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Breastfeeding and early tooth eruption as predictors of dental caries occurrence throughout childhood

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The relationship between prolonged breastfeeding and early childhood caries remains controversial. The present study investigated relationships between dental caries experience at 42 months of age and related risk factors, focusing on breastfeeding and the number of erupted teeth. Data from 6746 children aged 42 months were analyzed. Anthropometric measurements and oral examinations were performed, and an interview sheet was provided directly to the guardians. Logistic regression analysis was performed to clarify the risk factors related to dental caries occurrence at 42 months of age. Of the 5161 children included, 13.3% had experienced dental caries between 18 and 42 months of age. Logistic regression analysis results indicated a significant association with dental caries occurrence by 42 months of age for the following factors: 12 or fewer erupted teeth ($P < 0.05$), 17 or more erupted teeth ($P < 0.05$), breast feeding ($P < 0.001$), and breast and bottle feeding ($P < 0.01$) at 18 months of age. These results suggest that breastfeeding and the number of erupted teeth at 18 months of age are important factors for dental caries experience at 42 months of age. Dental visits and guidance on breastfeeding, diet, and oral hygiene beginning when primary teeth start to erupt may benefit oral health throughout childhood.

Keywords Early childhood caries, Early tooth eruption, Breastfeeding, Bottle feeding, Longitudinal analysis

Dental caries is a major public health problem and is the most prevalent noncommunicable disease[1]. In primary teeth, the disease affects 514 million children worldwide, and it can harm children's growth, general health, quality of life, and their families' socioeconomic condition[1,2]. The global prevalence of dental caries of primary teeth showed a minor decrease between 1990 and 2019, yet it remains relatively high in Asia[1,3]. In Japan, whereas the prevalence of primary teeth caries has been reported to be trending downwards owing to government preventive healthcare promotions, children in the high-risk population continue to experience the disease, and its distribution emphasizes the polarization of oral health in preschoolers[4].

The cause of dental caries is multifactorial, encompassing physical, biological, environmental, behavioral, and lifestyle-related factors[5]. Prolonged breastfeeding is also recognized as a risk factor for early childhood caries (ECC)[6,7], although the World Health Organization (WHO) recommends breastfeeding up to 2 years of age or beyond for its health benefits[8]. Some studies and systematic reviews have shown that breastfeeding beyond 12 months of age is associated with severe ECC[7,9,10], and the International Association of Paediatric Dentistry advises against breastfeeding and bottle use beyond 12 months of age[11]. Conversely, a recent cohort study revealed that although breastfeeding beyond 18 months increased caries risk, exclusive breastfeeding for 6–17 months offered protective benefits[12]. Additionally, a recent systematic review concluded that breastfeeding for less than 24 months is not associated with an increased risk of ECC[13], and a longitudinal study showed that a higher intake of free sugars, not breastfeeding itself, was associated with an increased risk of ECC[14]. Thus, the relationship between prolonged breastfeeding and ECC remains unclear.

Early tooth eruption can be considered a host factor in the development of severe ECC, because of the longer periods of exposure to cariogenic factors such as the colonization of cariogenic bacteria[15]. However, little

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research has been carried out on the relationship between dental caries and early tooth eruption. Our previous study found that dental caries occurrence was significantly associated with early tooth eruption at 18 months of age in a large-scale population[16]. Nevertheless, to the best of our knowledge, few studies have investigated the relationship between tooth eruption and dental caries longitudinally.

In this study, we performed a longitudinal analysis of the relationships between dental caries occurrence between 18 and 42 months of age (i.e., 1.5 years to 3.5 years) and the risk factors at 18 months of age in Japanese children in a core city, with a particular focus on breastfeeding and the number of erupted teeth.

Materials and methods

Ethics statement

This study was conducted with full adherence to the Declaration of Helsinki. The study protocol was approved by the Ethics Committee of Osaka University Graduate School of Dentistry (approval number R2-E25). Informed consent was obtained from all the participants and their legal guardians in the form of an opt-out on the website.

