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The Associations between Breastfeeding and Early Childhood Caries: A Prospective Cohort Study

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Keywords
Breast milk · WHO recommendations · Dental caries · Epidemiology

Abstract

Introduction: The association between breastfeeding status and early childhood caries (ECC) remains inconclusive. Few studies evaluate the breastfeeding status including both duration and exclusivity according to the WHO recommendations on breastfeeding. This study aimed to investigate the association between breastfeeding status and ECC.
Methods: This prospective cohort study comprised 3,666 children whose breastfeeding status was precisely

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evaluated. Poisson regression models and multivariable linear regression models were employed to analyze the associations of breastfeeding status with risk of ECC, and mean decayed, missing, and filled primary tooth surfaces (dmfs) in 3-year-old children, respectively. The data were collected from 2014 to 2020, and the analysis was conducted in 2023. ***Results:*** The prevalences of ECC in offspring breastfed for <6 months, 6–11 months, 12–24 months, and >24 months were 9%, 12%, 17%, and 23%, respectively. Offspring breastfed for 12–24 months and over 24 months had a 1.82 times (95% CI, 1.40–2.37; $p < 0.001$) and 2.48 times (95% CI, 1.63–3.75; $p < 0.001$) higher risk of ECC, compared to those breastfed for less than 6 months. Offspring breastfed for 12–24 months showed a mean dmfs increase of 0.32 (95% CI, 0.21–0.44; $p < 0.001$), while those breastfed for over 24 months had a mean dmfs increase of 0.51 (95% CI, 0.27–0.74; $p < 0.001$), compared to those breastfed for less than 6 months. Among offspring breastfed for over 24 months, those exclusively breastfed for at least 6 months had significantly lower mean dmfs compared to those exclusively breastfed for less than 6 months (p for heterogeneity = 0.003). A significant interaction was observed between breastfeeding duration and exclusive breastfeeding duration on the association with mean dmfs (p for interaction <0.001). ***Conclusion:*** Our findings suggest that breastfeeding for over 12 months was associated with increased risk of ECC. Preventive interventions for dental caries should be implemented as early as possible, as breastfeeding is beneficial to children's health. The associations between breastfeeding duration and exclusivity with ECC should be investigated more thoroughly, particularly with adjustments for accurately measured sugar consumption.

Introduction

Early childhood caries (ECC) is an aggressive presentation of dental caries that affects the primary teeth of infants and toddlers [1]. As the most common chronic childhood disease, ECC affects approximately 48% of preschool children globally [2] and imposes substantial economic burdens on families, societies, and healthcare systems due to its costly treatment [3, 4]. Though deciduous dentition will be replaced by permanent dentition ultimately, ECC can result in malnutrition [5], malocclusion [6], and suboptimal school performance, potentially exacerbating social inequalities [3, 7]. Significantly, ECC is largely preventable [3]; therefore, identifying its risk factors is paramount for enhancing the effectiveness of preventive measures.

Exclusive breastfeeding for the initial 6 months of life and continuing to breastfeed for up to 2 years of age or beyond is recommended by World Health Organization (WHO) [8], given its protective effect against a wide range of diseases and reduced mortality risk [9–11]. However, studies on the association between breastfeeding and ECC have yielded inconsistent conclusions. While some research suggests that breastfeeding for over 12 or 24 months is associated with an increased risk of ECC [12–14], other studies have found that breastfeeding for specific durations may have a protective effect against ECC [15]. Yet these investigations lack a comprehensive evaluation of the relationship between both the duration and exclusivity of breastfeeding and ECC according to the WHO recommendation on breastfeeding [12–16]. Additionally, the formation of primary dentition commences in utero and is completed at 18 months–36 months [17], which could be affected by the breastfeeding practice. Therefore, an in-depth examination of both the duration of breastfeeding and the period of exclusive breastfeeding, along with their cumulative impact on ECC, is crucial for effective prevention strategies.

This study aimed to examine the association between the duration and exclusivity of breastfeeding according to the WHO recommendations on breastfeeding and the risk and severity of ECC in offspring at 3 years of age.

