

RESEARCH ARTICLE

# Early childhood caries intervention in Aboriginal Australian children: Follow-up at child age 9 years

Xiangqun Ju<sup>1\*</sup>, Joanne Hedges<sup>1</sup>, Dandara Gabriela Haag<sup>1</sup>, Gustavo Hermes Soares<sup>1</sup>, Lisa Gaye Smithers<sup>2</sup>, Lisa M. Jamieson<sup>1</sup>

**1** Australian Research Centre for Population Oral Health (ARCPHO), Adelaide Dental School, University of Adelaide, Adelaide, Australia, **2** School of Health and Society, University of Wollongong, Wollongong, Australia

\* [xiangqun.ju@adelaide.edu.au](mailto:xiangqun.ju@adelaide.edu.au)



## Abstract

### Objective

Dental caries is one of the most common preventable diseases among Indigenous children. The study aimed to estimate the efficacy of an Early Childhood Caries (ECC) intervention among Aboriginal Australian children over 9 years, and to explore potential risk factors associated with dental caries among Indigenous Australian children.

### Methods

Data were from a randomized controlled trial conducted in South Australia, Australia. Four hundred and forty-eight women pregnant with an Aboriginal child were randomly allocated to either an immediate (II) or delayed (DI) intervention group between January 2011 and May 2012. The immediate intervention comprised (1) provision of dental care to mothers during pregnancy; (2) application of fluoride varnish to teeth of children at ages 6, 12; and 18 months; (3) motivational interviewing delivered in conjunction with; and (4) anticipatory guidance. Mothers/children in the DI group received the same intervention commencing at child aged 2 years. Follow-ups occurred when children were aged 2-, 3-, 5-, 7- and 9-years. In this analysis, outcomes were severity of caries experience: mean dmft/DMFT at child aged 9 years. Dependent variables included mothers' baseline and seven years follow-up characteristics (age, education level, source of income, residential location, smoking and alcohol status) and children's birth and feeding, and dental behaviours characteristics (sex, gestation, birth weight, breastfeeding status and sweet food consumption, and frequency of tooth brushing). Multivariable log-Poisson regression models with robust standard error estimation were applied as a statistical model to estimate multivariable relationships

## OPEN ACCESS

**Citation:** Ju X, Hedges J, Haag DG, Soares GH, Smithers LG, Jamieson LM (2025) Early childhood caries intervention in Aboriginal Australian children: Follow-up at child age 9 years. *PLoS One* 20(9): e0317024. <https://doi.org/10.1371/journal.pone.0317024>

**Editor:** Yolanda Malele-Kolisa, University of the Witwatersrand Johannesburg Faculty of Health Sciences, SOUTH AFRICA

**Received:** December 14, 2024

**Accepted:** August 14, 2025

**Published:** September 3, 2025

**Peer Review History:** PLOS recognizes the benefits of transparency in the peer review process; therefore, we enable the publication of all of the content of peer review and author responses alongside final, published articles. The editorial history of this article is available here: <https://doi.org/10.1371/journal.pone.0317024>

**Copyright:** © 2025 Ju et al. This is an open access article distributed under the terms of the [Creative Commons Attribution License](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution,

and reproduction in any medium, provided the original author and source are credited.

**Data availability statement:** The data cannot be shared publicly due to the participants' privacy concerns. Data are available from the University of Adelaide Data Access (contact via Australian Research Centre for Population Oral Health: [arcpoh@adelaide.edu.au](mailto:arcpoh@adelaide.edu.au)) for researchers who meet the criteria for access to confidential data.

**Funding:** This study was funded by the National Health and Medical Research Council of Australia (NHMRC, Project Grant 627350).

**Competing interests:** The authors have declared that no competing interests exist.

of dental caries and other covariates. Risk ratios (RRs) with their 95%CI were calculated. Sensitivity analyses were conducted by using the inverse-probability-of censoring weighting (IPCW) to overcome the loss-follow-up issues.

## Results

Data were available for 367 (II = 180 and DI = 187) children at age 9 years. The mean dmft was 3.41 (95% CI: 2.95–3.87) and DMFT was 0.31(95%CI: 0.22–0.41). In multi-variable modelling, mean dmft was higher (RR = 1.13, 95% CI: 1.01–1.26) among DI children than II children, but there were no significant differences in the permanent dentition. Risk factors for caries severity in both the primary and permanent dentition included lower mothers' education level (<12 years level: dmft; RR = 1.56, 95% CI: 1.31–1.86; and 'Trade or TAFT: DMFT: RR = 3.40, 95%CI: 1.16-9.98). Other risk factors for dental caries experience in the primary dentition included preterm birth, low birth weight, child not breastfed and sugar consumption more than 10%, and in permanent dentition was self-rated 'fair/poor' or 'Good' children's oral health, compared with self-rated 'Excellent/very good' oral health.

## Conclusion

The present study suggests that, within this cohort, initiating an early childhood caries intervention during pregnancy and infancy may be associated with lower caries experience in the primary dentition by age 9 years compared to a later start. Low maternal education level was associated with caries severity in both primary and permanent dentitions. Sugar consumption, a modifiable risk factor, greater than 10% was an important contributor to dental caries in primary teeth.

## Introduction

Dental caries is one of the most common diseases to impact children at a global level; ranked 10<sup>th</sup> and 1<sup>st</sup> for the primary and permanent dentition, respectively [1,2]. The negative impact of dental caries on oral health-related quality of life of children and their parents has been observed [3,4]. These include child experiences of pain, difficulties in chewing and swallowing, difficulties concentrating in school settings and shame, and loss of workdays and/or financial stress relating to accessing dental care for parents. In Australia, national child oral health surveys estimate the prevalence of caries experience to be over 40% among children aged 5–10 years with primary teeth and under 25% among children aged 6–14 years in the permanent dentition [5].

Indigenous Australians are those who identify as being of Aboriginal and/or Torres Strait Islander descent. Aboriginal and Torres Strait Islander children make up 5.9% (an estimated 278,000) of the total child population in Australia [6]. They represent more than one-third of the total Indigenous population (34%). In the 2012–14 National Child Oral Health Survey, Indigenous children had approximately three times higher teeth with untreated decay in children aged 5–10 years (3.5 vs 1.2) and 8–14

years (0.8 vs 0.3), and had nearly two times higher the mean number of decayed, missing or filled tooth surfaces (DMFs/dmfs) in primary (2.9 vs 6.3) and permanent dentitions (0.7 vs 1.3) than their non-Indigenous counterparts [5,7].

Dental caries is a preventable chronic disease with multiple potential contributing factors. Maternal characteristics (including residing in regional and remote areas [8], low education and income, maternal smoking during pregnancy [9,10] and children's birth, feeding and oral health behavior characteristics (including low birthweight and preterm birth, consumption of free sugar food and beverages and brushing teeth less than twice daily [10,11]), have been positively associated with early childhood caries (ECC). ECC is the strongest predictor of dental caries in adulthood [12].

Motivational interviewing (MI) is an effective method [13] to modify knowledge and behaviours, which can be used as a brief intervention to increase motivation to improve people's oral health-related knowledge and behaviours, such as developing a good daily oral hygiene routine, reducing sugar consumption, smoking cessation, and alcohol advice, ultimately reducing the incidence of ECC [14]. However, Batliner and colleagues' study [15] found that MI intervention appeared to improve maternal knowledge but had no effect on oral health behaviors. Previous reports from this long-term study showed that a MI-based intervention was effective in preventing dental caries in the primary dentition of Aboriginal children [16–18]. However, the benefits of the intervention on the permanent dentition have not been tested. This aim of this study was to present data, collected at ages 7 and 9, from the participants of the "Baby Teeth Talk" study; estimate trends over time; test whether the early oral health benefits were sustained over time; and explore potential risk factors associated with dental caries among Indigenous Australian children.

## Methods

### Study design and sample size

The long-term 'Baby Teeth Talk (BTT)' study was an outcome assessor-blinded, closed-cohort cross-in randomized controlled trial (Registration ID: ACTRN12611000111976, the Australian New Zealand Clinical Trials Registry (ANZCTR)) conducted in South Australia, Australia. The BTT study randomly allocated 448 women, pregnant with an Aboriginal child, to either an immediate (II) or delayed (DI) intervention group between January 2011 and May 2012. The detail of how the participants were randomised has been previously reported [18,19]. Study staff were trained in MI by a registered member of the Motivational Interviewing Network of Trainers. They attended a basic two-day MI training course, followed by an intense one-day follow-up course. Monthly one-day follow-up training was continued for six months, followed by bi-monthly one-day coaching, and occasional ad-hoc telephone coaching, for another year [16].

The immediate intervention comprised: (1) provision of dental care to mothers during pregnancy; (2) application of fluoride varnish to teeth of children at ages 6, 12; and 18 months; (3) Multiple sessions of motivational interviewing (fidelity was scrutinised and found to be acceptable) [16] were delivered in conjunction with; (4) anticipatory guidance: in our study, tailored oral health educational packages were compiled with dental-specific information relevant for mothers (focus on dental care provision, pregnancy gingivitis) and for children (focus on first solid foods, caring for infant teeth when they first erupt, tooth brushing and fluoride, avoiding sugar-containing foods and beverages, baby's first dental check-up, eruption of molar teeth). Mothers/children in the DI group received the same intervention at 24, 30 and 36 months. After 36 months, the children were re-examined and had fluoride varnish applied at 5-, 7-, and 9-year-olds (Fig 1).