Study design

This study was a historical cohort study. In Japan, children receive free medical and dental health examinations from their resident municipality when they reach the age of 18 months and 36 or 42 months (different for each local government) by Maternal and Child Health Law. The examinations include an oral examination, anthropometric measurements of height and weight, and an interview sheet survey. The data for the study were obtained from all three public health centers in Toyonaka city which is a core city to the north of Osaka prefecture located in a metropolitan area in western Japan, with a total population of approximately 400,000. In Toyonaka city, regional public healthcare centers send invitations about the examination to families with a child aged 18 months and again at 42 months.

Subjects

The subjects of this study were 6746 42-month-old children who received oral examinations at three public healthcare centers in Toyonaka City from April 2018 to March 2020 (participation rate > 92%). The inclusion criterion was any child who had received oral examinations at the public healthcare centers in Toyonaka City at 18 months of age (participation rate > 95%) and had a complete set of records of their dental and clinical examinations. The exclusion criterion was any child whose examination data or interview sheet provided by the parents/guardians were incomplete.

Clinical examination

The physical examinations included anthropometric measurements of height and weight (at 18 and 42 months of age). In the oral examinations, the number of erupted teeth (at 18 months of age), the number of decayed teeth (at 18 months of age), and the number of decayed, missing, and filled primary teeth (dmft) (at 18 and 42 months of age) were recorded per child by visual inspection with a dental mirror under lighting according to criteria established by the WHO[17]. The number of erupted teeth at 18 months was divided into three categories (≤ 12, 13–16, 17 ≤)[16]. Based on the eruption order of primary teeth in Japanese children reported by the Japanese Society of Pediatric Dentistry, having 17 or more erupted teeth is assumed to correspond to eruption of the primary second molars, having 13–16 erupted teeth is assumed to correspond to the primary canine eruption stage, and having 12 or fewer erupted teeth is assumed to indicate that the primary canines have not yet erupted[18]. The oral examinations were performed by dentists from the Toyonaka Dental Association.

Microbiological assessment

The microbiological status was assessed at 18 months of age using Cariostat® (Dentsply Sirona, Tokyo, Japan), which is a caries-risk test measuring the presence of acidogenic microorganisms in a colorimetric manner[19]. Plaque collected from the buccal surfaces of all maxillary teeth using a sterilized cotton swab was soaked into a test medium in a Cariostat® test tube and incubated at 37 °C for 48 h. After incubation, the color of the test medium turns from blue to yellow via green, determined by the sampled plaque acidity. The color was graded according to the color chart and classified into four categories: (-), (+), (++), and (+++)[19].

Interview sheet

The structured self-administered interview sheet developed by the public healthcare centers was given to the parents/guardians onsite and collected before the examinations. The interview sheet was completed at the 18-month examinations, which included the following information[16]: sex, parenting environment (commuting to nursery or not), birth order (first, second, third or later), eating before bed (never, weekly, daily), snacking habits per day (never, 1 or 2 times, 3 times or more), feeding habits (weaned, bottle, breast, breast and bottle) and bedtime (before 21:00, 21:00–22:00, after 22:00, unsettled), and topical fluoride application experience (yes or no).

Statistical analysis

Descriptive analyses included calculation of relative frequencies, absolute frequencies, medians, and IQRs. Dental caries prevalence was defined as the presence of children with at least one carious tooth. After excluding children with dental caries at 18 months of age, we performed forward stepwise binary logistic regression with dental caries occurrence between 18 and 42 months of age as the dependent variable. All variables with a P value lower than 0.05 in the univariate analysis were entered in the regression models as independent variables. The ORs and their 95% CI were estimated as risk factors for dental caries occurrence between 18 and 42 months

of age. The fit of the data to the model was tested using the Hosmer–Lemeshow test and multicollinearity was assessed by using the VIF.

For reliable multivariate analysis, we required at least 10 events of the primary outcome measure per variable; that is, an estimated 220 events for 22 variables[20]. Given the prevalence of dental caries at 3 years of age is 20.7% in Japan[21], the required sample size in each multivariate analysis was 1063 or more. All data were analyzed using IBM SPSS Statistics version 28.0.1.0® (IBM Japan, Tokyo, Japan), and the level of statistical significance was set at $P<0.05$.