Methods

Study Sample

This study was conducted within Jiangsu Birth Cohort Study, a well-designed prospective and longitudinal cohort study in eastern China [18]. Briefly, the cohort comprised couples in the first trimester of spontaneous conception or who were planning to receive assisted reproductive technology (ART) treatment from three hospitals across Jiangsu, China. Baseline information was collected from both the biological mother and father. During pregnancy, questionnaire surveys for women were conducted at the first, second, and third trimesters. Detailed clinical data including physical examination, clinical test, and pregnancy complications were extracted from medical records. For the postnatal follow-up, mothers were interviewed via telephone at 42 days and 6 months after childbirth to complete a questionnaire including information on offspring's feeding patterns. When children reached the ages of 1 year and 3 years, they were invited back to the hospital for physical examinations and other health-related assessments [18].

The study was approved by the Human Research Ethics Committee of Nanjing Medical University. All the adult participants had provided written informed consent at enrollment, and for the participants under the age of 18 years, written informed consent was obtained from the participants' legal guardian in the study.

In the present study, we included families of JBC recruited from the Women's Hospital of Nanjing Medical University, the Suzhou Affiliated Hospital of Nanjing Medical University, and the Changzhou Maternal and Child Health Care Hospital. Between April 2014 and June 2020, a total of 7,797 families had live births, resulting in 8,101 offspring, who were followed up through the age of three. Of these, 3,473 mothers and 3,672 offspring with complete questionnaires on breastfeeding status at 6 months, 1 year, and 3 years of age were included. Among them, 6 offspring with missing information on dental examination records were excluded. Ultimately, the analysis included 3,467 mothers and 3,666 offspring (online suppl. Fig. 1; for all online suppl. material, see https://doi.org/10.1159/000543380).

Measures

Information about the exclusivity and duration of breastfeeding was obtained from the questionnaires administered at 6 months, 1 year, and 3 years after birth. In each questionnaire, parents were asked about the breastfeeding status of their offspring (exclusive breastfeeding, mixed breastfeeding, or without breastfeeding) since the last questionnaire, and the time of weaned breastfeeding was also collected if the answer was "without breastfeeding." In the study, two distinct breastfeeding categories were employed: the age at which complete cessation of breastfeeding occurred (breastfeeding duration) and the age at which other foods except breast milk were first introduced (exclusive breastfeeding duration). Breastfeeding duration was further categorized into four groups by months of offspring age: less than 6 months, 6–11 months, 12–24 months, and over 24 months according to the original options in the three questionaries (online suppl. Table 1). Furthermore, as several former studies reported that breastfeeding for up to 12 months can protect the offspring against ECC, a three-level category of breastfeeding duration by months of offspring age was also utilized as follows: 12 months or less, 13–24 months, and over 24 months. Besides, since the WHO recommends that infants should be breastfed for the first 6 months of life, exclusive breastfeeding duration was categorized into two groups by months of offspring age: less than 6 months, 6 months and above, according to the options in one questionnaire (online suppl. Table 2).

Dental assessments were conducted by proficient dentists when the offspring were invited back to the hospital at 3 years of age (27 to 46 months). ECC was defined as the presence of a primary tooth with one or more carious (noncavitated or cavitated lesions), missing (due to caries), or filled surfaces on any primary tooth in children below 6 years, according to the Bangkok Declaration [19]. Additionally, the number of decayed, missing, and filled primary tooth surfaces (dmfs) was also measured to evaluate the severity of ECC.

Other related data regarding maternal characteristics and offspring characteristics were collected during the pregnancy and postnatal period. Maternal characteristics included residence, annual household income, education level, smoke exposure, prepregnancy body mass index, delivery age, and parity. Offspring characteristics included sex, low birth weight, and starting oral hygiene time. All these factors were included as they were considered to be associated with ECC or breastfeeding in the former studies [12–15, 20–22]. A framework was constructed to identify potential confounders of the outcomes using DAGitty software, version 3.0 (online suppl. Fig. 2). The missing frequencies of each covariate were shown in online supplementary Table 3. All the missing covariates were assigned a different value when they were taken into adjusted models except delivery age. Although we did not collect data on the sugar consumption of the offspring in our study, a portion of the participants (N = 905) were involved in another study conducted by the Department of Stomatology at the Women's Hospital of Nanjing Medical University at 3 years of age, where data on sugar consumption before sleeping (Yes/No) were collected. Given our assumption that sugar consumption before sleeping could reflect the overall sugar intake of the offspring, we conducted a sensitivity analysis by comparing our primary results before and after adjusting for sugar consumption before sleeping. Information on the mode of conception, preterm birth, and congenital malformation was also considered in the sensitive analysis.