Ethics approval was obtained from the University of Adelaide Human Research Ethics Committee (H-057–2010), the Aboriginal Health Council of South Australia (04-09-362), the Government of South Australia and the Human Research Ethics Committees of the three participating South Australian birthing hospitals. The study additionally used the Ethical Conduct in Aboriginal and Torres Strait Islander Health Research guidelines to obtain consent. All participants provided written informed consent at each phase of the study. Meanwhile, written informed consent was obtained from the study child's parent, legal guardian, or next of kin to participate in the study.

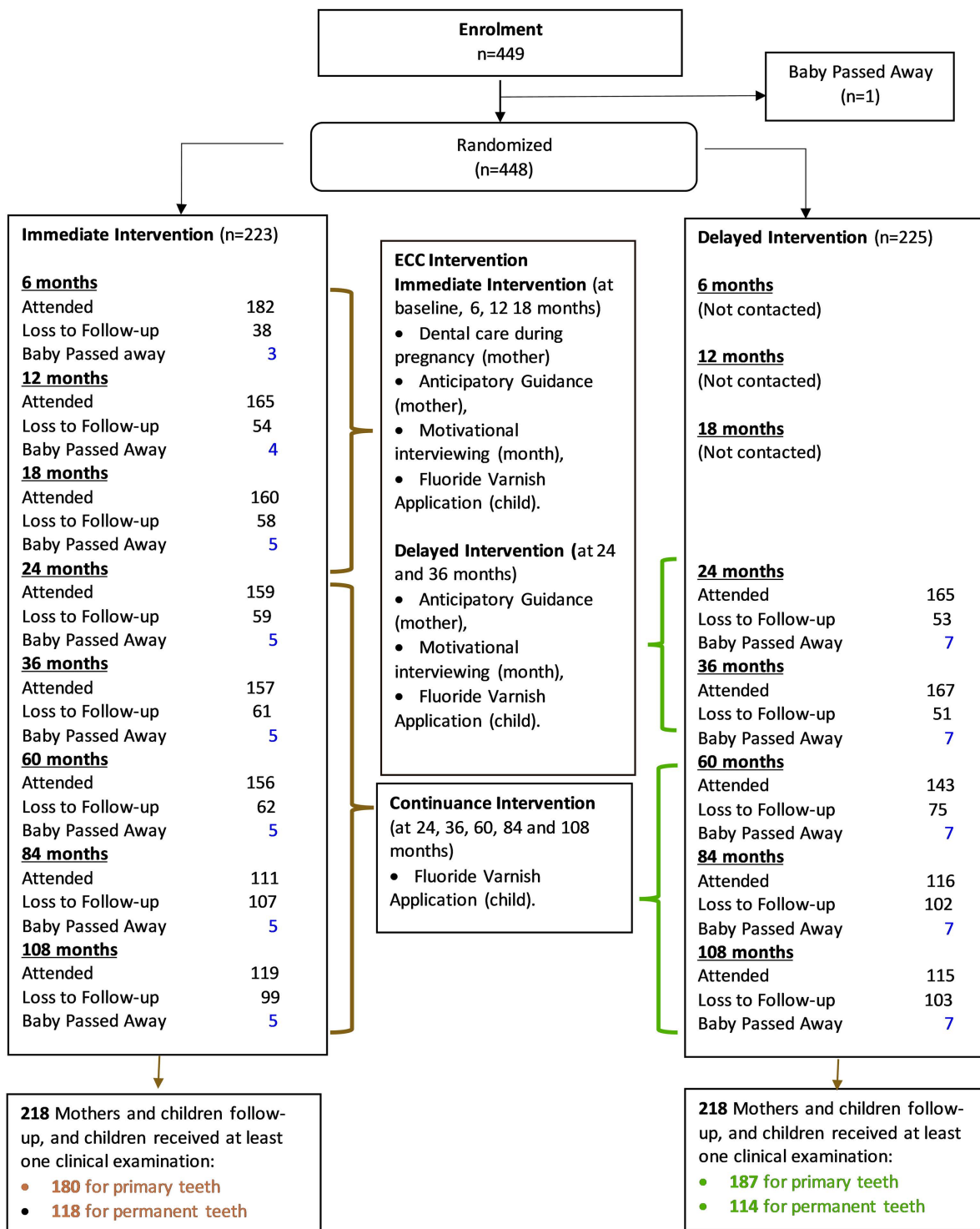


Fig 1. Flow chart of participants through the key stages of the Randomised Clinical Trial.

<https://doi.org/10.1371/journal.pone.0317024.g001>

## Inclusivity in global research

Additional information regarding the ethical, cultural, and scientific considerations specific to inclusivity in global research is included in the Supporting Information (See Inclusivity in global research checklist).

## Data collection

Face-to-face interviews were conducted by experienced researchers, with three calibrated oral health professionals conducting oral examinations for children at ages 2, 3, 5, 7 and 9 years. Intra-class correlations for mean dt between each examiner and the gold standard examiner ranged from 0.80 to 0.88 [16].

## Variables

Outcome variables were severity of caries experience: the mean number of decayed (d/D), missing (m/M) and filled (f/F) teeth, and estimated dmft/ DMFT for primary and permanent dentitions, respectively. Because decayed and filled deciduous teeth were being exfoliated over the study period dmft was treated as an accumulated score – retaining the status of exfoliated teeth.

The exposure variable was early childhood caries (ECC) intervention status, which was identified as either immediate (II) or delayed (DI) group.

Covariates included:

- 1) mothers' baseline characteristics: maternal age, education level, source of income ('Job' or 'Centrelink': Centrelink is the Australian agency providing financial support for those who are unemployed), residential location, and smoking and alcohol status. Child variables included sex, gestational age, birth weight, breastfeeding, free sugar consumption of total energy intake at two years (This variable was calculated using dietary data collected at the 2-year follow-up, based on the average of one 24-hour dietary recall conducted by a trained researcher using a food model booklet, and, where available, up to two additional 24-hour diet diaries. Based on this, the variable was categorised as '<5%', '5%–10%', '11%–15%', or '>15%') [20], and frequency of tooth brushing.
- 2) mothers/primary carers and children's characteristics at seven years follow-up included primary carer's age, education level ('High school or less', 'Trade or TAFE: Technical and Further Education' or 'University'), employed status, source of income, and smoking and alcohol status (The two variables were identified from responses to 'What is your 'Smoking status' and 'What is your Alcohol drinking status'? These were then were categorised as 1) Currently smoke/drink alcohol. 2) Used to smoke/drink alcohol, 3) Have never smoked/drank alcohol). Study child's characteristics included self-rated general and oral health, sugar-sweetened beverage (SSB) consumption of total food intake (the proportion of SSB=(SSB scores/Dietary Guideline Index (DGI) scores)\*100) [21] was derived from dietary data at 7-year follow-up, and was classified '<5%', '5%–10%', '11%–15%', or '>15%', and frequency of tooth brushing.

## Statistical analysis

The analysis began with the computation of univariate statistics describing the frequency and percentage of covariates and associated mean and 95% confidence intervals (CI) of dental caries. The intervention effects were also compared between the II and DI group. Multivariable log-Poisson regression models with robust standard error estimation were then applied as a statistical model to estimate multivariable relationships of dental caries and other covariates (including intervention status, mothers' and children's characteristics). Maternal and child characteristics were assessed at baseline and at the 2-year follow-up for the primary dentition analysis, and at the 7-year follow-up for the permanent dentition analysis. Risk ratios (RRs) with their 95%CI were calculated. The dependent variable of these models was dental caries experience (dmft/DMFT). Unadjusted models (Model 1): bivariate relationships of dental caries and other covariates. Mothers/primary

carers characteristics were entered in Model 2; Children's birth and feeding, dental behavior and free sugar or SSB consumption characteristics were added in Model 3, with the final model (Model 4) comprising all covariates. Sensitivity analyses were conducted by using the inverse-probability-of censoring weighting (IPCW) to overcome the loss-follow-up issues. Under the assumption that data were missing at random (MAR), IPCW was calculated and examined the balance of covariates. Data analyses were performed using SAS statistical software (SAS 9.4, SAS Institute Inc., Cary, NC, USA).

## Results

Of the 448 participants recruited at baseline, 12 babies who died before 2 years follow-up (5 in II and 7 in DI group), 84.2% children had at least one primary teeth and 53.2% received at least one permanent teeth examination at age 9 followed up. There was no difference in followup rates between the intervention groups. (Fig 1). Loss-to-follow-up was tracked, and reason included moving away from the study site, or becoming ill and unable to communicate.

### Dental caries in primary dentition

Mothers' baseline characteristics and children's birth and feeding characteristics at child aged 9 years follow-up is presented in Table 1. A higher proportion of pregnant mothers had an education level <12 years (more than 70%), received support from Centrelink (approximately 85%), were current smokers (50%), resided in non-metropolitan locations (approximately 65%), and used to drink alcohol (80%). A higher proportion of children were normal gestation (92%) and normal birth weight (90%), no breast feeding (58%), free sugar consumption 11% to 15% of total energy intake (56%) and less than twice/per day brushing teeth (71%).

The accumulated caries experience (dmft) trend in primary dentition from child aged 2–9 years is shown in Fig 2. The mean number of dmft increased from 0.77 to 3.41 (a more than 4.4 times increase). The mean number of dmft was higher in DI group (from 0.89 to 3.61) than in II group (from 0.64 to 3.20) at each follow-up time point (Fig 2a), but the growth rate of accumulated dmft was slowed in DI group (110%, 35.7%, 18.6% and 4.6%), compared to the II group (131%, 41.9%, 29.5%, 17.1%) from 2 to 9 years follow-up after receiving ECC intervention in both groups (Fig 2b). Also, the mean dt, mt, ft and dmft was shown in S1 Table.