Results

Of 6746 children, 5161 (76.5%) (2716 boys [52.6%] and 2445 girls [47.4%]) were included (Fig. 1). There were no deficiencies in the data from their clinical examinations or the interview sheet answered by parents/guardians. Of the 5161 children, 738 (14.3%) had experienced dental caries by 42 months of age. Additionally, 50 (1.0%) had experienced dental caries by 18 months of age and 688 (13.3%) had experienced dental caries between 18 and 42 months of age. In the 50 children with dental caries at 18 months of age, dmft was 5 (interquartile range [IQR]: 3–8) at 42 months of age, and in the 688 children who experienced dental caries between 18 and 42 months of age, dmft was 2 (IQR: 1–4) at 42 months of age. Therefore, further caries risk analyses were performed in 5111 children, excluding the 50 children with dental caries at 18 months of age (Fig. 1).

Of the 5111 children, the median height was 96.4 cm (IQR: 94.0–98.7), median weight was 14.6 kg (IQR: 13.6–15.6), and median body mass index was 15.7 kg/m^2 (IQR: 15.0–16.4) at 42 months of age. The number of erupted teeth at 18 months of age was 16 (IQR: 14–16) (Fig. 2). Additionally, 67.1 (%) had weaned until 18 months of age.

Table 1 shows the results of the univariate analysis of dental caries distribution between 18 and 42 months of age among the 5111 children without dental caries at 18 months of age. The following factors were significantly associated with dental caries occurrence: birth order (second: $P<0.001$; third or later: $P<0.001$), number of erupted teeth (≤12: $P<0.05$; ≥17: $P<0.05$), Cariostat score (+: $P<0.05$; + +: $P<0.001$; + + +: $P<0.001$), eating before bed (weekly: $P<0.001$; daily: $P<0.001$), snacking (≤2 times: $P<0.001$; ≥3 times: $P<0.001$), feeding habits (bottle feeding: $P<0.001$; breast feeding: $P<0.001$; breast and bottle feeding: $P<0.001$), bedtime (21:00–22:00: $P<0.001$; after 22:00: $P<0.001$; unsettled: $P<0.001$), commuting to nursery (yes: $P<0.001$), and topical fluoride application experience (yes: $P<0.05$).

Table 2 shows the results of the binary logistic regression analyses of risk factors associated with dental caries occurrence between 18 and 42 months of age. Adjusted by potential confounders, the following factors were significantly associated with dental caries occurrence between 18 and 42 months of age: second child (odds ratio [OR] = 1.86; 95% confidence interval [CI]: 1.54–2.24, $P<0.001$), third or later child (OR = 2.46; 95% CI:1.93–3.14, $P<0.001$), 12 or fewer erupted teeth (OR = 0.78; 95% CI: 0.63–0.97, $P<0.05$), 17 or more erupted teeth (OR = 2.06; 95% CI: 1.12–3.79, $P<0.05$), Cariostat score (+ +) (OR = 3.02; 95% CI: 1.60–5.67, $P<0.001$), Cariostat score (+ + +) (OR = 5.94; 95% CI: 2.70–13.03, $P<0.001$), weekly eating before bed (OR = 1.51; 95% CI: 1.18–1.94, $P<0.001$), daily eating before bed (OR = 1.33; 95% CI: 1.06–1.66, $P<0.05$), snacking twice or less per day (OR = 1.69; 95% CI: 1.34–2.13, $P<0.001$), snacking three times or more per day (OR = 1.76; 95% CI: 1.35–2.28, $P<0.001$), breastfeeding (OR = 2.03; 95% CI: 1.68–2.46, $P<0.001$), breast and bottle feeding (OR = 2.45; 95% CI: 1.36–4.44, $P<0.01$), going to bed at 21:00–22:00 (OR = 1.40; 95% CI: 1.12–1.74, $P<0.01$), going to bed after 22:00

