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Parent–Child Concordance in Toothbrushing Behaviours and Its Association with Early Childhood Caries: A Dyadic Cross-Sectional Study

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Abstract

Background

To quantify parent–child concordance in toothbrushing behaviours and to determine whether dyadic toothbrushing phenotypes are associated with early childhood caries (ECC) among preschool children.

Methods

This analytical cross-sectional study included 486 parents–child dyads recruited consecutively during routine dental visits to a university dental clinic in Selangor, Malaysia. Parallel parent and child toothbrushing behaviours, parental modelling, supervision, dietary practices, and the Malay Parenting and Child Tooth Brushing Assessment (M-PACTA) were recorded. Children underwent calibrated caries examinations via the dmft index. Item-level concordance was assessed with Cohen's kappa, and dyads were classified as favourable concordant (FF), parent-favourable/child-unfavourable (FU), parent-unfavourable/child-favourable (UF), or unfavourable concordant (UU). Multivariable logistic and negative binomial regression models were used to examine ECC and dmft, respectively.

Results

ECC was present in 278/486 children (57.2%), and the mean dmft was 3.16 (SD 3.48). The phenotype distribution was 174 FFs (35.8%), 112 FUs (23.0%), 76 UFs (15.6%), and 124 UUs (25.5%). Kappa was 0.49 for twice-daily brushing, 0.44 for bedtime brushing, and 0.31 for brushing duration. The prevalence of ECC increased from 39.1% in FF dyads to 83.1% in UU dyads ($p < 0.001$). Relative to FF, the adjusted odds of ECC were greater in FU (aOR 1.82, 95% CI 1.09–3.04) and UU dyads (aOR 4.72, 95% CI 2.79–7.98); UF was imprecise (aOR 1.69, 95% CI 0.96–2.98). The UU dyads also had higher dmft counts (adjusted IRR 2.31, 95% CI 1.77–3.02).

Conclusion

Unfavourable parent–child brushing concordance was strongly associated with both ECC incidence and caries burden. Family-centred prevention may benefit from assessing parental self-care, modelling, supervision, and child brushing together.

Background

Early childhood caries (ECC) remains one of the most prevalent chronic diseases of childhood worldwide and reflects interactions among biological, behavioural, and social determinants rather than a single exposure [1–4]. Contemporary evidence consistently reveals that previous caries, visible plaque,

socioeconomic disadvantage, dietary sugar exposure, fluoride exposure, and toothbrushing behaviours are among the relevant components of caries risk in young children [3, 4].

Twice-daily toothbrushing with fluoride toothpaste is a central preventive behavior. Evidence from fluoride-toothpaste trials and systematic reviews supports regular fluoride exposure, whereas home-based and early-education interventions emphasise the importance of sustained, structured brushing routines and parental involvement during preschool years [5–7].

Preschool toothbrushing is not an exclusively child-level behavior. Parents or caregivers purchase oral hygiene products, structure morning and bedtime routines, prompt or perform brushing, manage child resistance, and decide when independent brushing is permitted. Research has shown that parent behaviour-management skills and parent-led brushing are associated with children's oral health outcomes [8]. Similarly, social-cognitive studies indicate that parental self-efficacy, intention, planning, and action control contribute to supervised toothbrushing [9–11].

The evidence increasingly supports a family or dyadic perspective. In an Australian national sample, parent and child oral health measures showed concordance at the dyadic level [12]. Longitudinal data have also demonstrated reciprocal caregiver—child influences in toothbrushing over time [13]. More recently, a large Australian cohort study revealed that mothers' toothbrushing frequency independently predicted their preschool children's toothbrushing frequency at both 2 and 5 years of age, further supporting family-centered oral health promotion [14]. These findings suggest that children may learn not only from explicit instruction but also from routines, expectations, and behaviours modelled within the household. This pattern is consistent with social learning theory, whereby children may acquire oral hygiene habits partly by observing and imitating parental brushing behaviour [15].

Parenting processes may help explain why favourable parental self-care does not always translate into favourable child brushing. The Parenting and Child Tooth Brushing Assessment (PACTA) was developed to capture child noncompliance/avoidance, parental strategies, attitudes, and oral health knowledge, and its domains predict child brushing behaviour [16]. The Malay adaptation (M-PACTA) has demonstrated satisfactory psychometric properties among Malaysian parents of preschool children [17], and population-specific cut-off scores have subsequently been proposed [18]. Recent studies have also linked parental attitudes, maternal control, parenting characteristics, and parental psychosocial factors with children's toothbrushing or oral health outcomes [19–21].

Malaysian observational evidence has highlighted discrepancies between reported and observed preschool toothbrushing and has shown that several brushing parameters are associated with plaque, gingival, and caries outcomes [22]. A recent Malaysian qualitative study further identified time pressure, child resistance, limited confidence, inconsistent routines, and contextual constraints as barriers to parental toothbrushing supervision [23]. However, most studies analyse parent or child behaviours separately. A dyadic concordance approach may reveal clinically relevant combinations that are obscured when behaviours are considered only as isolated covariates.

Thus, the primary aim of this study was to quantify parent–child concordance in toothbrushing behaviours and to investigate the association between the dyadic toothbrushing phenotype and ECC among preschool children. The secondary aims were to identify factors associated with concordantly unfavourable brushing and to examine whether phenotype was associated with dmft severity. We hypothesised that children in concordantly unfavourable dyads would have the highest caries prevalence and burden, whereas those in concordantly favourable dyads would have the lowest.

Methods

Study design and setting

This clinic-based analytical cross-sectional study was conducted from November 2025 to May 2026 at the Lincoln University Dental Clinic in Petaling Jaya, Selangor, Malaysia. Parent–child dyads were recruited consecutively from among parents and children attending the clinic for a routine dental visit. The parent–child dyad was the unit of analysis. The study was reported with reference to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations for cross-sectional studies **(Supplementary File 1)** [24].

Ethics approval and consent to participate

The study received approval from the Institutional Ethics and Review Committee (reference number: LUC/SOD-FR/AP-0126/25) prior to participant recruitment. Written informed consent was obtained from parents or legal guardians before participation, and age-appropriate assent procedures were followed for the participating children **(Supplementary File 2: Part IV)**. The study was conducted in accordance with the Declaration of Helsinki.