The associations between dental caries experience (dmft) in the primary dentition and covariates at child aged 9 years are presented in Table 2. Higher mean dmft was observed among children in the DI group, whose mothers were in the younger maternal age group, education level < 12 years, Centrelink as source of income, non-metropolitan residential location, boys, free sugar consumption more than 5% and had low birth weight. After adjusting for all covariates, the mean dmft was 1.16 to 1.80 times higher among children whose mothers at baseline were in the younger maternal age group, had an education level less than 12 years, resided in non-metropolitan locations, used to consume alcohol, children who were preterm, had low birth weight, were not breast fed, had sweet food consumption more than 15% and between 11%–15% than their counterparts consuming less sweet foods/beverages. The mean dmft was 0.73 times lower among children whose mothers at baseline used to smoke tobacco than those who never smoked.

After the IPCW, similar results were observed in both unadjusted and adjusted models (Table 3), except the adjusted full model for people who brushed their teeth less than twice daily had a higher mean dmft than those who brushed their teeth more than twice daily. Also, the associations between untreated decay (dt) and filled teeth (ft) in the primary dentition and baseline covariates at child age 9 years are shown in S2 and S3 Tables.

### Dental caries in permanent dentition

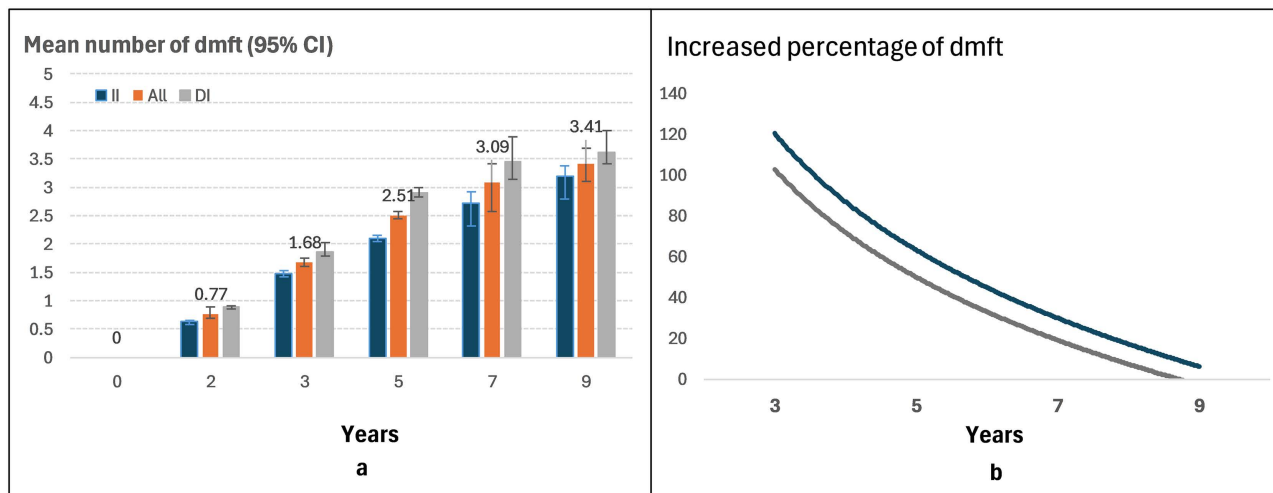
Mothers/primary carers characteristics and children's characteristics at child aged 7 years follow-up is presented in Table 4. At seven years follow-up, a higher proportion of carers were aged less than 30 years (around 35%), 'Trade or TAFE' education level (nearly 45%), not employed (more than 60%) and received support from Centrelink (nearly 65%), and current smokers (more than 45%) and current drink alcohol (approximately 50%); and a higher proportion were children with

**Table 1. Baseline mother-child pairs characteristics by intervention status among Indigenous Australians at 9 years follow-up.**

Baseline characteristics	All (n=367)		II (n=180)		DI (n=187)	
	N	% (95% CI)	N	% (95% CI)	N	% (95% CI)
<b>Mothers' characteristics</b>						
<b>Maternal age</b>						
14-24	194	52.9 (47.7-58.0)	101	56.1 (48.8-63.4)	93	49.7 (42.5-57.0)
25+	173	47.1 (42.0-52.3)	79	43.9 (36.6-51.2)	94	50.3 (43.0-57.5)
<b>Education</b>						
≤12 years	258	70.7 (66.0-75.4)	126	70.8 (64.0-77.5)	132	70.6 (64.0-77.2)
>12 years	107	29.3 (24.6-34.0)	52	29.2 (22.5-36.0)	55	29.4 (22.8-36.0)
<b>Source of Income</b>						
Centrelink	304	83.7 (79.9-87.6)	147	82.6 (77.0-88.2)	157	84.9 (79.7-90.1)
Job	59	16.3 (12.4-20.1)	31	17.4 (11.8-23.0)	28	15.1 (9.9-20.3)
<b>Residential location</b>						
Non-metropolitan	229	63.1 (58.1-68.1)	120	67.0 (60.1-74.0)	109	59.2 (52.1-66.4)
Metropolitan	134	36.9 (31.9-41.9)	59	33.0 (26.0-39.9)	75	40.8 (33.6-47.9)
<b>Smoking status</b>						
Current	175	50.4 (45.1-55.7)	85	49.4 (41.9-57.0)	90	51.4 (44.0-58.9)
Former	86	24.8 (20.2-29.3)	47	27.3 (20.6-34.1)	39	22.3 (16.1-28.5)
Never	86	24.8 (20.2-29.3)	40	23.3 (16.9-29.6)	46	26.3 (19.7-32.9)
<b>Alcohol status</b>						
Current	35	10.1 (6.9-13.3)	19	11.0 (6.3-15.8)	16	9.1 (4.8-13.5)
Used	280	80.7 (76.5-84.9)	137	79.7 (73.6-85.7)	143	81.7 (75.9-87.5)
Never	32	9.2 (6.2-12.3)	16	9.3 (4.9-13.7)	16	9.1 (4.8-13.5)
<b>Children's characteristics</b>						
<b>Sex</b>						
Male	194	53.9 (48.7-59.1)	95	54.0 (46.5-61.4)	99	53.8 (46.5-61.1)
Female	166	46.1 (40.9-51.3)	81	46.0 (38.6-53.5)	85	46.2 (38.9-53.5)
<b>Gestation</b>						
Preterm	24	7.6 (4.7-10.6)	15	10.0 (5.1-14.9)	9	5.5 (2.0-9.0)
Normal	290	92.4 (89.4-95.3)	135	90.0 (85.1-94.9)	155	94.5 (91.0-98.0)
<b>Baby birth weight</b>						
Low	27	9.7 (6.2-13.3)	15	11.4 (5.9-16.8)	12	8.3 (3.7-12.8)
Normal	250	90.3 (86.7-93.8)	117	88.6 (83.2-94.1)	133	91.7 (87.1-96.3)
<b>Breast feeding</b>						
No	197	57.9 (52.7-63.2)	94	57.3 (49.7-65.0)	103	58.5 (51.2-65.9)
Yes	143	42.1 (36.8-47.3)	70	42.7 (35.0-50.3)	73	41.5 (34.1-48.8)
<b>Free sugar consumption of total energy intake</b>						
> 15%	35	13.5 (9.3-17.6)	16	11.9 (6.4-17.5)	19	15.1 (8.7-21.4)
11%–15%	145	55.8 (49.7-61.8)	77	57.5 (49.0-65.9)	68	54.0 (45.1-62.8)
5%–10%	62	23.8 (18.6-29.1)	31	23.1 (15.9-30.4)	31	24.6 (17.0-32.2)
< 5%	18	6.9 (3.8-10.0)	10	7.5 (3.0-12.0)	8	6.3 (2.0-10.7)
<b>Tooth brushing</b>						
< 2/day	210	71.2 (66.0-76.4)	103	70.5 (63.1-78.0)	107	71.8 (64.5-79.1)
≥ 2/day	85	28.8 (23.6-34.0)	43	29.5 (22.0-36.9)	42	28.2 (20.9-35.5)

Notes: II: Immediate intervention, DI: delayed intervention.

<https://doi.org/10.1371/journal.pone.0317024.t001>



**Fig 2. Mean and increased percentage of caries experience (dmft) in primary dentition by Immediate intervention (II) and delayed intervention (DI) groups between child ages 2 and 9 years.**

<https://doi.org/10.1371/journal.pone.0317024.g002>

self-rated excellent/very good general health (nearly 80%) and oral health (approximately 60%), SSB consumption 11% to 15% of total food intake (nearly 40%), and less than twice/per day brushing teeth (around 60%). A similar pattern was observed in both II and DI groups.

The accumulated caries experience (DMFT) trend in the permanent dentition from children aged 7–9 years is shown in [Fig 3](#). The mean number of DMFT from the age of 7–9 years increased from 0.13 to 0.31 (a more than 2 times increase). The mean number of DMFT was higher (0.14) at 7 years but was lower (0.30) at 9 years in DI group, compared with II group (0.12 and 0.33, respectively) ([Fig 3a](#)), and the growth rate of accumulated DMFT was slowed in DI group (11.4%) than in II group (17.5%) from 7 years to 9 years follow-up ([Fig 3b](#)). Also, the mean DT, MT, FT and DMFT was shown in [S1 Table](#).