Statistical Analysis

This study employed the Poisson regression model to examine the association of breastfeeding duration and exclusive breastfeeding duration with the ECC. Besides, the multivariate linear regression model was used to analyze the correlation of breastfeeding duration and exclusive breastfeeding duration with the mean dmfs. Regression models were fitted with the use of a

generalized linear mixed model given the nonindependence of observations from twin pairs [23]. The results of both crude and adjusted models were reported as risk ratios (RRs) or βs, accompanied by 95% CIs.

Since breastfeeding duration was found to be a strong confounder when investigating the relationship between exclusive breastfeeding duration and ECC, a stratified analysis was further conducted to explore the associations of breastfeeding duration with ECC among offspring in different exclusive breastfeeding duration subgroups. β values were utilized to explain the variations in ECC and mean dmfs between different exclusive breastfeeding duration categories. In addition, a product term of breastfeeding duration and exclusive breastfeeding duration was incorporated into the model to evaluate the multiplicative interactions.

Further sensitivity analyses were performed to examine the results' robustness. Models were established among offspring with different modes of conception, as the proportion of offspring conceived using ART in our cohort is observed higher than in similar studies. Furthermore, offspring with preterm birth or congenital malformation, which could both have an impact on breastfeeding status and ECC, were excluded from the sensitivity analysis of the models. Offspring with missing data were also excluded from another sensitivity analysis of the models.

In addition to the traditional sensitivity analyses, g-estimation, a state-of-the-art method for assessment of unmeasured confounders was utilized to evaluate the influence of the unmeasured confounding on the observed associations between breastfeeding duration and ECC [24]. Using g-estimation, we sought to quantify unmeasured confounding by comparing the magnitude of measured confounding with the critical threshold of unmeasured confounding at which the association between exposure and outcome became insignificant. In simple terms, α_1 represents the magnitude of confounding, and the RR with its 95% CI is calculated for different values of α_1. When $\alpha_1 = 0$, the RR with 95% CI reflects the effect after adjusting for measured confounding, while that under α_1* represents the effect without adjusting for measured confounding. By comparing α_1* with the critical value of α_1, where the confidence interval includes the null value (for RR, the null is 1), we can determine how many times larger the unmeasured confounding would need to be compared to the measured confounding for the observed results to lose significance.

Moreover, the baseline characteristics of the included and excluded populations in this study were compared using Student's *t* test to identify any potential selection bias. Statistical analyses were performed using R statistical software, version 4.1.0. Two-sided $p < 0.05$ was considered statistically significant. The analysis was conducted in 2023. This study was complied with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) protocol.

Results

Of the total study population, 3.9% ($n = 144$) of the offspring were breastfed for over 24 months and 27.9% ($n = 1,022$) of the offspring were exclusively breastfed for at least 6 months. The mean age of the offspring was 3.04 [0.09] (mean [SD]) years at the dental examination. The rate of ECC was 14.0% ($n = 514$), with a mean dmfs of 0.39 [1.31]. No significant differences were found in the distribution of residence, annual household income, smoke exposure, parity, and offspring sex among the four breastfeeding duration groups. The proportion of mothers with lower prenatal age, lower education level, lower or higher body mass index, conception with ART, and offspring with low birth weight, starting oral hygiene later was higher among offspring breastfed for less than 6 months (Table 1).

The prevalences of ECC in offspring breastfed for <6 months, 6–11 months, 12–24 months, and >24 months were 9%, 12%, 17%, and 23%, respectively. The rate of ECC among offspring was significantly elevated when breastfed over 12 months. Compared to those who were breastfed for less than 6 months, offspring who were breastfed for 12–24 months and over 24 months had a 1.82-fold (95% CI, 1.40–2.37; $p < 0.001$) and 2.48-fold (95% CI, 1.63–3.75; $p < 0.001$) risk of ECC, respectively. A dose-response relationship was observed between breastfeeding duration and the rate of ECC ($p < 0.001$ for trend). Offspring who were breastfed for 12–24 months showed a mean dmfs increase of 0.31 (95% CI, 0.19–0.42; $p < 0.001$), while those breastfed for over 24 months had a mean dmfs increase of 0.47 (95% CI, 0.24–0.70; $p < 0.001$), in comparison with those breastfed for less than 6 months. There was also a dose-response relationship between breastfeeding duration and the mean dmfs ($p < 0.001$ for trend) (Table 2).