Participants

Parents or primary caregivers with a child aged 3-6 years who could understand Malay or English were eligible if they attended the University Dental Clinic for a routine dental visit, child who had at least one erupted primary tooth, and had a caregiver who lived in the same household and was familiar with the child's oral health routine. Children with medical or developmental conditions that substantially prevented routine oral-hygiene assessment or clinical examination were excluded. When more than one eligible sibling was available, one child was randomly selected to preserve dyadic independence.

Sampling and sample size

Parent–child dyads attending the University Dental Clinic for a routine dental visit were invited consecutively during the study period until the target sample size was reached. The a priori target was

480 dyads, selected to provide approximately 80% power at a two-sided α of 0.05 to detect an odds ratio of approximately 1.8 for ECC between the concordant-favourable (FF) and concordant-unfavourable (UU) phenotype groups, the principal contrast of interest, under an anticipated ECC prevalence of 50-60%, with allowance for nonresponse. The final analytical sample comprised 486 complete dyads.

Questionnaire and behavioural exposures

A self-administered structured questionnaire in their preferred language collected information on child age and sex, caregiver relationships, parental education, household income, dental attendance, sugar exposure, parental toothbrushing, and child toothbrushing **(Supplementary File 2: Part IA).** Parallel parent and child items were used for brushing frequency, bedtime brushing, brushing duration, fluoride-toothpaste use, and a regular brushing routine. Parental modelling was assessed by whether the child saw the parent brush, whether they brushed together, and whether the parent deliberately brushed. Child brushing involvement was classified as parent-performed, parent-completed/assisted, supervised, or independent.

Malay Parenting and Child Tooth Brushing Assessment (M-PACTA)

Parenting processes were assessed via the validated M-PACTA, which was adapted from the original PACTA [16, 17] **(Supplementary File 2: Part II).** The instrument assesses child behaviour, parental strategies, parental attitudes, and oral health knowledge. Published Malaysian cut-off values of 37, 98, 44, and 41, respectively, were applied via the directionality established in the validation work: lower child-behavior scores and higher parental-strategy, attitude, and knowledge scores indicate more favourable profiles [18].

Questionnaire validity and reliability

The questionnaire comprises two measurement components: a prespecified single-item demographic, dietary, dental-attendance, and toothbrushing indicators that were developed by an investigator and the validated M-PACTA. The former were treated as factual or behavioural variables rather than as a unidimensional scale; therefore, scale-level internal-consistency coefficients (e.g., Cronbach's α) were not considered meaningful for these items, which is consistent with standard measurement guidance for single-item behavioural indicators. Their content and face validity were instead established during pilot testing among 35 parents, assessing clarity, completion time, and response distributions before the main study, with minor wording changes made to locally used terms and they were not included in the final analysis. Measurement consistency for the parallel parent and child-reported toothbrushing items was evaluated empirically through item-level parent—child concordance, which ranged from fair for brushing duration (κ=0.31) to substantial for fluoride-toothpaste use (κ=0.62), providing direct, study-

specific evidence of measurement consistency for these items rather than a classical scale-level coefficient. The sociodemographic and dietary items, which were single-report factual variables without a parallel comparator, relied on face and content validity from pilot testing alone; no reliability coefficient was reported for these items, and this was noted as a limitation.

No new translation of the M-PACTA was undertaken because the Malay version had previously undergone formal cross-cultural adaptation and psychometric evaluation in Malaysian parents. The Malaysian validation included face and content validation, forward and back translation, and exploratory factor analysis. Although its factor structure was not identical to that of the original PACTA, the M-PACTA demonstrated good construct validity, internal consistency (Cronbach's α >0.90 across the reported scales), and test–retest reliability in the Malaysian context [17]. The original PACTA also showed satisfactory reliability for most subscales together with convergent and predictive validity [16]. In the present sample, the internal consistency of each M-PACTA domain was re-estimated via Cronbach's α, with values ≥0.70 interpreted as acceptable. Published Malaysian scoring directions and cut-off values were retained without modification.

To extend accessibility to Malay-speaking respondents, the investigator-developed parent-report questionnaire **(Supplementary File 2: Part IA)** was additionally translated into Malay **(Supplementary File 2: Part IB)**, retaining identical item content and numbering across both language versions so that responses collected using either version map onto the same underlying variables.

Operational definitions of favourable brushing and a dyadic phenotype

For the primary phenotype analysis, a favourable parental brushing pattern required brushing at least twice daily, routine bedtime brushing, and the use of fluoride toothpaste. A favourable child pattern requires the same three behaviours plus regular parental assistance or supervision for children aged 3-5 years or at least active supervision for children aged 6 years. This composite definition was specified before analysis. A sensitivity analysis repeated the primary model in which twice-daily brushing alone was used to define favourable behaviour. Brushing duration and the regular brushing routine item were deliberately not included in this primary composite definition: both showed the lowest parent–child concordance among the behaviours measured **(Table 3)** and were more susceptible to recall imprecision than the binary frequency and product-based items were; thus, they were retained as descriptive and covariate-level indicators rather than as components of the primary exposure classification. For descriptive reporting **(Table 4)**, 'adequate parental supervision/assistance' was defined via the same age-differentiated criterion applied to the favourable child-brushing definition above: regular parental assistance or supervision for children aged 3-5 years, or at least active supervision for children aged 6 years, versus predominantly independent, unsupervised brushing.

Dyads were classified as favourable concordant (FF) when both the parent and child met the favourable definition; parent-favourable/child-unfavourable (FU); parent-unfavourable/child-favourable (UF); or unfavourable concordant (UU) when neither met the favourable definition. Item-level concordance for directly comparable behaviours was estimated via Cohen's kappa; weighted kappa was used for ordinal brushing-duration categories. Agreement was categorised descriptively as fair (κ 0.21-0.40), moderate (κ 0.41-0.60), or substantial (κ 0.61-0.80) [25]. For fluoride-toothpaste use, kappa was calculated among dyads with known fluoride status.

Dietary and dental-care covariates

Potential confounders were selected conceptually rather than solely on univariable statistical significance. High-frequency free-sugar exposure was defined as sugary snacks or drinks on three or more occasions per day outside main meals. Additional covariates included bedtime sweetened drinks, child age and sex, parental education, household income, previous dental attendance, and parental oral health knowledge.