The association between dental caries experience in permanent dentition (DMFT) and covariates in children aged 7–9 years is presented in [Table 5](#). Higher mean DMFT was observed among children whose primary carers had ‘Trade or TAFE’ education, self-rated ‘Good’ general health and ‘Fair/poor’ and ‘Good’ oral health and brushing less than twice times daily; and lower mean DMFT were among children whose primary carer was not employed, received support from Centrelink and consumed SSB being 11% to 15% of total food intake. After adjusting for all covariates, the mean DMFT was more than 3 times higher among children whose primary carers had ‘Trade or TAFE’ education than those had ‘University’ education; 2–3 times higher among children who self-rated oral health were ‘Fair/poor’ and ‘Good’ than those with ‘Excellent/very good’ self-rated oral health; and nearly 2 times higher among children who brushed their teeth less than twice daily than those brushing twice or more times daily. After the IPCW, the similar results were observed in both unadjusted and adjusted models ([Table 6](#)), except crude model for people who brushed their teeth less than twice daily had higher the mean DMFT (RR = 1.93, 95% CI: 1.10–3.40) than those brushed their teeth more than twice daily. Also, the associations between dental caries experience (DMFT), untreated decay (DT) and filled teeth (FT) in the permanent dentition and baseline covariates at child aged 9 years are shown in [S4–S6 Tables](#), and sensitivity analysis of association between DMFT and baseline mother-child pairs characterisers is presented in [S7 table](#).

## Discussion

Our study showed that the ECC intervention delivered in early childhood had an effect on reducing dental caries experience in the primary dentition, but not the permanent dentition at child aged 9 years. Low maternal education level was

**Table 2. Models for the mean number of dmft at 9 years follow-up (RR, 95% CI).**

	<b>Model 1</b>	<b>Model 2</b>	<b>Model 3</b>	<b>Model 4</b>
	<b>RR (95% CI)</b>	<b>RR (95% CI)</b>	<b>RR (95% CI)</b>	<b>RR (95% CI)</b>
<b>Intervention group</b>				
DI	*1.13 (1.01-1.26)	*1.19 (1.06-1.34)	1.07 (0.93-1.23)	1.11 (0.97-1.28)
II	ref	ref	ref	ref
<b>Mothers' characteristics at baseline</b>				
<b>Maternal age</b>				
14-24	*1.16 (1.03-1.30)	1.02 (0.91-1.16)		*1.16 (1.00-1.35)
25+	ref	ref		
<b>Education level</b>				
≤12 years	***1.62 (1.41-1.86)	**1.57 (1.35-1.82)		**1.56 (1.31-1.86)
>12 years	ref	ref		ref
<b>Source of Income</b>				
Centrelink	**1.34 (1.13-1.59)	1.07 (0.89-1.29)		0.97 (0.80-1.19)
Job	ref	ref		ref
<b>Residential location</b>				
Non-metropolitan	**1.61 (1.42-1.83)	**1.63 (1.43-1.86)		***1.84 (1.57-2.16)
Metropolitan	ref	ref		ref
<b>Smoking status</b>				
Current	0.97 (0.85-1.11)	0.95 (0.82-1.10)		0.82 (0.69-1.02)
Former	*0.71 (0.60-0.85)	*0.77 (0.65-0.92)		*0.73 (0.60-0.89)
Never	ref	ref		ref
<b>Alcohol status</b>				
Current	0.71 (0.55-1.08)	1.05 (0.86-1.28)		1.18 (0.89-1.57)
Used	*0.72 (0.60-0.85)	1.28 (0.99-1.66)		1.45 (1.02-2.05)
Never	ref	ref		ref
<b>Children's characteristics</b>				
<b>Sex</b>				
Male	*1.12 (1.01-1.24)		1.06 (0.92-1.22)	1.12 (0.97-1.30)
Female	ref		ref	ref
<b>Gestation</b>				
Preterm	1.01 (0.80-1.28))		1.11 (0.81-1.54)	*1.45 (1.02-2.05)
Normal	ref		ref	ref
<b>Baby birth weight</b>				
Low	**1.56 (1.19-2.05)		*1.50 (1.13-2.09)	*1.35 (1.02-1.86)
Normal	ref		ref	ref
<b>Breast feeding</b>				
No	1.02 (0.90-1.14)		0.99 (0.86-1.14)	*1.32 (1.01-1.78)
Yes	ref		ref	ref
<b>Free sugar consumption of total energy intake</b>				
> 15%	**1.53 (1.13-2.08)		*1.52 (1.07-2.18)	**1.39 (1.15-3.71)
11%–15%	**1.49 (1.17-1.89)		*1.34 (1.02-1.76)	*1.25 (1.08-1.66)
5%–10%	*1.28 (1.03-1.60)		1.16 (0.91-1.49)	1.16 (0.90-1.50)
< 5%	ref		ref	ref
<b>Tooth brushing</b>				
< 2/day	1.09 (0.95-1.25)		*1.25 (1.04-1.51)	1.16 (0.96-1.40)
≥ 2/day	ref		ref	ref

Notes: RR: risk ratio, II: Immediate intervention, DI: delayed intervention; \*P<0.05, \*\*P<0.01, \*\*\*P<0.001.

Model 1: unadjusted model; Model 2: Adjusted for mothers/primary carers' characteristics; Model 3: adjusted for children's birth and feeding, dental behavior and free sugar consumption characteristics; Model 4: Full model, adjusting for all covariates.

<https://doi.org/10.1371/journal.pone.0317024.t002>

**Table 3. Models using IPCW for the mean number of dmft at 9 years follow-up (RR, 95% CI).**

	<b>Model 1</b> RR (95% CI)	<b>Model 2</b> RR (95% CI)	<b>Model 3</b> RR (95% CI)	<b>Model 4</b> RR (95% CI)
<b>Intervention group</b>				
DI	*1.13 (1.02-1.25)	*1.20 (1.08-1.33)	1.04 (0.90-1.21)	1.04 (0.90-1.21)
II	ref	ref	ref	ref
<b>Mothers' characteristics</b>				
<b>Maternal age</b>				
14-24	**1.17 (1.06-1.30)	1.03 (0.92-1.15)		1.08 (0.92-1.26)
25+	ref	ref		
<b>Education level</b>				
≤12 years	***1.67 (1.46-1.90)	**1.60 (1.39-1.84)		**1.45 (1.21-1.75)
>12 years	ref	ref		ref
<b>Source of Income</b>				
Centrelink	**1.37 (1.16-1.62)	1.09 (0.91-1.31)		0.92 (0.75-1.12)
Job	ref	ref		ref
<b>Residential location</b>				
Non-metropolitan	***1.59 (1.42-1.78)	**1.60 (1.42-1.80)		***1.62 (1.38-1.92)
Metropolitan	ref	ref		ref
<b>Smoking status</b>				
Current	0.97 (0.86-1.10)	0.95 (0.83-1.09)		0.98 (0.82-1.18)
Former	*0.73 (0.63-0.86)	*0.79 (0.67-0.93)		*0.76 (0.62-0.95)
Never	ref	ref		ref
<b>Alcohol status</b>				
Current	0.73 (0.58-1.02)	0.80 (0.63-1.01)		0.43 (0.29-1.64)
Used	*0.73 (0.62-0.85)	*0.82 (0.69-0.97)		*0.72 (0.56-0.91)
Never	ref	ref		ref
<b>Children's characteristics</b>				
<b>Sex</b>				
Male	*1.11 (1.04-1.23)		0.92 (0.79-1.07)	0.91 (0.78-1.06)
Female	ref		ref	ref
<b>Gestation</b>				
Preterm	1.02 (0.83-1.27)		1.14 (0.82-1.58)	*1.26 (1.01-1.75)
Normal	ref		ref	ref
<b>Baby birth weight</b>				
Low	**1.60 (1.25-2.05)		1.28 (0.97-1.70)	1.02 (0.75-1.37)
Normal	ref		ref	ref
<b>Breast feeding</b>				
No	0.99 (0.89-1.11)		0.83 (0.72-1.02)	*1.19 (1.02-1.39)
Yes	ref		ref	ref
<b>Free sugar consumption of total energy intake</b>				
> 15%	**1.54 (1.17-2.04)		**1.50 (1.09-2.08)	*1.27 (1.05-1.64)
11%–15%	**1.51 (1.22-1.87)		*1.37 (1.07-1.75)	*1.14 (1.09-1.43)
5%–10%	*1.27 (1.04-1.55)		1.13 (0.90-1.41)	1.12 (0.80-1.58)
< 5%	ref		ref	ref
<b>Tooth brushing</b>				
< 2/day	1.10 (0.97-1.25)		**1.34 (1.13-1.58)	*1.22 (1.02-1.45)
≥ 2/day	ref		ref	ref

Notes: RR: risk ratio, IPCW: the inverse-probability-of-censoring weighting, II: Immediate intervention, DI: delayed intervention, \*P<0.05, \*\*P<0.01, \*\*\*P<0.001.

Model 1: unadjusted model; Model 2: Adjusted for mothers/primary carers' characteristics; Model 3: adjusted for children's birth and feeding, dental behaviour and free sugar consumption characteristics; Model 4: Full model, adjusted for all covariates.