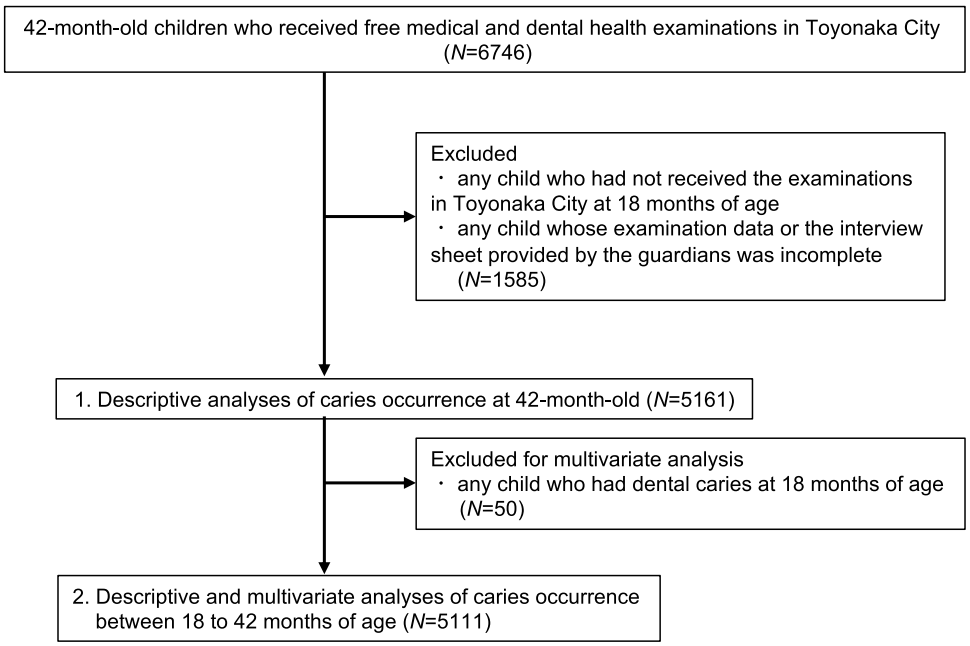

Fig. 1. Flowchart of the present study cohort selection.

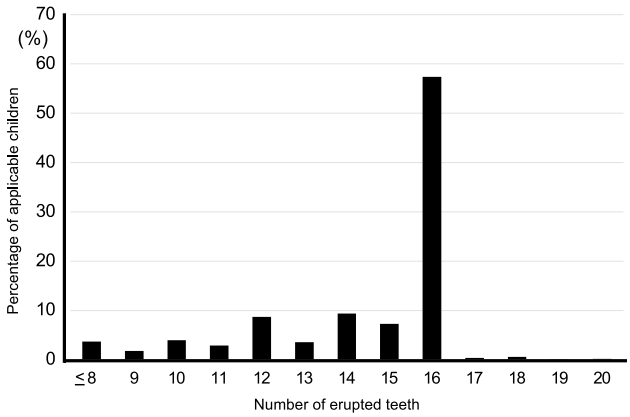

Fig. 2. Distribution of the number of erupted teeth at 18 months of age.

(OR = 1.46; 95% CI: 1.09–1.94, $P < 0.05$), unsettled at bedtime (OR = 2.22; 95% CI: 1.51–3.25, $P < 0.001$) and commuting to nursery (OR = 0.82; 95% CI: 0.69–0.98, $P < 0.05$). In the regression model, the Hosmer–Lemeshow test showed a good fit ($P = 0.349$), and the variance inflation factor (VIF) showed the absence of multicollinearity for each independent variable (< 4.0).