Clinical examination and outcomes

Children were examined in the dental clinic via standard dental-chair operating lights, disposable mouth mirrors, and WHO/CPI probes where needed **(Supplementary File 2: Part III)**. Individual teeth were charted via the FDI two-digit notation system, and caries experience was recorded at the tooth level using the decayed, missing due to caries, and filled primary teeth (dmft) index according to the World Health Organisation diagnostic criteria [26]. ECC was operationalised as dmft>0 for the primary binary analysis. The dmft count and untreated decayed primary teeth (dt) were secondary outcomes.

Examiner calibration

Two examiners completed theoretical training and duplicate examinations on 30 preschool children who were not included in the analytical sample. The inter-examiner agreement for caries status was κ=0.88. Ten percent of the study children were re-examined after 7-14 days; the intra-examiner κ values were 0.91 and 0.89, indicating high reproducibility.

Pilot testing

The questionnaire was piloted with 35 parents attending the clinic on nonstudy days to assess clarity, completion time, and response distributions. Minor wording changes were made to locally used terms. Pilot participants were not included in the analytical sample.

Measures to minimise bias and ensure data quality

Several procedures were specified to strengthen internal validity. Consecutive recruitment was used throughout the study period, and when more than one eligible sibling was present, one child was randomly selected to preserve the independence of observations. Parent and child brushing questions were framed in parallel to support direct dyadic comparison, and the composite favourable/unfavourable phenotype was specified before analysis. Clinical outcomes were measured via standard WHO caries criteria by calibrated examiners, with duplicate examinations used to quantify inter and intra-examiner reproducibility. Potential confounders were selected on conceptual grounds rather than by univariable statistical significance alone.

Data completeness and analytical sample

The analytical dataset was restricted to dyads with a completed clinical examination and sufficient paired parent–child brushing data for phenotype classification. Dyads whose clinical examination could not be completed and questionnaires lacking sufficient paired brushing information were excluded before analysis. For the item-level fluoride toothpaste agreement analysis, responses with unknown or unsure fluoride status were excluded from that specific kappa estimate only.

Statistical analysis

Analyses were conducted via IBM SPSS Statistics version 29.0 and R version 4.5. Continuous variables are summarised as the means (SDs) or medians (IQRs), and categorical variables are summarised as n (%). Across phenotype groups, categorical variables were compared via Chi (χ^2) tests, whereas continuous variables were compared via ANOVA or Kruskal–Wallis tests according to distributional assumptions. Binary logistic regression was used to estimate adjusted odds ratios (aORs) and 95% confidence intervals (CIs) for ECC. The prespecified adjusted model included child age, sex, parental education, household income, high-frequency free-sugar exposure, bedtime sweetened drinks, previous dental attendance, and the M-PACTA knowledge category. The internal consistency of the four M-PACTA domains was evaluated in the study sample via Cronbach's α, with $\alpha \geq 0.70$ considered acceptable. Collinearity was assessed via variance inflation factors, all of which were <2.0. Because dmft counts were over dispersed, negative binomial regression was used, and adjusted incidence rate ratios (IRRs) with 95% CIs were reported. A separate multivariable logistic model was used to examine factors associated with the UU phenotype versus the other three phenotypes combined. All tests were two-sided, and $p<0.05$ was considered statistically significant. The four-level dyadic phenotype was modelled as a categorical exposure rather than as a formal statistical interaction between separately coded parental and child-favourable statuses; the phenotype contrasts reported below can equivalently be interpreted as evidence of a parent-by-child interaction on ECC risk, although a formal interaction term was not separately estimated. The M-PACTA parental strategies and child-behaviour domains were not

entered into the primary ECC and dmft models because of their conceptual overlap with the toothbrushing-behaviour-based phenotype exposure; they were considered only in the secondary model of the UU phenotype itself, where they were treated as candidate parenting-process correlates rather than as adjustment covariates for the primary exposure–outcome association.

Results

Participants and clinical profile

Among the 564 eligible parents–child dyads attending the clinic for a routine dental visit during the study period, 511 (90.6%) consented to participate. For 21 children, the consultation ended before the clinical examination could be completed, and an additional four questionnaires lacked sufficient paired brushing data, leaving 486 dyads for analysis (86.2% of eligible attendees (**Figure 1).** The mean child age was 4.8 (SD 0.9) years, and 248 (51.0%) were boys. Mothers represented 392 (80.7%) participating caregivers, and 288 (59.3%) parents had tertiary education **(Table 1).**

ECC was present in 278 children (57.2%, 95% CI 52.8–61.5). The mean dmft was 3.16 (SD 3.48), the median dmft was 2 (IQR 0–5), and the mean untreated dft was 2.36 (SD 2.86). High-frequency free-sugar exposure was reported for 184 children (37.9%), and 208 (42.8%) had previously visited a dentist.

Parent and child toothbrushing behaviours and concordance

Parents reported brushing at least twice daily in 363/486 dyads (74.7%), compared with 321/486 children (66.0%). Routine bedtime brushing was reported by 382 parents (78.6%) and 306 children (63.0%); fluoride-toothpaste use was reported by 413 parents (85.0%) and 389 children (80.0%) **(Table 2).**

Parental modelling of toothbrushing was also common: 298/486 (61.3%) parents reported that the child usually saw them brushing their own teeth, 197/486 (40.5%) reported brushing together with the child at the same time, and 142/486 (29.2%) reported deliberately demonstrating the correct brushing technique to the child.

Item-level concordance was greatest for fluoride-toothpaste use among dyads with known fluoride status (κ=0.62, 95% CI 0.53-–0.71). Kappa was 0.49 (95% CI 0.41–0.57) for twice-daily brushing, 0.44 (95% CI 0.36–0.52) for bedtime brushing, and 0.43 (95% CI 0.35–0.51) for a regular brushing routine. The weighted kappa coefficient for brushing duration was 0.31 (95% CI 0.24–0.38) **(Table 3).** The internal consistency in the study sample was α=0.84 for M-PACTA child behaviour, 0.88 for parental strategies, 0.81 for attitudes, and 0.79 for knowledge.