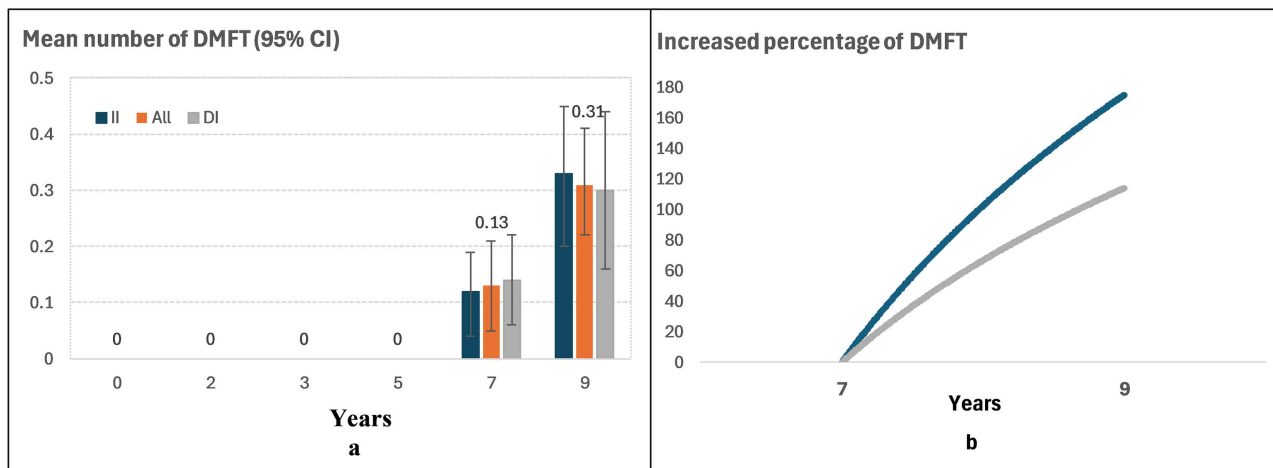
<https://doi.org/10.1371/journal.pone.0317024.t003>

**Table 4. Primary carer-child pairs characteristics at seven years follow-up by intervention status among Indigenous Australians.**

	All (n=232)		II (n=118)		DI (n=114)	
	N	% (95% CI)	N	% (95% CI)	N	% (95% CI)
<b>Primary carers characteristics at seven-year follow-up</b>						
<b>Primary carers' age (years)</b>						
< 30	78	33.6 (27.5-39.7)	33	28.0 (19.7-36.2)	45	39.5 (30.4-48.6)
30-34	56	24.1 (18.6-29.7)	33	28.0 (19.7-36.2)	23	20.2 (12.7-27.7)
35-39	48	20.7 (15.4-25.9)	22	18.6 (11.5-25.8)	26	22.8 (15.0-30.6)
≥ 40	50	21.6 (16.2-26.9)	30	25.4 (17.5-33.4)	20	17.5 (10.5-24.6)
<b>Education level</b>						
High school or less	92	39.7 (33.3-46.0)	43	36.4 (27.6-45.3)	49	43.0 (30.4-48.6)
Trade or TAFE	104	44.8 (38.4-51.3)	58	49.2 (40.0-58.3)	46	40.4 (31.2-49.5)
University	36	15.5 (10.8-20.2)	17	14.4 (8.0-20.8)	19	16.7 (9.7-23.6)
<b>Employed status</b>						
No	141	61.0 (54.7-67.4)	71	60.2 (51.2-69.1)	70	61.9 (52.9-71.0)
Yes	90	39.0 (32.6-45.3)	47	39.8 (30.9-48.8)	43	38.1 (29.0-47.1)
<b>Source of Income</b>						
Centrelink	147	63.4 (57.1-69.6)	73	61.9 (53.0-70.8)	74	64.9 (56.0-73.8)
Job	85	36.6 (30.4-42.9)	45	38.1 (29.2-47.0)	40	35.1 (26.2-44.0)
<b>Smoking status</b>						
Current	107	46.3 (39.8-52.8)	61	52.1 (43.0-61.3)	46	40.4 (31.2-49.5)
Former	63	27.3 (21.5-33.1)	31	26.5 (18.4-34.6)	32	28.1 (19.7-36.4)
Never	61	26.4 (20.7-32.1)	25	21.4 (13.8-28.9)	36	31.6 (22.9-40.2)
<b>Alcohol status</b>						
Current	112	48.5 (42.0-55.0)	64	54.7 (45.5-63.9)	48	42.1 (32.9-51.3)
Used	102	44.2 (37.7-50.6)	46	39.3 (30.3-48.3)	56	49.1 (39.8-58.4)
Never	17	7.4 (4.0-10.8)	7	6.0 (1.6-10.3)	10	8.8 (3.5-14.0)
<b>Children's characteristics</b>						
<b>Sex</b>						
Male	131	56.5 (50.0-62.9)	66	55.9 (46.8-65.0)	65	57.0 (47.8-66.2)
Female	101	43.5 (37.1-50.0)	52	44.1 (35.0-53.2)	49	43.0 (33.8-52.2)
<b>Self-rated general health</b>						
Fair/poor	4	1.7 (0.0-3.4)	3	2.6 (0.0-5.5)	1	0.9 (0.0-2.6)
Good	45	19.5 (14.3-24.6)	20	17.1 (10.2-24.0)	25	21.9 (14.2-29.6)
Excellent/very good	182	78.8 (73.5-84.1)	94	80.3 (73.0-87.7)	88	77.2 (69.4-85.0)
<b>Self-rated oral health</b>						
Fair/poor	27	11.7 (7.5-15.9)	12	10.3 (4.7-15.8)	15	13.2 (6.9-19.5)
Good	68	29.4 (23.5-35.4)	35	29.9 (21.5-38.3)	33	28.9 (20.5-37.4)
Excellent/very good	136	58.9 (52.5-65.3)	70	59.8 (50.8-68.8)	66	57.9 (48.7-67.1)
<b>% SSB consumption of total DGI at seven years follow-up</b>						
> 15%	55	24.6 (18.9-30.2)	28	24.1 (16.2-32.0)	27	25.0 (16.7-33.3)
11%–15%	86	38.4 (32.0-44.8)	44	37.9 (29.0-46.9)	42	38.9 (29.5-48.2)
5%–10%	26	11.6 (7.4-15.8)	14	12.1 (6.1-18.1)	12	11.1 (5.1-17.1)
< 5%	57	25.4 (19.7-31.2)	30	25.9 (17.8-34.0)	27	25.0 (16.7-33.3)
<b>Tooth brushing</b>						
< 2/day	127	58.3 (51.7-64.9)	64	57.1 (47.8-66.5)	63	59.4 (49.9-68.9)
≥ 2/day	91	41.7 (35.1-48.3)	48	42.9 (33.5-52.2)	43	40.6 (31.1-50.1)

Notes: II: Immediate intervention, DI: delayed intervention. SSB: Sugar-sweetened beverage; DGI: Dietary Guideline Index

<https://doi.org/10.1371/journal.pone.0317024.t004>



**Fig 3. Mean and increased percentage of caries experience (DMFT) by Immediate intervention (II) and delayed intervention (DI) groups between children aged 7 and 9 years.**

<https://doi.org/10.1371/journal.pone.0317024.g003>

associated with caries severity in both primary and permanent dentitions. Free sugar consumption greater than 10% was an important contributor to dental caries in primary teeth, a modifiable risk factor.

The findings revealed that the mean dmft at child aged 9 years (3.41) was higher among Indigenous South Australian children in our study than non-Indigenous Australian children (2.29), but lower than Indigenous Australian children at a national level (3.66) [22]. The mean DMFT (0.31) for children in our study at age 9 years was lower than both Indigenous (1.13) and non-Indigenous (0.61) Australian children aged 9 years [22], and a similar MI intervention effect was reported in another RCT study [23]. These findings indicate that the ECC intervention, which was community co-designed and culturally safe, may reduce dental caries in both the primary and permanent dentitions (although the permanent dentition was very similar across both II and DI group, even higher DMFT score was in II group (0.14) than in DI group (0.12)) in comparison to standard care. This is possibly because both II and DI groups received motivational interviewing at a very early stage, which provided not only increased motivation to improve parents' and children's oral hygiene behaviours, but also a framework for delivering diet, smoking cessation, and continuous use of fluoride varnish [24], results in reducing children's dental caries experience in both deciduous and permanent teeth. The high prevalence of missing teeth in the primary dentition [17], primarily due to early extractions from severe caries rather than natural exfoliation, contributed to the premature eruption of permanent teeth, thereby increasing the risk of dental caries in the permanent dentition. In addition, other clinical, sociodemographic and dental health-related behaviours factors, such as a higher prevalence of untreated caries in the primary teeth, lower family socioeconomic status, higher free sugar consumption, poor dental hygiene and irregular dental visits, are associated with caries incidence in the permanent dentition [25]. This result also reflects, from another perspective, that intervention for dental caries should be long-term and continuous to maintain its effectiveness.

This study is unique in global literature as this work is very hard to do by using culturally relevant ECC intervention involving MI among Indigenous Australians; and a randomised controlled trial design with substantial follow-up enabled not only the intervention effect to be estimated at child aged 9 years, but also the calculation of the time trend on dental caries of both primary and permanent dentitions; sensitivity analyses using IPCW to ensure unbiased estimation, although there were missing values in our study. Study limitations included not estimating time (age) when children were first introduced to free sugar and the number of cigarettes smoked by mothers during pregnancy [17].

