This cross-sectional, single-city study cannot establish causality, may be subject to self-report bias, and limits generalisability. Future work should adopt multi-centre longitudinal designs with repeated 24-h/3-d sugar logs, pre-sleep plaque staining, and salivary biomarkers to track cumulative behavioural effects. IRT-based refinement and invariance testing across SES strata would strengthen measurement. A cluster-randomised kindergarten trial comparing a comprehensive package of structural subsidies, objective monitoring, and parental decision training with standard education could test for a 1-year dmft reduction. Overall, our SEM findings highlight a structure-priority, behaviour-lag, and cognition-weak pattern, offering a quantitative basis for staged, hierarchical interventions.

Conclusions

This cross-sectional path study of 595 preschoolers quantified direct and indirect links among SES, BeliefPrev, BehaviourRisk, and dmft. In the pooled model, SES retained a direct inverse association with dmft ($\beta = -0.329$; 95% CI: -0.649 to -0.009), while indirect paths via BeliefPrev or BehaviourRisk were non-significant (bootstrap CIs spanning zero). Age-stratified patterns showed the SES association strengthened to $\beta \approx -0.13$ at age 5. Within this dataset, structural disadvantage outweighed short-term self-reported behaviours and parental beliefs, indicating that knowledge-based education/behaviour coaching alone is unlikely to close the gradient. Effective prevention should blend economic or service-level supports, such as subsidised fluoride and accessible paediatric care, with targeted behaviour coaching. The strengths of the study include its large sample, age-specific modelling, and bootstrap validation; the chief limitations are the cross-sectional, single-city design, reliance on self-reports, and limited precision of the belief-scale. Multi-centre longitudinal research using objective behavioural metrics and validated cognitive instruments is needed to confirm these associations and refine the timing of combined structural-behavioural interventions.

Author contributions

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Ethics approval

This study was approved by the Ethics Committee of Nantong Stomatological Hospital [PJ 2021 002 01]. Informed consent was obtained from participants or their legal guardians involved in the study.

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Conflict of interest

None disclosed.

REFERENCES

1. Peres MA, Macpherson LMD, Weyant RJ, et al. Oral diseases: a global public health challenge. Lancet 2019;394(10194):249–60. doi: 10.1016/S0140-6736(19)31146-8.
2. Uribe SE, Innes N, Maldupa I. The global prevalence of early childhood caries: a systematic review with meta-analysis using the WHO diagnostic criteria. Int J Paediatr Dent 2021;31(6):817–30. doi: 10.1111/ipd.12783.
3. Saikia A, Aarthi J, Muthu MS, et al. Sustainable development goals and ending ECC as a public health crisis. Front Public Health 2022;10:931243. doi: 10.3389/fpubh.2022.931243.
4. Du MQ, Li Z, Jiang H, et al. Dental caries status and its associated factors among 3- to 5-year-old children in China: a national survey. Chin J Dent Res 2018;21(3):167–79. doi: 10.3290/j.cjdr.a41076.
5. Tinanoff N, Baez RJ, Diaz Guillory C, et al. Early childhood caries epidemiology, aetiology, risk assessment, societal burden, management, education, and policy: global perspective. Int J Paediatr Dent 2019;29(3):238–48. doi: 10.1111/ipd.12484.
6. Chen J, Chen W, Lin L, Ma H, Huang F. The prevalence of dental caries and its associated factors among preschool children in Huizhou, China: a cross-sectional study. Front Oral Health 2024;5:1461959. doi: 10.3389/froh.2024.1461959.
7. Folayan MO, El Tantawi M, Aly NM, et al. Association between early childhood caries and poverty in low and middle income countries. BMC Oral Health 2020;20(1):8. doi: 10.1186/s12903-019-0997-9.
8. Singh A, Purohit BM, Purohit A, Nilima N. Independent contributions of nuclear and extended families to risk of early childhood caries among children from low socio-economic status in India. Community Dent Hlth 2024. doi: 10.1922/CDH_00109Singh07.
9. Zhai LY, Yao N, Kong JX, Ding ZM, Xu Y, Zhao CN. Analysis of latent class and heterogeneous associations of oral health behaviors with preschool children caries. Shanghai J Stomatol 2024;33(4):415.
10. Legendre E, Kelly D, Franke F, et al. Health mediation for promoting cancer screening and vaccination in deprived neighbourhoods in France. Eur J Public Health 2024;34(Suppl 3):144–589. doi: 10.1093/eurpub/ckae144.589.
11. Mudd AL, van Lenthe FJ, Verra SE, Bal M, Kamphuis CB. Socioeconomic inequalities in health behaviors: exploring mediation pathways through material conditions and time orientation. Int J Equity Health 2021;20(1):184. doi: 10.1186/s12939-021-01522-2.