Dyadic phenotype and caries

The primary composite classification identified 174 FF dyads (35.8%), 112 FU dyads (23.0%), 76 UF dyads (15.6%), and 124 UU dyads (25.5%). The ECC prevalence differed across groups: 39.1% in FF, 57.1% in FU, 56.6% in UF, and 83.1% in UU dyads (χ^2=57.2, df=3, p<0.001**).** The mean dmft showed a corresponding gradient from 1.65 (SD 2.46) in the FF dyads to 5.55 (SD 3.91) in the UU dyads (p<0.001). Untreated dt and high-frequency sugar exposure also differed across phenotypes **(Table 4 and Figure 2).**

Multivariable associations

According to the fully adjusted logistic model, FU dyads were more likely to have ECC than FF dyads were (aOR 1.82, 95% CI 1.09-3.04; p=0.022). The UF estimate was elevated, but the 95% CI included the null estimate (aOR 1.69, 95% CI 0.96–2.98; p=0.069). Children in UU dyads had substantially higher adjusted odds of ECC (aOR 4.72, 95% CI 2.79–7.98; p<0.001) **(Figure 3).** High-frequency free-sugar exposure (aOR 2.11, 95% CI 1.39–3.19; p<0.001) and lower parental education (aOR 1.58, 95% CI 1.04–2.40; p=0.032) were also independently associated with ECC. Older child age was also independently associated with increased odds of ECC (aOR 1.20 per 1-year increase, 95% CI 1.01–1.43; p=0.040) **(Table 5).**

In the negative binomial analysis, dmft counts remained higher in UU dyads than in FF dyads after adjustment (IRR 2.31, 95% CI 1.77-–3.02; p<0.001). FU dyads also had higher dmft counts (IRR 1.46, 95% CI 1.10–1.95; p=0.009), whereas the UF estimate did not reach conventional statistical significance (IRR 1.32, 95% CI 0.97–1.79; p=0.075). High-frequency free-sugar exposure (IRR 1.48, 95% CI 1.22–1.80; p<0.001), lower parental education (IRR 1.27, 95% CI 1.04–1.55; p=0.019), older child age (IRR 1.12 per 1-year increase, 95% CI 1.04–1.21; p=0.003), and bedtime sweetened drink (IRR 1.24, 95% CI 1.02–1.51; p=0.032) were also independently associated with higher dmft counts **(Table 6).**

In the secondary model for the UU phenotype, unfavourable M-PACTA parental strategies (aOR 2.67, 95% CI 1.67–4.27), unfavourable M-PACTA child behavior (aOR 2.31, 95% CI 1.45–3.68), high-frequency free-sugar exposure (aOR 1.88, 95% CI 1.20–2.95), lower parental education (aOR 1.74, 95% CI 1.10–2.76), and lower household income (aOR 1.61, 95% CI 1.03–2.53) were independently associated with concordantly unfavourable brushing **(Table 7).**

Sensitivity analysis

When favourable behaviour was defined via twice-daily brushing alone, the adjusted association between UU status and ECC remained strong and statistically significant, although somewhat attenuated relative to the primary composite definition (aOR 3.89, 95% CI 2.39–6.33, vs. 4.72 in the primary analysis), indicating some sensitivity of the effect magnitude to the specific operational definition used;

corresponding sensitivity estimates for the FU and UF categories under this alternative definition are not reported here.

Discussion

This dyadic analysis revealed a clear gradient in ECC prevalence and caries burden across parent-child toothbrushing phenotypes. Children in families where both parents and children had unfavourable brushing patterns had the greatest caries burden, whereas those in FF dyads had the lowest burden. After adjustment for age, socioeconomic indicators, sugar exposure, dental attendance, and parental knowledge, UU status remained strongly associated with both ECC presence and dmft count. The FU phenotype also retained an independent association with ECC, suggesting that favourable parental self-care alone may not be sufficient when the child's own routine remains unfavourable.

The observed concordance in twice-daily brushing, bedtime brushing, and a regular brushing routine supports the concept that oral-hygiene behaviours cluster within families. This finding is in accordance with dyadic evidence of parent—child oral health concordance [12], longitudinal evidence of reciprocal caregiver—child toothbrushing influences [13], and recent Australian evidence that mothers' toothbrushing frequency predicts children's toothbrushing frequency during preschool years [14]. The four-group phenotype used here adds a clinically interpretable distinction between concordant and discordant dyads rather than reducing family behaviour to a single correlation coefficient.

The strongest association was observed in UU dyads. When both parent and child have irregular or otherwise unfavourable brushing patterns, the child is likely to receive fewer consistent opportunities for fluoride exposure, bedtime routine reinforcement, and behavioral modelling. Systematic-review evidence supports regular fluoride-toothpaste use and parent-supported brushing [5, 6, 27], whereas international consensus for early education settings supports structured toothbrushing with fluoride toothpaste as a feasible population strategy for ECC prevention [7].

The FU group is particularly informative because the parent met the favourable self-brushing definition, whereas the child did not. This suggests that modelling may need to be translated into active supervision, behavior-management strategies, and routine implementation. Descriptive data on parental modelling in this sample indicate that a majority of parents reported some form of modelling, yet this was not sufficient to guarantee favourable child brushing among FU dyads, which is consistent with video observation evidence that parents themselves often have brushing technique deficits that may limit modelling as a teaching mechanism [28]. This modelling pattern is consistent with cross-cultural evidence: parental oral health literacy and behavior have been linked to preschool children's oral health in China [29], and a social-cognitive-theory-based analysis of school-age children's oral hygiene behaviours identified comparable behavioral determinants [30]. Collett et al. [8] reported that parent behaviour-management skills and parent-led brushing are related to children's oral health, whereas PACTA research has shown that child avoidance/noncompliance, parenting strategies, attitudes, and knowledge contribute to brushing behaviour [16]. Recent Malaysian qualitative evidence similarly describes child

resistance, competing parental responsibilities, inconsistent routines, and limited confidence as barriers to toothbrushing supervision [23].

The UF phenotype provides a complementary perspective: some children maintain a favourable routine despite an unfavourable parental self-brushing pattern. This could reflect another caregiver, structured preschool routines, previous professional advice, sibling influence, or child-specific habit formation. The adjusted UF estimate for ECC was elevated but imprecise and included the null. Accordingly, the present data support an association between parental and child routines but do not imply that parental personal brushing deterministically governs a child's behavior.