**Table 5. Models for the mean number of DMFT at 9 years follow-up (RR, 95% CI).**

	Model 1	Model 2	Model 3	Model 4
	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
<b>Intervention group</b>				
DI	0.78 (0.49-1.23)	0.89 (0.54-1.43)	0.78 (0.48-1.27)	0.88 (0.52-1.49)
II	ref	ref	ref	ref
<b>Primary carers' characteristics at seven years follow-up</b>				
<b>Primary carers' age (years)</b>				
< 30	1.08 (0.61-1.93)	1.15 (0.63-2.09)		1.28 (0.67-2.45)
30-34	0.45 (0.20-1.01)	*0.40 (0.18-0.91)		0.47 (0.19-1.15)
35-39	0.97 (0.49-1.90)	0.85 (0.43-1.70)		1.16 (0.55-2.48)
≥ 40	ref	ref		ref
<b>Education level</b>				
High school or less	2.46 (0.86-7.04)	**3.08 (1.04-9.17)		2.41 (0.77-7.59)
Trade or TAFE	***3.67 (1.32-10.2)	***3.71 (1.32-10.48)		**3.40 (1.16-9.98)
University	ref	ref		ref
<b>Employed status</b>				
No	*0.47 (0.29-0.75)	*0.35 (0.17-0.74)		0.44 (0.19-1.05)
Yes	ref	ref		ref
<b>Source of Income</b>				
Centrelink	*0.58 (0.37-0.91)	1.01 (0.51-2.00)		0.95 (0.43-2.09)
Job	ref	ref		ref
<b>Smoking status</b>				
Current	1.70 (0.91-3.18)	*1.94 (1.00-3.77)		1.49 (0.75-2.98)
Former	1.51 (0.76-3.01)	1.60 (0.78-3.30)		1.36 (0.63-2.93)
Never	ref	ref		ref
<b>Alcohol status</b>				
Current	1.91 (0.59-6.17)	1.39 (0.42-4.63)		1.16 (0.33-4.04)
Used	1.71 (0.52-5.57)	1.68 (0.50-5.59)		1.36 (0.39-4.77)
Never	ref	ref		ref
<b>Children's characteristics</b>				
<b>Sex</b>				
Male	0.66 (0.42-1.05)		*0.52 (0.30-0.88)	0.64 (0.36-1.12)
Female	ref		ref	ref
<b>Self-rated general health</b>				
Fair/poor	2.37 (0.58-9.75)		1.76 (0.38-8.14)	0.77 (0.15-3.92)
Good	*1.70 (1.02-2.83)		1.15 (0.64-2.05)	1.05 (0.57-1.95)
Excellent/very good	ref		ref	ref
<b>Self-rated oral health</b>				
Fair/poor	**3.00 (1.65-5.46)		**3.82 (1.85-7.89)	**2.86 (1.35-6.04)
Good	**1.88 (1.11-3.17)		*1.78 (1.00-3.18)	*1.86 (1.01-3.44)
Excellent/very good	ref		ref	ref
<b>% SSB consumption of total DGI at seven years follow-up</b>				
> 15%	0.91 (0.51-1.63)		1.20 (0.62-2.31)	1.03 (0.52-2.05)
11%–15%	*0.45 (0.24-0.85)		0.83 (0.40-1.69)	0.61 (0.28-1.30)
5%–10%	1.08 (0.53-2.15)		1.82 (0.84-3.96)	1.28 (0.56-2.95)

(Continued)

**Table 5.** (Continued)

	Model 1	Model 2	Model 3	Model 4
	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
< 5%	ref		ref	ref
<b>Tooth brushing</b>				
< 2/day	**2.49 (1.43-4.34)		*1.84 (1.01-3.33)	1.77 (0.96-3.24)
≥ 2/day	ref		ref	ref

Notes: RR: risk ratio, II: Immediate intervention, DI: delayed intervention; \*P<0.05, \*\*P<0.01, \*\*\*P<0.001. SSB: Sugar-sweetened beverage, DGI: Dietary Guideline Index.

Model 1: unadjusted model; Model 2: Adjusted for mothers/primary carers' characteristics; Model 3: adjusted for children's birth and feeding, dental behavior and SSB characteristics; Model 4: Full model, adjusted for all covariates.

<https://doi.org/10.1371/journal.pone.0317024.t005>

### Maternal education level and children's dental caries

Maternal education is an important predictor of child dental caries, with findings from our study replicating previous investigations [26,27]. Low education is associated with low oral health literacy and knowledge, which in turn impacts understanding of the risk factors and behaviours related to dental caries, such as smoking, high consumption of sweet foods, irregular dental visiting and infrequent tooth brushing. Carer education level is positively associated with employment status and family income. Children from low- income families often have poor nutrition and foods that are high in free sugar or SBB [28], which predisposes children to development of dental caries. Level of education is highly correlated to residential location [29]. Higher educational attainment is less common among Indigenous adults residing in regional and remote areas [8] due to lack of quality education resources and limited access to education services (such as libraries and information technology).

### Sweet food intake and dental caries

Sugar consumption is one of the main causes of dental caries, both quantity (dose-response relationship) [2,30] and child ages when sugar consumption is initiated. Evidence shows that children with an early introduction to sugar (<12 months) had 1.5 times higher dental caries experience and untreated dental caries than children introduced to sugar at an older age (after 24 months) [31]. Sugar consumption before bedtime particularly increases the risk of caries [32]. This is due to reduced saliva flow and sustained low plaque pH later in the day, leading to erosion of tooth enamel and greater susceptibility to dental caries. Our findings support the World Health Organization (WHO) [33] recommendation of reducing the level of free sugar consumption to less than 5% –10% of total energy intake per day to prevent dental caries.

### Maternal smoking and children's caries

Evidence demonstrates that maternal smoking during pregnancy is significantly associated with dental caries in children [34,35] and is dose-related (children whose mothers smoked during pregnancy more than half pack/day were more likely to develop dental caries) [36]. One possible mechanism is that tobacco smoking affects the formation or mineralization of the primary teeth [37]. Maternal smoking during pregnancy is also harmful to the health of the foetus, leading to foetal malformations, shortened gestational age and low birth weight [38]. Preterm birth and low birth weight are positively associated with dental caries [39,40]. The structure of dental enamel can be affected in premature babies [41], which is likely to increase susceptibility to dental caries, while premature babies are often associated with low birth weight. Our study did not produce similar results to previous studies [34,35] that maternal smoking during pregnancy was significantly associated with dental caries in children.

**Table 6. Models using IPCW for the mean number of DMFT at 9 years follow-up (RR, 95% CI).**

	Model 1	Model 2	Model 3	Model 4
	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
<b>Intervention group</b>				
DI	0.88 (0.59-1.31)	0.85 (0.55-1.32)	0.78 (0.50-1.21)	0.87 (0.54-1.41)
II	ref	ref	ref	ref
<b>Primary carers' characteristics at seven years follow-up</b>				
<b>Primary carers' age (years)</b>				
< 30	1.21 (0.71-2.08)	1.26 (0.73-2.18)		1.46 (0.80-2.67)
30-34	0.50 (0.23-1.05)	*0.44 (0.21-0.94)		0.53 (0.23-1.20)
35-39	1.10 (0.59-2.05)	0.95 (0.51-1.80)		1.29 (0.64-2.59)
≥ 40	ref	ref		ref
<b>Education level</b>				
High school or less	2.44 (0.91-6.50)	*3.07 (1.11-8.46)		2.44 (0.84-7.05)
Trade or TAFE	**3.72(1.43-9.67)	**3.75 (1.42-9.89)		*3.45 (1.27-9.41)
University	ref	ref		ref
<b>Employed status</b>				
No	**0.45 (0.29-0.68)	*0.36 (0.19-0.68)		0.45 (0.21-1.02)
Yes	ref	ref		ref
<b>Source of Income</b>				
Centrelink	*0.55 (0.36-0.83)	0.97 (0.52-1.80)		0.92 (0.45-1.89)
Job	ref	ref		ref
<b>Smoking status</b>				
Current	1.63 (0.93-2.89)	*1.90 (1.04-3.46)		1.42 (0.75-2.67)
Former	1.44 (0.76-2.71)	1.56 (0.81-3.02)		1.39 (0.68-2.82)
Never	ref	ref		ref
<b>Alcohol status</b>				
Current	1.94 (0.68-5.56)	1.44 (0.49-4.23)		1.15 (0.37-3.53)
Used	1.75 (0.61-5.05)	1.74 (0.59-5.10)		1.32 (0.43-4.10)
Never	ref	ref		ref
<b>Children's characteristics</b>				
<b>Sex</b>				
Male	*0.62 (0.41-0.92)		*0.51 (0.32-0.83)	0.64 (0.38-1.07)
Female	ref		ref	ref
<b>Self-rated general health</b>				
Fair/poor	2.15 (0.60-7.75)		1.65 (0.41-6.50)	0.72 (0.17-3.12)
Good	*1.62 (1.02-2.59)		1.10 (0.64-1.87)	1.06 (0.60-1.88)
Excellent/very good	ref		ref	ref
<b>Self-rated oral health</b>				
Fair/poor	***2.95 (1.71-5.09)		**3.63 (1.88-7.02)	**2.64 (1.33-5.24)
Good	**1.86 (1.15-3.00)		*1.71 (1.01-2.91)	*1.78 (1.01-3.13)
Excellent/very good	ref		ref	ref
<b>% SSB consumption of total DGI at seven years follow-up</b>				
> 15%	0.49 (0.27-1.05)		1.15 (0.63-2.07)	1.00 (0.54-1.86)
11%–15%	1.29 (0.68-2.45)		0.81 (0.42-1.55)	0.58 (0.29-1.18)
5%–10%	1.12 (0.66-1.90)		2.02 (0.99-4.05)	1.36 (0.64-2.89)

(Continued)

**Table 6.** (Continued)

	Model 1	Model 2	Model 3	Model 4
	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
< 5%	ref		ref	ref
<b>Tooth brushing</b>				
< 2/day	**2.63 (1.56-4.43)		*2.00 (1.15-3.49)	*1.93 (1.10-3.40)
≥ 2/day	ref		ref	ref

Notes: RR: risk ratio; IPCW: the inverse-probability-of-censoring weighting; II: Immediate intervention, DI: delayed intervention; \*P<0.05, \*\*P<0.01, \*\*\*P<0.001. SSB: Sugar-sweetened beverage, DGI: Dietary Guideline Index.