Discussion

The International Association of Paediatric Dentistry reported that the prevalence of ECC was 43% and 55% in children aged 3 and 4 respectively, but these figures are widely divergent throughout the world[22]. A systematic review also reported a prevalence in Asia of 52% (95% CI: 43–61)[3]. The present results reflect the high standard of oral public health in Japan, a developed country in the twenty-first century. According to some studies from the last decade in Japan, the dental caries prevalence rate at 3 years of age was 14.7%–22.4%[21,23–25], which is higher than the results of the present study. This may be indicative of the high oral health standards in the city of the present study. However, a large-scale study in Sweden reported a caries prevalence of 6.0% in 3-year-old children[26]. In Japan, because dental caries still occurs in certain high-risk populations, and the polarization of oral health in children is becoming more apparent[16], there is still considerable room for improvement in oral public health.

Prolonged breastfeeding has been associated with severe ECC[6,7,9,10,12], and the International Association of Paediatric Dentistry recommends avoiding breastfeeding and bottle feeding beyond 12 months of age[11]. Our previous cross-sectional study disclosed that breastfeeding at 18 months of age is significantly associated with dental caries occurrence[16]. In the present longitudinal study, breastfeeding at 18 months of age was a significant risk factor for dental caries occurrence by 42 months of age. The WHO recommends that breastfeeding up to 2 years of age or beyond benefits children's health[8]. Additionally, early breastfeeding can protect against dental caries by delaying the introduction of sugar-containing foods[12–14]. In the present study, 70%–80% of the children who continued breastfeeding up to 18 months of age had no caries at 42 months of age. However, if the management of habits and behaviors including sugar consumption and night-time feeding are inappropriate, prolonged breastfeeding is thought to influence dental caries risk throughout childhood[10,14]. Therefore, the results of the present study suggest that breastfeeding up to 18 months of age could be a notable factor in oral hygiene management, even taking the potential benefits of breastfeeding into account. Early dental visits and accompanying guidance on breastfeeding, diet, and oral hygiene may support better oral health throughout childhood.

Little research has been undertaken on the relationship between dental caries and early tooth eruption[15,16]. One study suggested that early tooth eruption at 12 months of age is weakly associated with decayed, missing, and filled surfaces of primary teeth at 30 and 48 months of age[15]. Our previous study disclosed that early tooth eruption at 18 months of age was a significantly high risk factor for dental caries, and late tooth eruption was a significantly low risk factor cross-sectionally[16]. In the present study, tooth eruption at 18 months of age was a significant risk factor for dental caries occurrence by 42 months of age longitudinally. The present results may suggest that early tooth eruption leads to early colonization of cariogenic bacteria, such as *Mutans streptococci*, and that dental caries may develop more readily with the early introduction of a mature diet, including sugar-containing foods and beverages[27,28]. Our findings suggest that not only dental caries but also oral morphological development should be evaluated at 18 months of age to help prevent dental caries occurrence throughout childhood.

Birth order was significantly associated with dental caries occurrence by 42 months of age in the present study, and at 18 months of age in our previous study[16]. Later-born children are likely to have more sibling influences and less parental attention, resulting in less individual care and earlier exposure to sugar-containing foods compared with first-born children[29]. Therefore, the habits of eating before bed and frequent snacking, both high-risk factors for dental caries in the present study, are more easily established in later-born children, resulting in dental caries development in early childhood and beyond. Additionally, the Cariostat score at 18 months of age was significantly associated with dental caries occurrence by 42 months of age, as well as 18 months[16]. The