Parenting and psychosocial processes offer plausible mechanisms for the observed family patterns. Meta-analytic evidence links parental self-efficacy, attitudes, and intention with preschool oral hygiene behavior [10], and prospective work based on the health action process approach identifies self-efficacy, planning, and action control as predictors of supervised toothbrushing [9, 11]. Studies published more recently have associated maternal attitudes, maternal control, and parenting characteristics with child toothbrushing and caries-related outcomes [19-21]. These findings support the assessment of implementation barriers and parenting processes rather than relying on knowledge provision alone.

The Malaysian context strengthens the relevance of this approach. Khan et al. [22] documented discrepancies between reported and observed brushing among preschool children and reported that multiple brushing parameters contributed to oral health variation. The M-PACTA provides a culturally adapted instrument for Malaysian families [17], with locally derived cut-offs that facilitate interpretation of behavioural domains [18]. In the present study, unfavourable M-PACTA parental strategies and child behavior were independently associated with the UU phenotype, suggesting that the concordance classification captures more than parental knowledge alone. This association should be interpreted with some caution; however, because the M-PACTA parental strategies domain conceptually overlaps with parents' own toothbrushing-related behaviour used to help define the phenotype, the extent to which it reflects a genuinely independent parenting-process pathway, rather than shared measurement content, cannot be fully disentangled from the present data.

High-frequency free sugar exposure was independently associated with both ECC and the UU phenotype. This finding is consistent with contemporary caries risk evidence showing that diet, plaque, socioeconomic conditions, and fluoride-related behaviours act together [3, 4]. The brushing phenotype should therefore be interpreted as a family-level behavioural marker embedded within a wider social and dietary risk system rather than as a complete causal explanation for ECC.

Clinically, the four-group classification may offer a simple framework for family-centred counselling. FF families may require reinforcement and maintenance. FU families may benefit from practical strategies for child resistance, parent completion of brushing, habit cues, and bedtime implementation. UF families could be encouraged to maintain the child's favourable routine while strengthening parental modelling. UU families may require more intensive support addressing both parent and child brushing, fluoride use, sugar frequency, and dental attendance. This finding is consistent with meta-analytic evidence that

supervised toothbrushing produces measurable reductions in caries increment, supporting supervision-focused counselling, particularly for FU and UU families [31]. Such targeting is compatible with risk-based prevention and the broader family-centred direction of current paediatric oral health research [14, 32].

This study has several strengths. The dyadic unit of analysis distinguishes concordance from parent and child behaviours in parallel; caries outcomes are examiner-derived with high inter- and intraexaminer reproducibility; dietary and socioeconomic variables are considered in multivariable models; and parenting processes are measured with a locally validated instrument. The use of logistic and negative binomial regression also allowed separate evaluations of caries presence and cumulative dmft counts.

Several limitations should also be considered. First, the cross-sectional design cannot establish the temporal direction of parent—child behavioural influence, and caries reflects cumulative past exposure, whereas the questionnaire captures current routines. Second, self-reported brushing is vulnerable to recall and social desirability bias; Malaysian evidence indicates that reported and observed behaviours can differ [22]. Third, the composite favourable/unfavourable definition may conceal differences between frequency, fluoride exposure, brushing duration, and brushing quality. Fourth, residual confounding factors, such as unmeasured family routines, parental psychosocial characteristics, and more detailed dietary exposures, may remain. Fifth, demographic or clinical information on families who did not consent or whose clinical examination could not be completed was not systematically collected beyond precluding formal comparison with the analytical sample or assessment of the direction of any resulting response bias. Sixth, whether clinical examiners were blinded to parents' questionnaire responses was not formally documented and cannot be confirmed retrospectively; because dmft scoring relies on largely objective WHO visual/tactile criteria, the scope for differential detection bias is likely limited but cannot be fully excluded. Seventh, several secondary covariate associations and the sensitivity analysis involved multiple statistical comparisons without formal correction, so *p*-values close to the conventional threshold should be interpreted cautiously. Finally, participants were recruited from parent—child dyads already attending a university dental clinic for routine dental care, which may overrepresent families with greater access to dental services and higher oral—health engagement than the general population does; this single-centre, clinic-based sample from Selangor may therefore not represent Malaysian preschool children who do not routinely access dental care, and the direction of any resulting bias in the observed associations cannot be determined from these data.

Prospective studies should test the phenotype over time, incorporate direct observation or objective brushing measures where feasible, and evaluate whether modifying parental routines or family-level behavioural strategies leads to sustained changes in child brushing and caries incidence. Trial evidence indicates that the parental psychosocial profile can moderate the effectiveness of oral hygiene interventions in preschool children [33], and technology-enabled anticipatory guidance with peer support has shown feasibility for empowering parents to prevent ECC [34], illustrating practical avenues for testing family-level strategies prospectively. The longitudinal reciprocity reported by Endrighi et al. [13] and recent evidence that maternal toothbrushing behaviour predicts child brushing frequency during

preschool years [14] provide a further rationale for interventions that treat the household, rather than only the child, as the unit of prevention.

Conclusion

Parent–child toothbrushing behaviours clustered within family routines, and concordantly unfavourable brushing was strongly associated with both ECC prevalence and dmft burden. Favourable parental self-care did not fully offset an unfavourable child brushing pattern. These findings support family-centred assessment of parental modelling, supervision, behaviour-management strategies, fluoride use, and shared routines alongside conventional dietary and socioeconomic risk assessment.

Abbreviations

aOR: adjusted odds ratio;

CI: confidence interval;

CPI: Community Periodontal Index;

dmft: decayed, missing (due to caries), and filled primary teeth;

dt: decayed primary teeth (untreated);

ECC: early childhood caries;

FDI: Fédération Dentaire Internationale (World Dental Federation) two-digit tooth-notation system;

FF: favourable parent/favourable child;

FU: favourable parent/unfavourable child;

UF: unfavourable parent/favourable child;

UU: unfavourable parent/unfavourable child;

IQR: interquartile range; IRR: incidence rate ratio;

M-PACTA: Malay Parenting and Child Tooth Brushing Assessment;

OR: odds ratio;

PACTA: Parenting and Child Tooth Brushing Assessment;

SD: standard deviation;

STROBE: Strengthening the Reporting of Observational Studies in Epidemiology;

WHO: World Health Organisation.