Model 1: unadjusted model; Model 2: Adjusted for mothers/primary carers' characteristics; Model 3: adjusted for children's birth and feeding, dental behaviour and SSB characteristics; Model 4: Full model, adjusted for all covariates.

<https://doi.org/10.1371/journal.pone.0317024.t006>

## Conclusion

The present study suggests that, within this cohort, initiating an early childhood caries intervention during pregnancy and infancy may be associated with lower caries experience in the primary dentition by age 9 years compared to a later start. Mother's education level was negatively associated with dental caries in both primary and permanent teeth. Sugar consumption of more than 10% was an important contributor to dental caries in the primary dentition. The social and commercial determinants of health play an important role in shaping the oral health profile of Indigenous children through the life course.

## Supporting information

**S1 Table. Baseline mother-child pairs characteristics and dental caries among Indigenous Australians at 9 years follow-up.**

(DOCX)

**S2 Table. Models for the mean number of dt at 9 years follow-up (RR, 95% CI).**

(DOCX)

**S3 Table. Models for the mean number of ft at 9 years follow-up (RR, 95% CI).**

(DOCX)

**S4 Table. Models for the mean number of DMFT at 9 years follow-up (RR, 95% CI).**

(DOCX)

**S5 Table. Models for the mean number of DT at 9 years follow-up (RR, 95% CI).**

(DOCX)

**S6 Table. Models for the mean number of FT at 9 years follow-up (RR, 95% CI).**

(DOCX)

**S7 Table. Models using IPCW for the mean number of DMFT at 9 years follow-up (RR, 95% CI).**

(DOCX)

**S1 Checklist. CONSORT 2010 Checklist MS Word.**

(DOCX)

**S1 File. Inclusivity in global research questionnaire.**

(DOCX)

## Acknowledgments

The authors gratefully acknowledge the support of Baby Teeth Talk (Australia) study participants, study staff and partners: South Australian Dental Service, Colgate Palmolive, Women's and Children's Hospital, Lyell McEwen Hospital, Flinders' Medical Centre, Aboriginal Family Support Services, Aboriginal Primary Health Unit, Metro Aboriginal Family Birthing Program, Kura Yerlo Centre, Aboriginal Legal Rights Movement, Wodlitanattoai Program, Ninko Kutangga Patpangga, Kangawodli Step Down Service, Kurna Plains, Fleurieu Families, Gilles Plains Community Health, MADEC Community Support Services, Naporendi Aboriginal Forum, Nunga MiMinar, Aboriginal Strategy Unit of Families South Australia, Inbarendi College, Para West Adult Campus, Pungula Mannanurna Aboriginal Health Corporation and the Muno Parra Medical Centre, Second Story, Inner Southern Health Service, The Corner House, Louise Place, PARKS, Talking Realities Program, Child Youth Women's Health Services, Southern Junction Community Services, TAFE campuses, GP Plus centres, employment programs, childcare centres, women's centres, domestic violence shelters, and primary and high schools.

## Author contributions

**Conceptualization:** Xiangqun Ju, Lisa Gaye Smithers, Lisa M Jamieson.

**Data curation:** Joanne Hedges, Lisa Gaye Smithers, Lisa M Jamieson.

**Formal analysis:** Xiangqun Ju.

**Funding acquisition:** Lisa Gaye Smithers, Lisa M Jamieson.

**Investigation:** Joanne Hedges, Lisa Gaye Smithers, Lisa M Jamieson.

**Methodology:** Xiangqun Ju, Dandara Gabriela Haag, Gustavo Hermes Soares, Lisa Gaye Smithers, Lisa M Jamieson.

**Project administration:** Joanne Hedges, Lisa M Jamieson.

**Software:** Xiangqun Ju.

**Supervision:** Lisa Gaye Smithers, Lisa M Jamieson.

**Validation:** Joanne Hedges, Gustavo Hermes Soares, Lisa Gaye Smithers, Lisa M Jamieson.

**Visualization:** Dandara Gabriela Haag, Gustavo Hermes Soares, Lisa M Jamieson.

**Writing – original draft:** Xiangqun Ju.

**Writing – review & editing:** Xiangqun Ju, Joanne Hedges, Dandara Gabriela Haag, Gustavo Hermes Soares, Lisa Gaye Smithers, Lisa M Jamieson.

## References

1. Marcenes W, Kassebaum NJ, Bernabé E, Flaxman A, Naghavi M, Lopez A, et al. Global burden of oral conditions in 1990-2010: a systematic analysis. *J Dent Res*. 2013;92(7):592–7. <https://doi.org/10.1177/0022034513490168> PMID: [23720570](https://pubmed.ncbi.nlm.nih.gov/23720570/)
2. Roberts-Thomson KF, Spencer AJ, Jamieson LM. Oral health of Aboriginal and Torres Strait Islander Australians. *Med J Aust*. 2008;188(10):592–3. <https://doi.org/10.5694/j.1326-5377.2008.tb01798.x> PMID: [18484934](https://pubmed.ncbi.nlm.nih.gov/18484934/)
3. Sakaryali D, Bani M, Cinar C, Alacam A. Evaluation of the impact of early childhood caries, traumatic dental injury, and malocclusion on oral health-Related quality of life for Turkish preschool children and families. *Niger J Clin Pract*. 2019;22(6):817–23. [https://doi.org/10.4103/njcp.njcp\\_581\\_18](https://doi.org/10.4103/njcp.njcp_581_18) PMID: [31187768](https://pubmed.ncbi.nlm.nih.gov/31187768/)
4. Feldens CA, Rodrigues PH, de Anastácio G, Vítolo MR, Chaffee BW. Feeding frequency in infancy and dental caries in childhood: a prospective cohort study. *Int Dent J*. 2018;68(2):113–21. <https://doi.org/10.1111/idj.12333> PMID: [28868798](https://pubmed.ncbi.nlm.nih.gov/28868798/)
5. Ha D, Roberts-Thomson KF, Arrow P, Peres KG, Do LG. Children's oral health status in Australia, 2012-14. *Australia's Oral Health: National Study of Adult Oral Health 2017–18*. Adelaide: The University of Adelaide Press; 2019. p. 86–152.
6. Australian Institute of Health and Welfare. *Australia's children*. Cat. no. CWS 69. Canberra: AIHW. 2020.