The same effects were also observed when using three-level categorical breastfeeding as exposure. Compared to those breastfed for 12 months or less, offspring breastfed for 13–24 months and over 24 months had a 1.37-fold (95% CI, 1.14–1.64; $p < 0.001$) and 1.88-fold (95% CI, 1.31–2.70; $p < 0.001$) increased risk of ECC, respectively.

Table 1. Baseline characteristics of mother and offspring

Variables	BD			
	<6	6–11	12–24	>24
Maternal characteristics (*N* = 3,467)	(*n* = 696)	(*n* = 1,270)	(*n* = 1,359)	(*n* = 142)
Age, mean (SD), years	30.57 (4.03)	29.92 (3.75)	30.53 (3.76)	31.62 (4.39)
Prepregnancy BMI				
<18.5 kg/m^2	100 (14.4)	176 (13.9)	165 (12.2)	14 (9.9)
18.5–23.9 kg/m^2	444 (64.0)	883 (69.9)	962 (71.0)	100 (70.9)
24–27.9 kg/m^2	105 (15.1)	168 (13.3)	187 (13.8)	23 (16.3)
≥28 kg/m^2	45 (6.5)	37 (2.9)	41 (3.0)	4 (2.8)
Residence				
Urban	480 (69.0)	890 (70.1)	967 (71.2)	107 (75.4)
Town	117 (16.8)	214 (16.9)	183 (13.5)	21 (14.8)
Country	99 (14.2)	166 (13.1)	209 (15.4)	14 (9.9)
Annual household income				
<100,000 CNY	232 (34.2)	362 (28.8)	403 (30.0)	36 (25.7)
100,000–200,000 CNY	277 (40.9)	544 (43.3)	608 (45.3)	66 (47.1)
≥200,000 CNY	169 (24.9)	349 (27.8)	331 (24.7)	38 (27.1)
Education level				
<12 years	87 (12.7)	91 (7.2)	104 (7.7)	5 (3.5)
≥12 years	597 (87.3)	1,171 (92.8)	1,244 (92.3)	137 (96.5)
Smoke exposure				
No	517 (88.1)	970 (87.5)	1,074 (87.8)	113 (91.9)
Yes	70 (11.9)	139 (12.5)	149 (12.2)	10 (8.1)
Parity				
Nulliparous	536 (80.1)	948 (77.5)	1,016 (77.1)	97 (72.4)
Multiparous	133 (19.9)	275 (22.5)	302 (22.9)	37 (27.6)
Mode of conception				
Spontaneous	470 (67.5)	970 (76.4)	998 (73.4)	100 (70.4)
ART	226 (32.5)	300 (23.6)	361 (26.6)	42 (29.6)
Offspring characteristics (*N* = 3,666)	(*n* = 781)	(*n* = 1,340)	(*n* = 1,401)	(*n* = 144)
Sex				
Boys	425 (54.4)	693 (51.7)	735 (52.5)	72 (50.0)
Girls	356 (45.6)	647 (48.3)	666 (47.5)	72 (50.0)
Low birth weight				
No	686 (88.7)	1,253 (94.3)	1,319 (94.9)	137 (95.8)
Yes	87 (11.3)	76 (5.7)	71 (5.1)	6 (4.2)
Starting oral hygiene time				
≤12 months	317 (42.4)	627 (47.8)	694 (50.4)	76 (53.1)
>12 months	430 (57.6)	685 (52.2)	684 (49.6)	67 (46.9)

BD, breastfeeding duration by months of offspring age; ART, assisted reproductive technology; BMI, body mass index; CNY, China Yuan.

A significant dose-response relationship was noted between breastfeeding duration and ECC risk ($p < 0.001$ for trend). Offspring breastfed for 13–24 months showed a mean dmfs increase of 0.18 (95% CI, 0.09–0.27; $p < 0.001$), while those breastfed for over 24 months had a mean increase of 0.39 (95% CI, 0.17–0.61; $p < 0.001$) compared to those breastfed for 12 months or less. A dose-response trend was also found between breastfeeding duration and mean dmfs scores ($p < 0.001$ for trend) (online suppl. Table 4).