12. Moreno-Llamas A, San Sebastián M, Gustafsson PE. The transmission of social inequalities through economic difficulties and lifestyle factors on body mass index: an intersectional mediation analysis in the Swedish population. Soc Sci Med 2024;360:117314. doi: 10.1016/j.socscimed.2024.117314.
13. Sanaeinasab H, Saffari M, Taghavi H, et al. An educational intervention using the health belief model for improvement of oral health behavior in grade-schoolers: a randomized controlled trial. BMC Oral Health 2022;22(1):94. doi: 10.1186/s12903-022-02132-2.
14. Endawkie A, Keleb A, Dilnesa T, Tsega Y. Generalized structural equation modeling of direct and indirect determinants of chronic undernutrition among under-five children in Ethiopia: further analysis of the 2019 mini Ethiopian demographic and health survey. J Health Popul Nutr 2025;44(1):1–11. doi: 10.1186/s41043-025-00792-8.
15. Al-Harrasi A, Pinto AD, Jayapal SK, Morsi M, Al-Mawali A. Structural equation modeling to identify the direct and indirect risk factors of diabetes in adults: findings from a national survey. Am J Med Sci 2022;364(3):274–80. doi: 10.1016/j.amjms.2022.03.003.
16. Nikooyeh B, Neyestani TR. Contribution of vitamin D status as a determinant of cardiometabolic risk factors: a structural equation model, National Food and Nutrition Surveillance. BMC Public Health 2021;21(1):1819. doi: 10.1186/s12889-021-11839-w.
17. Qin Y, Zhang R, Yuan B, et al. Structural equation modelling for associated factors with dental caries among 3–5-year-old children: a cross-sectional study. BMC Oral Health 2019;19(1):102. doi: 10.1186/s12903-019-0787-4.
18. Lima LCM, Neves ÉTB, Perazzo MF, et al. Structural equation modeling of the association between oral health literacy and dental caries in children. Braz Oral Res 2025;39:e021. doi: 10.1590/1807-3107bor-2025.vol39.021.
19. Liu P, Wong HC, Gao X, et al. Development and validation of the health belief model scale for early childhood caries prevention behaviors of parents. BMC Oral Health 2025;25(1):25. doi: 10.1186/s12903-025-06416-1.
20. Fernández-Bonet J, Marichalar-Mendia X, Lertxundi-Manterola A. Childhood dental caries experience in northern Spain: a cross-sectional study. Eur Arch Paediatr Dent 2023;24(1):95–103. doi: 10.1007/s40368-022-00762-2.
21. Maklennan A, Borg-Bartolo R, Wierichs RJ, Esteves-Oliveira M, Campus G. A systematic review and meta-analysis on early-childhood-caries global data. BMC Oral Health 2024;24(1):835. doi: 10.1186/s12903-024-04605-y.
22. Touger-Decker R, van Loveren C. Sugars and dental caries. Am J Clin Nutr 2003;78(4):881S–92S. doi: 10.1093/ajcn/78.4.881S.
23. Zou J, Du Q, Ge L, et al. Expert consensus on early childhood caries management. Int J Oral Sci 2022;14(1):35. doi: 10.1038/s41368-022-00186-0.
24. Nazari A, Hajihashemi M, Safavi SR, Ataei R, Hosseinnia M. Health promotion theory-based educational interventions for improving oral health in children and adolescents: a systematic review and meta-analysis. BMC Oral Health 2025;25(1):3747. doi: 10.1186/s12903-025-06549-3.
25. Major Poljak K, Barać I, Kovačević I, et al. Psychometric analysis and cross-cultural adaptation of the Croatian version of the Oral Health Values Scale (OHVS). Dent J (Basel) 2025;13(2):56. doi: 10.3390/dj13020056.
26. Broomhead T, England R, Mason S, et al. Using standardised international oral health-related datasets in 6 countries. Int Dent J 2024;74(3):647–55. doi: 10.1016/j.identj.2024.01.001.
27. Chou YC, Cheng FS, Weng SH, Tseng CH, Hu HY, Liu CH. Impact of parental health beliefs on early childhood caries: a two-year longitudinal study. Int Dent J 2025;75(5):100902. doi: 10.1016/j.identj.2025.100902.