Declarations

Ethics approval and consent to participate

The study received approval from the Institutional Ethics and Review Committee, Lincoln University College (IERC Reference number: LUC/SOD-FR/AP-0126/25) prior to participant recruitment. Written informed consent was obtained from parents or legal guardians before participation, and age-appropriate assent procedures were followed for the participating children. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not Applicable

Availability of data and materials

The dataset analysed during the current study is available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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2. **Jyoti Sharma:** Literature review, methodology, examiner calibration, data collection, data curation, statistical analysis, interpretation of data, writing–original draft, writing–review and editing, and critical revision of the manuscript.

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All the authors have read and approved the final manuscript.

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Tables

Table 1. Characteristics of the analytical sample (N = 486)

Characteristic	Summary
Child age, years, mean (SD)	4.8 (0.9)
Boys, n (%)	248 (51.0)
Girls, n (%)	238 (49.0)
Mother respondent, n (%)	392 (80.7)
Parent tertiary education, n (%)	288 (59.3)
Lower household income category, n (%)	189 (38.9)
High-frequency free-sugar exposure, n (%)	184 (37.9)
Bedtime sweetened drink, n (%)	116 (23.9)
Previous dental visit, n (%)	208 (42.8)
ECC (dmft>0), n (%) [95% CI]	278 (57.2) [52.8-61.5]
dmft, mean (SD); median (IQR)	3.16 (3.48); 2 (0-5)
Untreated dt, mean (SD)	2.36 (2.86)

Abbreviations: SD, standard deviation; CI, confidence interval; ECC, early childhood caries; dmft, decayed, missing (due to caries), and filled primary teeth; dt, decayed primary teeth (untreated).

Table 2. Parent and child toothbrushing behaviours

Behaviour	Parent, n (%)	Child, n (%)	Absolute difference, percentage points
Brushes ≥2 times/day	363 (74.7)	321 (66.0)	8.7
Routine bedtime brushing	382 (78.6)	306 (63.0)	15.6
Brushes ≥2 min	291 (59.9)	213 (43.8)	16.1
Uses fluoride toothpaste	413 (85.0)	389 (80.0)	5.0
Regular brushing routine	398 (81.9)	330 (67.9)	14.0

The values are descriptive paired parent–child reports. The absolute difference is the parent prevalence minus the child prevalence, in percentage points.

Table 3. Item-level parent–child concordance

Behaviour	κ/weighted κ (95% CI)	Agreement
Twice-daily brushing	0.49 (0.41-0.57)	Moderate
Bedtime brushing	0.44 (0.36-0.52)	Moderate
Brushing duration	0.31 (0.24-0.38)	Fair
Fluoride-toothpaste use*	0.62 (0.53-0.71)	Substantial
Regular brushing routine	0.43 (0.35-0.51)	Moderate

Abbreviations: κ, Cohen's kappa; weighted κ was used for ordinal brushing-duration categories. The agreement bands are descriptive (fair, 0.21–0.40; moderate, 0.41–0.60; substantial, 0.61–0.80) [25]. *Dyads with "unsure" fluoride status were excluded from this estimate.

Table 4. Clinical and behavioural characteristics according to dyadic toothbrushing phenotype

Characteristic	FF (n=174)	FU (n=112)	UF (n=76)	UU (n=124)	*p*-value
ECC, n (%) [95% CI]	68 (39.1) [32.1-46.5]	64 (57.1) [47.9-65.9]	43 (56.6) [45.4-67.1]	103 (83.1) [75.5-88.6]	<0.001
dmft, mean (SD)	1.65 (2.46)	3.03 (3.20)	2.92 (3.08)	5.55 (3.91)	<0.001
Untreated dt, mean (SD)	1.11 (1.91)	2.31 (2.61)	2.17 (2.49)	4.29 (3.36)	<0.001
High-frequency free-sugar exposure, n (%)	45 (25.9)	40 (35.7)	29 (38.2)	70 (56.5)	<0.001
Adequate parental supervision/assistance, n (%)	151 (86.8)	54 (48.2)	59 (77.6)	42 (33.9)	<0.001
Favourable M-PACTA parental strategies, n (%)	143 (82.2)	67 (59.8)	47 (61.8)	45 (36.3)	<0.001

Abbreviations: FF, favourable parent/favourable child; FU, favourable parent/unfavourable child; UF, unfavourable parent/favourable child; UU, unfavourable parent/unfavourable child. For categorical comparisons, χ^2 tests were used; for continuous comparisons, prespecified distribution-appropriate group tests (ANOVAs or Kruskal—Wallis tests) were used.

Table 5. Multivariable logistic regression for early childhood caries

Predictor	Adjusted OR	95% CI	*p*-value
FF (reference)	1.00	-	-
FU	1.82	1.09-3.04	0.022
UF	1.69	0.96-2.98	0.069
UU	4.72	2.79-7.98	<0.001
High-frequency free-sugar exposure	2.11	1.39-3.19	<0.001
Lower parental education	1.58	1.04-2.40	0.032
Bedtime sweetened drink	1.52	0.96-2.41	0.074
Previous dental visit	1.21	0.81-1.81	0.352
Child age, per 1-year increase	1.20	1.01-1.43	0.040
Male sex	1.14	0.76-1.70	0.523
Lower household income	1.44	0.95-2.19	0.087
Unfavourable M-PACTA knowledge	1.36	0.91-2.04	0.135

Abbreviations: OR, odds ratio; CI, confidence interval; FF, favourable parent/favourable child; FU, favourable parent/unfavourable child; UF, unfavourable parent/favourable child; UU, unfavourable parent/unfavourable child. Model N=486. FF was the reference phenotype.

Table 6. Negative binomial regression for the dmft count

Predictor	Adjusted IRR	95% CI	*p*-value
FF (reference)	1.00	-	-
FU	1.46	1.10-1.95	0.009
UF	1.32	0.97-1.79	0.075
UU	2.31	1.77-3.02	<0.001
High-frequency free-sugar exposure	1.48	1.22-1.80	<0.001
Lower parental education	1.27	1.04-1.55	0.019
Child age, per 1-year increase	1.12	1.04-1.21	0.003
Male sex	1.08	0.91-1.28	0.377
Lower household income	1.18	0.99-1.40	0.061
Bedtime sweetened drink	1.24	1.02-1.51	0.032
Previous dental visit	1.10	0.93-1.30	0.265
Unfavourable M-PACTA knowledge	1.15	0.97-1.37	0.113

Abbreviations: IRR, incidence rate ratio; CI, confidence interval. N=486. FF was the reference phenotype.