Table 2. Associations of breastfeeding duration with early childhood caries

	BD	No. of ECC cases	Rate of ECC	Crude model		Adjusted model[a]	
				RR (95% CI)	*p* value	RR (95% CI)	*p* value
Prevalence of ECC[b]	<6	74	0.09	Ref	–	Ref	–
	6–11	162	0.12	1.28 (0.97, 1.68)	0.08	1.26 (0.95, 1.66)	0.11
	12–24	245	0.17	1.85 (1.42, 2.39)	<0.001	1.82 (1.40, 2.37)	<0.001
	>24	33	0.23	2.42 (1.60, 3.65)	<0.001	2.48 (1.63, 3.75)	<0.001
	–	–	–	p_{trend}	<0.001	–	<0.001
	BD	No. of ECC cases	Mean dmfs	β (95% CI)	*p* value	β (95% CI)	*p* value
Mean dmfs[c]	<6	74	0.20	Ref	–	Ref	–
	6–11	162	0.31	0.09 (−0.02, 0.21)	0.11	0.10 (−0.02, 0.22)	0.10
	12–24	245	0.53	0.31 (0.19, 0.42)	<0.001	0.31 (0.19, 0.42)	<0.001
	>24	33	0.72	0.47 (0.24, 0.70)	<0.001	0.47 (0.24, 0.70)	<0.001
	–	–	–	p_{trend}	<0.001	–	<0.001

BD, breastfeeding duration by months of offspring age; ECC, early childhood caries; dmfs, decayed, missing, and filled primary tooth surfaces. [a]Adjusted for maternal age at delivery, prepregnancy body mass index, residence, annual household income, education level, smoke exposure, parity, offspring sex, low birth weight, starting oral hygiene time. [b]RR obtained from Poisson regression. [c]β coefficients obtained from multivariable linear regression.

The associations between exclusive breastfeeding duration and ECC were found without significance. However, a reverse trend was observed in the associations between exclusive breastfeeding duration and ECC both in terms of the rate of ECC and mean dmfs. Exclusive breastfeeding duration was found to change from being a risk factor (RR_{adj1}, 1.15; 95% CI, 0.95–1.39; $p = 0.14$) to becoming a protective factor (RR_{adj2}, 0.93; 95% CI, 0.76–1.14; $p = 0.48$) against ECC after adjusting for breastfeeding duration (Table 3).

In the stratified analysis, significant heterogeneity was found between different exclusive breastfeeding durations among offspring breastfed for over 24 months on the mean dmfs (p for heterogeneity = 0.003). Breastfeeding over 24 months increased the mean dmfs by 0.76 (95% CI, 0.40–1.12; $p < 0.001$) among offspring exclusively breastfed for less than 6 months, whereas the associations were not significant among offspring exclusively breastfed for over 6 months (β, 0.01; 95% CI, −0.34–0.35; $p = 0.97$) (Table 4). A significant interaction was observed between exclusive breastfeeding duration and breastfeeding duration on the association with mean dmfs (p for interaction <0.001) (Table 5).

The effects of breastfeeding duration and exclusive breastfeeding duration on the rate of ECC and mean dmfs in the subset of offspring with data on sugar consumption before sleeping ($N = 905$) remained largely unchanged before and after adjusting for sugar consumption before sleeping (online suppl. Tables 5, 6). There was no significant heterogeneity between modes of conception in the effects of breastfeeding duration and exclusive breastfeeding duration on the rate of ECC and mean dmfs (online suppl. Tables 7, 8). And the main findings did not change substantially in the sensitivity analysis when offspring with preterm birth and congenital malformation were excluded (online suppl. Tables 9 and 10) and when offspring with missing data were excluded (online suppl. Tables 11, 12), respectively.