Variables		Total	Caries	Crude OR (95% CI)	P
		N (%)	N (%)		
(Overall)		5111			
Caries	Yes	688 (13.5)			
	No	4423 (86.5)			
Sex	Male	2689 (52.6)	363 (13.5)		
	Female	2422 (47.4)	335 (13.4)	0.99 (0.85–1.17)	0.993
Birth order	First	2566 (50.2)	235 (9.2)		
	Second	1932 (37.8)	317 (16.4)	1.95 (1.63–2.33)	< 0.001
	Third or later	613 (12.0)	136 (22.2)	2.83 (2.24–3.57)	< 0.001
Body mass index	Ideal	2419 (47.3)	310 (12.8)		
	Underweight	1288 (25.2)	185 (14.4)	1.14 (0.94–1.39)	0.187
	Overweight	1404 (27.5)	193 (13.7)	1.08 (0.89–1.32)	0.412
Number of erupted teeth	13–16	3969 (77.7)	552 (13.9)		
	≤ 12	1076 (21.1)	120 (11.2)	0.78 (0.63–0.96)	0.019
	≥ 17	66 (1.3)	16 (24.2)	1.98 (1.12–3.50)	0.019
Cariostat score	–	183 (3.6)	12 (6.6)		
	+	4257 (83.3)	523 (12.3)	2.00 (1.10–3.61)	0.022
	+ +	599 (11.7)	128 (21.4)	3.87 (2.09–7.18)	< 0.001
	+ + +	72 (1.4)	25 (34.7)	7.58 (3.54–16.21)	< 0.001
Eating before bed	No	3640 (71.2)	401 (11.0)		
	Weekly	599 (11.7)	124 (20.7)	2.11 (1.69–2.64)	< 0.001
	Daily	872 (17.1)	163 (18.7)	1.86 (1.52–2.27)	< 0.001
Snacking	No	4038 (79.0)	446 (11.0)		
	≤ 2 times	625 (12.2)	137 (21.9)	2.26 (1.83–2.80)	< 0.001
	≥ 3 times	448 (8.8)	105 (23.4)	2.47 (1.94–3.13)	< 0.001
Feeding habit	Weaned	3431 (67.1)	342 (10.0)		
	Bottle feeding	501 (9.8)	85 (12.4)	1.85 (1.43–2.39)	< 0.001
	Breast feeding	1114 (21.8)	244 (21.9)	2.53 (2.11–3.04)	< 0.001
	Breast + bottle	65 (1.3)	17 (26.2)	3.20 (1.82–5.63)	< 0.001
Bedtime	Before 21:00	1352 (26.5)	127 (9.3)		
	21:00–22:00	2817 (55.1)	398 (14.1)	1.60 (1.30–1.98)	< 0.001
	After 22:00	725 (14.2)	110 (15.2)	1.74 (1.32–2.29)	< 0.001
	Unsettled	217 (4.2)	54 (24.9)	3.22 (2.25–4.61)	< 0.001
Nursery	No	3214 (62.9)	472 (14.7)		
	Yes	1897 (37.1)	216 (11.4)	0.75 (0.63–0.89)	< 0.001
Topical Fluoride Application	No	4552 (89.1)	629 (13.8)		
	Yes	559 (10.9)	59 (10.6)	0.74 (0.56–0.98)	0.033

Table 1. Dental caries distribution between 18 and 42 months of age and crude odds ratio (OR) among factors in children without dental caries at 18 months of age.

Cariostat score can be not only an indicator of oral hygiene at the time of examination, but also a predictor of ECC, and is useful for risk assessment in early childhood when oral check-ups are difficult. However, bedtime and commuting to nursery at 18 months of age was significantly associated with dental caries occurrence by 42 months of age in the present study, although this association was not significant at 18 months of age in our previous study[15]. Bedtime at 18 months of age has previously been reported to be associated with the incidence of dental caries at 3 years of age[30]. These results suggest that establishing a rhythm of life and sleeping habits at 18 months of age is important for developing eating and oral hygiene habits, assisting in preventing ECC.

The present study had several limitations. First, although the association between the number of erupted teeth at 18 months of age and dental caries was analyzed, the degree of tooth eruption and the type of erupted teeth were not investigated. The type of erupted teeth, such as first or second molars, may be more strongly associated with dental caries than the number of erupted teeth. Future studies on dental caries should also consider tooth eruption sequences. Second, although feeding habits at 18 months of age were divided into four categories, nocturnal feeding and the frequency of breastfeeding were not investigated in the present study. These may be important in the analysis of dental caries risk as well as the categorized feeding habits[9]. Therefore, future studies on the association between dental caries and infant feeding should address all aspects, including feeding habits, nocturnal feeding patterns, and breastfeeding frequency. Third, although the interview sheet used in the present study was developed by the local municipality for public health management and has been in use for many years, its reliability and validity have not been evaluated. Additionally, self-reported data may