Table 7. Factors associated with the concordantly unfavourable (UU) phenotype

Predictor	Adjusted OR	95% CI	*p*-value
Lower parental education	1.74	1.10-2.76	0.018
Lower household income	1.61	1.03-2.53	0.038
High-frequency free-sugar exposure	1.88	1.20-2.95	0.006
Unfavourable M-PACTA parental strategies	2.67	1.67-4.27	<0.001
Unfavourable M-PACTA child behaviour	2.31	1.45-3.68	<0.001
Unfavourable M-PACTA knowledge	1.43	0.91-2.25	0.121
No previous dental visit	1.36	0.87-2.12	0.177
Child age, per 1-year increase	1.09	0.88-1.34	0.422
Male sex	1.18	0.80-1.75	0.407

Outcome: UU phenotype (n=124) versus FF/FU/UF combined (n=362). The model was additionally adjusted for child age and sex.

Figures

Figure 1 Participant flow diagram.

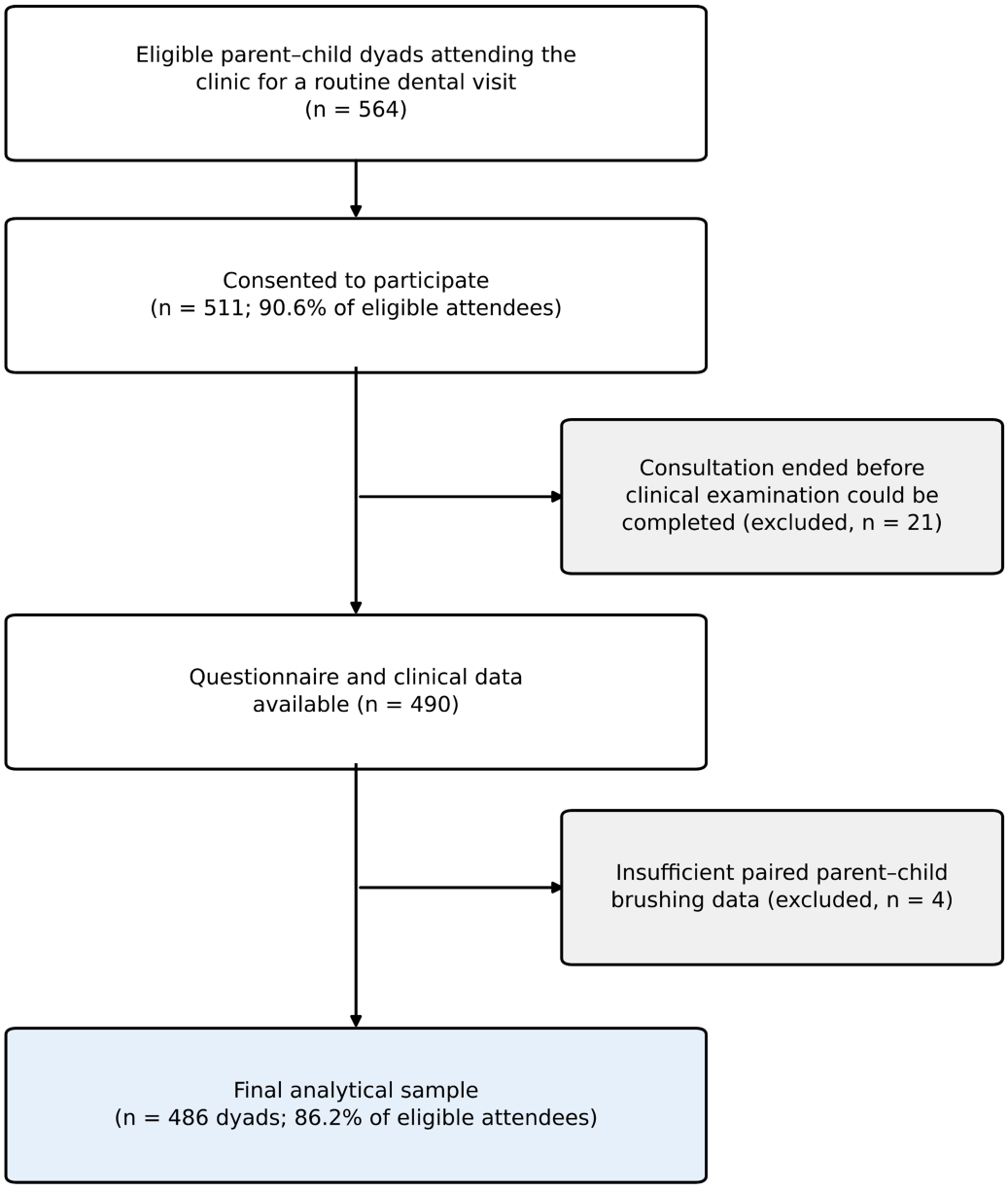
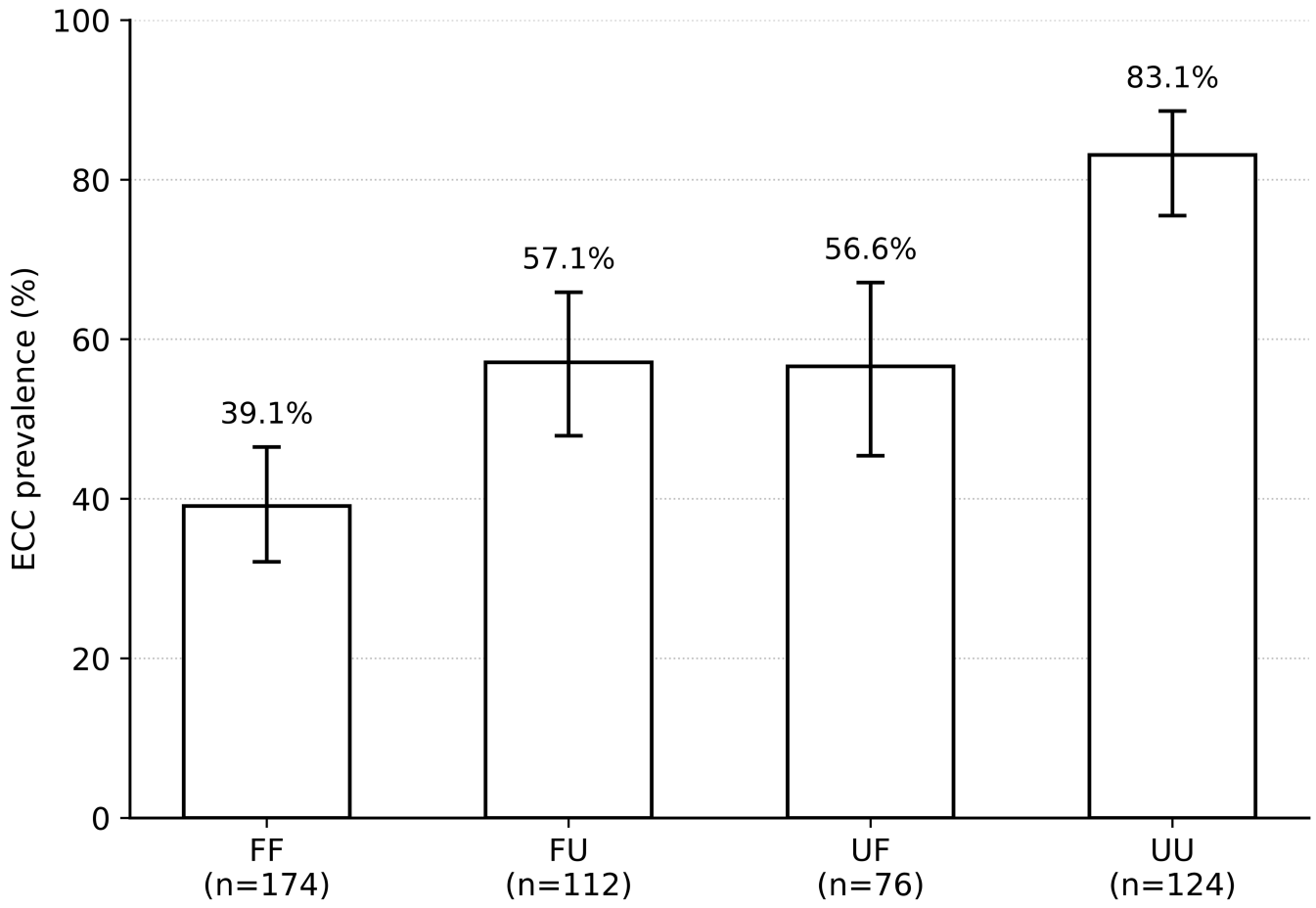