7. Ju X, Do L, Ha D, Jamieson L. Association of Modifiable Risk Factors With Dental Caries Among Indigenous and Nonindigenous Children in Australia. *JAMA Netw Open*. 2019;2(5):e193466. <https://doi.org/10.1001/jamanetworkopen.2019.3466> PMID: [31050787](https://pubmed.ncbi.nlm.nih.gov/31050787/)
8. AUSTRALIAN BUREAU OF STATISTICS. National Aboriginal and Torres Strait Islander Social Survey, 2014-15. 4714.0 - National Aboriginal and Torres Strait Islander Social Survey, 2014-15 (abs.gov.au). 2016. (accessed on 8 April 2024)).
9. Warren JJ, Blanchette D, Dawson DV, Marshall TA, Phipps KR, Starr D, et al. Factors associated with dental caries in a group of American Indian children at age 36 months. *Community Dent Oral Epidemiol*. 2016;44(2):154–61. <https://doi.org/10.1111/cdoe.12200> PMID: [26544674](https://pubmed.ncbi.nlm.nih.gov/26544674/)
10. Ndekero TS, Carneiro LC, Masumo RM. Prevalence of early childhood caries, risk factors and nutritional status among 3-5-year-old preschool children in Kisarawe, Tanzania. *PLoS One*. 2021;16(2):e0247240. <https://doi.org/10.1371/journal.pone.0247240> PMID: [33630949](https://pubmed.ncbi.nlm.nih.gov/33630949/)
11. Boustedt K, Roswall J, Kjellberg E, Twetman S, Dahlgren J. A prospective study of perinatal and metabolic risk factors for early childhood caries. *Acta Paediatr*. 2020;109(11):2356–61.
12. Isaksson H, Alm A, Koch G, Birkhed D, Wendt LK. Caries prevalence in Swedish 20-year-olds in relation to their previous caries experience. *Caries Res*. 2013;47(3):234–42. <https://doi.org/10.1159/000346131> PMID: [23328627](https://pubmed.ncbi.nlm.nih.gov/23328627/)
13. Faghihian R, Faghihian E, Kazemi A, Tarrahi MJ, Zakizade M. Impact of motivational interviewing on early childhood caries: A systematic review and meta-analysis. *J Am Dent Assoc*. 2020;151(9):650–9. <https://doi.org/10.1016/j.adaj.2020.06.003> PMID: [32854867](https://pubmed.ncbi.nlm.nih.gov/32854867/)
14. Harrison R, Benton T, Everson-Stewart S, Weinstein P. Effect of motivational interviewing on rates of early childhood caries: a randomized trial. *Pediatr Dent*. 2007;29(1):16–22. PMID: [18041508](https://pubmed.ncbi.nlm.nih.gov/18041508/)
15. Batliner TS, Tiwari T, Henderson WG, Wilson AR, Gregorich SE, Fehringer KA, et al. Randomized trial of motivational interviewing to prevent early childhood caries in American Indian children. *JDR Clin Trans Res*. 2018;3(4):366–75. <https://doi.org/10.1177/2380084418787785> PMID: [30238061](https://pubmed.ncbi.nlm.nih.gov/30238061/)
16. Jamieson L, Smithers L, Hedges J, Parker E, Mills H, Kapellas K, et al. Dental disease outcomes following a 2-year oral health promotion program for Australian Aboriginal children and their families: A 2-arm parallel, single-blind, randomised controlled trial. *EClinicalMedicine*. 2018;1:43–50. <https://doi.org/10.1016/j.eclinm.2018.05.001> PMID: [31193658](https://pubmed.ncbi.nlm.nih.gov/31193658/)
17. Jamieson LM, Smithers LG, Hedges J, Aldis J, Mills H, Kapellas K, et al. Follow-up of an intervention to reduce dental caries in Indigenous Australian children: a secondary analysis of a randomized clinical trial. *JAMA Netw Open*. 2019;2(3):e190648. <https://doi.org/10.1001/jamanetworkopen.2019.0648> PMID: [30874781](https://pubmed.ncbi.nlm.nih.gov/30874781/)
18. Ju X, Mittinty MN, Smithers L, Jamieson L. Early childhood caries intervention in Aboriginal Australian children: a cross-in randomized trial. *JDR Clin Trans Res*. 2024;9(3):239–47. <https://doi.org/10.1177/23800844231191714> PMID: [37615160](https://pubmed.ncbi.nlm.nih.gov/37615160/)
19. Merrick J, Chong A, Parker E, Roberts-Thomson K, Misan G, Spencer J, et al. Reducing disease burden and health inequalities arising from chronic disease among Indigenous children: an early childhood caries intervention. *BMC Public Health*. 2012;12:323. <https://doi.org/10.1186/1471-2458-12-323> PMID: [22551058](https://pubmed.ncbi.nlm.nih.gov/22551058/)
20. Smithers LG, Hedges J, Ribeiro Santiago PH, Jamieson LM. Dietary Intake and Anthropometric Measurement at Age 36 Months Among Aboriginal and/or Torres Strait Islander Children in Australia: A Secondary Analysis of the Baby Teeth Talk Randomized Clinical Trial. *JAMA Netw Open*. 2021;4(7):e2114348. <https://doi.org/10.1001/jamanetworkopen.2021.14348> PMID: [34236413](https://pubmed.ncbi.nlm.nih.gov/34236413/)
21. Tonkin E, Chatfield MD, Brimblecombe J, Kleve S, Chan E, Deen C, et al. Diet quality, food security and traditional food intake of pregnant and breastfeeding women, and children 6 months to 5 years, living in eight remote Australian Aboriginal and Torres Strait Islander communities. *BMC Public Health*. 2025;25(1):1604. <https://doi.org/10.1186/s12889-025-22815-z> PMID: [40312293](https://pubmed.ncbi.nlm.nih.gov/40312293/)
22. Australian Research Centre for Population Oral Health (ARCPHO). Oral health of Australian Indigenous children compared to non-Indigenous children enrolled in school dental services. *Australian Dental J*. 2014;59:395–400.
23. Wu L, Lo ECM, McGrath C, Wong MCM, Ho SMY, Gao X. Motivational interviewing for caries prevention in adolescents: a randomized controlled trial. *Clin Oral Investig*. 2022;26(1):585–94. <https://doi.org/10.1007/s00784-021-04037-w> PMID: [34254214](https://pubmed.ncbi.nlm.nih.gov/34254214/)
24. Ekstrand KR, Christiansen MEC. Outcomes of a non-operative caries treatment programme for children and adolescents. *Caries Res*. 2005;39(6):455–67. <https://doi.org/10.1159/000088180> PMID: [16251789](https://pubmed.ncbi.nlm.nih.gov/16251789/)
25. Tan SHX, Teo Y-Y, Tan MHX, Gao X. Childhood Factors and Dental Caries in the Permanent Dentition: Findings of an 8-Year Study Under a Nationwide School Dental Service. *Int Dent J*. 2021;71(6):508–15. <https://doi.org/10.1016/j.identj.2021.01.008> PMID: [33743991](https://pubmed.ncbi.nlm.nih.gov/33743991/)
26. Cianetti S, Lombardo G, Lupatelli E, Rossi G, Abraha I, Pagano S, et al. Dental caries, parents educational level, family income and dental service attendance among children in Italy. *Eur J Paediatr Dent*. 2017;18(1):15–8. <https://doi.org/10.23804/ejpd.2017.18.01.03> PMID: [28494596](https://pubmed.ncbi.nlm.nih.gov/28494596/)
27. Nembhwan HV, Varkey I. Caries experience and its relationship with mother's educational level and occupational status: a cross-sectional survey. *Int J Clin Pediatr Dent*. 2022;15(Suppl 2):S226–9. <https://doi.org/10.5005/jp-journals-10005-2163> PMID: [35645509](https://pubmed.ncbi.nlm.nih.gov/35645509/)
28. Mobley C, Marshall TA, Milgrom P, Coldwell SE. The contribution of dietary factors to dental caries and disparities in caries. *Acad Pediatr*. 2009;9(6):410–4. <https://doi.org/10.1016/j.acap.2009.09.008> PMID: [19945075](https://pubmed.ncbi.nlm.nih.gov/19945075/)
29. Ju X, Jamieson LM, Mejia GC. Estimating the effects of maternal education on child dental caries using marginal structural models: The Longitudinal Study of Indigenous Australian Children. *Community Dent Oral Epidemiol*. 2016;44(6):602–10. <https://doi.org/10.1111/cdoe.12259> PMID: [27681345](https://pubmed.ncbi.nlm.nih.gov/27681345/)

30. Ribeiro CCC, da Silva MCB, Nunes AMM, Thomaz EB de AF, Carmo CDS, Ribeiro MRC, et al. Overweight, obese, underweight, and frequency of sugar consumption as risk indicators for early childhood caries in Brazilian preschool children. *Int J Paediatr Dent*. 2017;27(6):532–9. <https://doi.org/10.1111/ipd.12292> PMID: [28222484](https://pubmed.ncbi.nlm.nih.gov/28222484/)
31. Echeverria MS, Schuch HS, Cenci MS, Motta JVDS, Bertoldi AD, Britto Correa M, et al. Early sugar introduction associated with early childhood caries occurrence. *Caries Res*. 2023;57(2):152–8. <https://doi.org/10.1159/000529210> PMID: [36682347](https://pubmed.ncbi.nlm.nih.gov/36682347/)
32. Mahboobi Z, Pakdaman A, Yazdani R, Azadbakht L, Montazeri A. Dietary free sugar and dental caries in children: A systematic review on longitudinal studies. *Health Promot Perspect*. 2021;11(3):271–80. <https://doi.org/10.34172/hpp.2021.35> PMID: [34660221](https://pubmed.ncbi.nlm.nih.gov/34660221/)
33. World Health Organization (WHO). Sugars and Dental Caries. World Health Organization. 2017. Available from: <https://www.who.int/news-room/fact-sheets/detail/sugars-and-dental-caries> (accessed on 8 April 2024).
34. Claudia C, Ju X, Mejia G, Jamieson L. The relationship between maternal smoking during pregnancy and parental-reported experience of dental caries in Indigenous Australian children. *Community Dent Health*. 2016;33(4):297–302. [https://doi.org/10.1922/CDH\\_3937Claudia06](https://doi.org/10.1922/CDH_3937Claudia06) PMID: [28537368](https://pubmed.ncbi.nlm.nih.gov/28537368/)
35. Zhong Y, Tang Q, Tan B, Huang R. Correlation between maternal smoking during pregnancy and dental caries in children: a systematic review and meta-analysis. *Front Oral Health*. 2021;2:673449. <https://doi.org/10.3389/froh.2021.673449> PMID: [35048017](https://pubmed.ncbi.nlm.nih.gov/35048017/)
36. Akinkugbe AA, Brickhouse TH, Nascimento MM, Slade GD. Prenatal smoking and the risk of early childhood caries: a prospective cohort study. *Prev Med Rep*. 2020;20:101201. <https://doi.org/10.1016/j.pmedr.2020.101201> PMID: [33083206](https://pubmed.ncbi.nlm.nih.gov/33083206/)
37. Yanagita M, Kashiwagi Y, Kobayashi R, Tomoeda M, Shimabukuro Y, Murakami S. Nicotine inhibits mineralization of human dental pulp cells. *J Endod*. 2008;34(9):1061–5. <https://doi.org/10.1016/j.joen.2008.06.005> PMID: [18718366](https://pubmed.ncbi.nlm.nih.gov/18718366/)
38. Petersen PE. Tobacco and oral health—the role of the world health organization. *Oral Health Prev Dent*. 2003;1(4):309–15. PMID: [15643759](https://pubmed.ncbi.nlm.nih.gov/15643759/)
39. Shi L, Jia J, Li C, Zhao C, Li T, Shi H, et al. Relationship between preterm, low birth weight and early childhood caries: a meta-analysis of the case-control and cross-sectional study. *Biosci Rep*. 2020;40(8):BSR20200870. <https://doi.org/10.1042/BSR20200870> PMID: [32729621](https://pubmed.ncbi.nlm.nih.gov/32729621/)
40. Weng X, Lou Y, Tao R, Li Y, Cao D, Yu M, et al. The association between low birth weight and dental caries among 11-to-13-year-old school age children in Ningbo, China. *BMC Pediatr*. 2021;21(1):491. <https://doi.org/10.1186/s12887-021-02968-7> PMID: [34736440](https://pubmed.ncbi.nlm.nih.gov/34736440/)
41. Seow WK. Effects of preterm birth on oral growth and development. *Aust Dent J*. 1997;42(2):85–91. <https://doi.org/10.1111/j.1834-7819.1997.tb00102.x> PMID: [9153835](https://pubmed.ncbi.nlm.nih.gov/9153835/)