Variables		Adjusted odds ratio (95% CI)	*P*	VIF
Birth order			< 0.001	1.03
	First	Ref		
	Second	1.86 (1.54–2.24)	< 0.001	
	Third or later	2.46 (1.93–3.14)	< 0.001	
Number of erupted teeth			0.004	1.01
	13–16	Ref		
	≤ 12	0.78 (0.63–0.97)	0.025	
	≥ 17	2.06 (1.12–3.79)	0.020	
Cariostat score			< 0.001	1.02
	–	Ref		
	+	1.74 (0.95–3.18)	0.074	
	+ +	3.02 (1.60–5.67)	< 0.001	
	+ + +	5.94 (2.70–13.03)	< 0.001	
Eating before bed			0.001	1.21
	No	Ref		
	Weekly	1.51 (1.18–1.94)	< 0.001	
	Daily	1.33 (1.06–1.66)	0.015	
Snacking			< 0.001	1.11
	No	Ref		
	≤ 2 times	1.69 (1.34–2.13)	< 0.001	
	≥ 3 times	1.76 (1.35–2.28)	< 0.001	
Feeding habit			< 0.001	1.14
	Weaned	Ref		
	Bottle feeding	1.30 (0.98–1.72)	0.068	
	Breast feeding	2.03 (1.68–2.46)	< 0.001	
	Breast + bottle	2.45 (1.36–4.44)	0.003	
Bedtime			< 0.001	1.04
	Before 21:00	Ref		
	21:00–22:00	1.40 (1.12–1.74)	0.003	
	After 22:00	1.46 (1.09–1.94)	0.010	
	Unsettled	2.22 (1.51–3.25)	< 0.001	
Nursery				1.02
	No	Ref		
	Yes	0.82 (0.69–0.98)	0.033	

Table 2. Logistic regression analysis with dental caries occurrence between 18 and 42 months of age as the dependent variable. Adjusted for birth order, number of erupted teeth, Cariostat score, eating before bed, snacking, feeding habit, bedtime, commuting to nursery, and topical fluoride application experience.

be subject to recall bias. Fourth, although the number of erupted teeth and carious teeth was assessed visually according to criteria established by the WHO, we did not verify consistency among examiners. Nevertheless, the present study clarified the importance of caries risk factors at an early age, especially the tooth eruption status in early childhood, which has been scarcely reported previously. Additionally, breastfeeding at 18 months of age can influence dental caries occurrence longitudinally. We consider that the risk factors for dental caries in early childhood examined in the present study are meaningful for the assessment of oral health throughout childhood.

Within the limitations of this longitudinal study, the following conclusions can be drawn:

- The number of erupted teeth at 18 months of age is a significant risk factor for dental caries occurrence throughout childhood.
- Breastfeeding at 18 months of age can influence dental caries occurrence longitudinally and can be interpreted as a notable factor in oral hygiene management.
- Dental visits and related guidance on breastfeeding, diet, and oral hygiene from the time primary teeth begin to erupt may be beneficial for maintaining oral health throughout childhood.

Data availability

All data generated or analyzed during this study are included in this published article.

Received: 16 October 2024; Accepted: 29 October 2025
Published online: 27 November 2025

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Acknowledgements

We thank the members of the Toyonaka Dental Association for the clinical examinations. We also appreciate the generous support from Drs. Atsushi Kondo, Makoto Kitatani, Shozo Wada, Tsutomu Sasabe, Takuji Hoshina, Takahiro Kato and Tetsuya Manabe from the Toyonaka Dental Association. This work was supported by KAKENHI research project grants (22K10268) from the Japan Society for the Promotion of Science and JST-Mirai Program (JP20348555). The funders had no roles in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Author contributions

YM and MO designed the study, and data inputting was performed by KM and MN. Data interpretation was performed by YM, MO, MK, YO, TK and KN. YM and MO wrote the paper under the supervision of TK and KN. All authors gave their final approval and agreed to be accountable for all aspects of the work.

Declarations

Competing interests
The authors declare no competing interests.

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