Figure 1

See image above for figure legend

Figure 2 Early childhood caries prevalence by parent–child toothbrushing phenotype, with 95% confidence intervals.

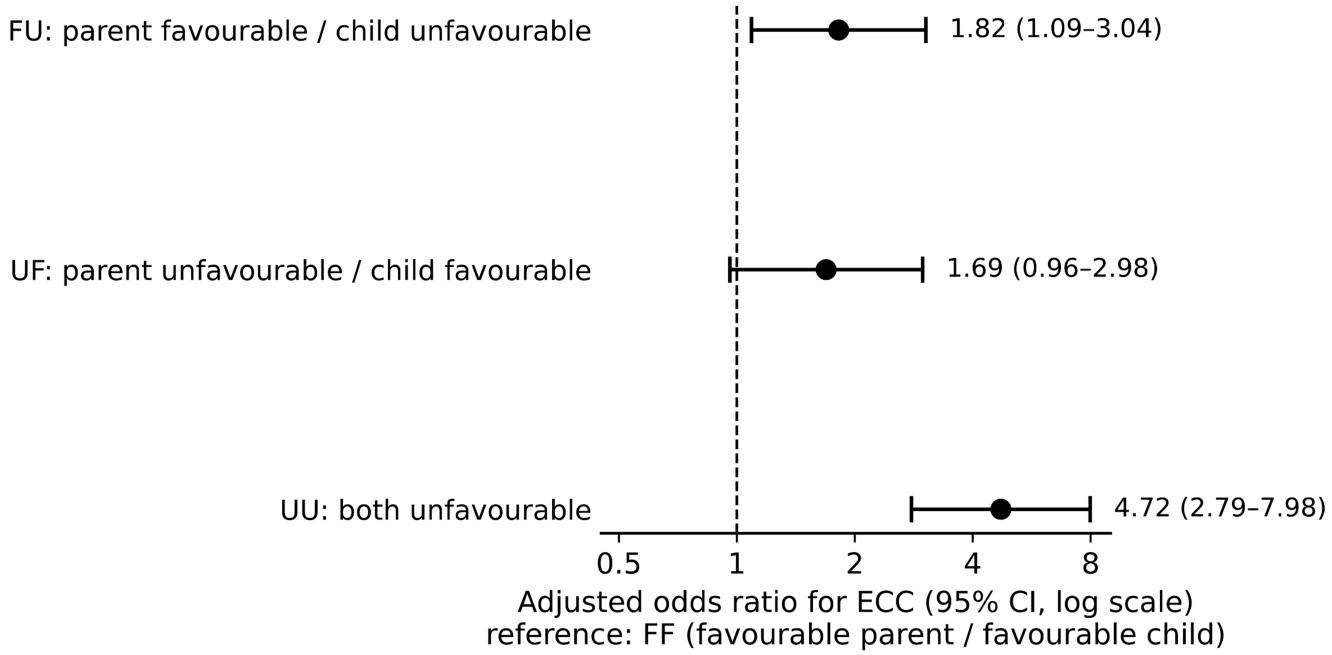


FF, favourable parent/favourable child; FU, favourable parent/unfavourable child; UF, unfavourable parent/favourable child; UU, unfavourable parent/unfavourable child.

Figure 2

See image above for figure legend

Figure 3 Adjusted odds ratios for early childhood caries by dyadic toothbrushing phenotype.



FF is the reference category; error bars indicate 95% confidence intervals.

Figure 3

See image above for figure legend

Supplementary Files

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