Online supplementary Figure 3 shows the estimated association between breastfeeding duration and ECC when α_1 ranges from −0.20 to 0.20, representing different magnitudes of unmeasured confounding relevant for this study (specific estimates can be found in online suppl. Table 13). From the figures, by comparing the measured confounding magnitude (α_1*) with the α_1 where the confidence interval includes the null value, we can assess the extent to which unmeasured confounding could affect the results. For breastfeeding between 12 and 24 months, the confidence interval of the association did not include the null value when $\alpha_1 = 0.20$, which was more than four times the value of α_1*, indicating that the elevated risk of ECC in this group, compared to breastfeeding for less than 6 months, is robust to unmeasured confounding exceeding 4 times

Table 3. Associations of exclusive breastfeeding duration with early childhood caries

	EBD	No. of ECC cases	Rate of ECC	Crude model		Adjusted model 1[a]		Adjusted model 2[b]	
				RR (95% CI)	*p* value	RR (95% CI)	*p* value	RR (95% CI)	*p* value
Prevalence of ECC[c]	<6	351	0.13	Ref	–	Ref	–	Ref	–
	≥6	163	0.16	1.20 (1.00, 1.45)	0.05	1.15 (0.95, 1.39)	0.14	0.93 (0.76, 1.14)	0.48
	EBD	No. of ECC cases	Mean dmfs	β (95% CI)	*p* value	β (95% CI)	*p* value	β (95% CI)	*p* value
Mean dmfs[d]	<6	351	0.36	Ref	–	Ref	–	Ref	–
	≥6	163	0.44	0.07 (−0.02, 0.17)	0.13	0.06 (−0.04, 0.15)	0.23	−0.07 (−0.17, 0.03)	0.19

EBD, exclusive breastfeeding duration by months of offspring age; ECC, early childhood caries; dmfs, decayed, missing, and filled primary tooth surfaces. [a]Adjusted for maternal age before delivery, prepregnancy body mass index, residence, annual household income, education level, smoke exposure, parity, offspring sex, low birth weight, starting oral hygiene time. [b]Adjusted for maternal age at delivery, prepregnancy body mass index, residence, annual household income, education level, smoke exposure, parity, offspring sex, low birth weight, starting oral hygiene time, breastfeeding duration. [c]RR obtained from Poisson regression. [d]β coefficients obtained from multivariable linear regression.

Table 4. Associations of breastfeeding duration with early childhood caries stratified by exclusive breastfeeding duration[a]

	Exclusive breastfeeding duration by months of offspring age									*p* for heterogeneity
		<6				≥6				
	BD	no. of ECC cases	rate of ECC	RR (95% CI)	*p* value	no. of ECC cases	rate of ECC	RR (95% CI)	*p* value	
Prevalence of ECC[b]	6–11	126	0.12	Ref	–	36	0.13	Ref	–	–
	12–24	135	0.18	1.49 (1.16, 1.90)	0.002	110	0.17	1.36 (0.92, 2.00)	0.12	0.70
	>24	18	0.26	2.30 (1.40, 3.78)	0.001	15	0.20	1.67 (0.90, 3.09)	0.11	0.43
	–	–	–	p_{trend}	<0.001	–	–	–	0.07	0.44
	BD	no. of ECC cases	mean dmfs	β (95% CI)	*p* value	no. of ECC cases	mean dmfs	β (95% CI)	*p* value	*p* for heterogeneity
Mean dmfs[c]	6–11	126	0.31	Ref	–	36	0.31	Ref	–	–
	12–24	135	0.55	0.19 (0.06, 0.31)	0.004	110	0.50	0.16 (−0.03, 0.35)	0.09	0.82
	>24	18	1.09	0.76 (0.40, 1.12)	<0.001	15	0.36	0.01 (−0.34, 0.35)	0.97	0.003
	–	–	–	p_{trend}	<0.001	–	–	–	0.36	0.06

BD, breastfeeding duration by months of offspring age; ECC, early childhood caries; dmfs, decayed, missing and filled primary tooth surfaces. [a]Adjusted for maternal age at delivery, prepregnancy body mass index, residence, annual household income, education level, smoke exposure, parity, offspring sex, low birth weight, starting oral hygiene time. [b]RR obtained from Poisson regression. [c]β coefficients obtained from multivariable linear regression.

the measured confounding. Similarly, the elevated risk of ECC associated with breastfeeding for over 24 months, compared to less than 6 months, remains robust to unmeasured confounding that is more than twice the level of measured confounding.

No significant differences were observed in the distribution of education level, parity, or offspring sex between the included and excluded populations. However, mothers in the included population were more likely to have older prenatal age, higher BMI,

Table 5. Interaction analysis for the association of breastfeeding duration and exclusive breastfeeding duration with early childhood caries[a]

	Joint groups of BD and EBD	No. of ECC cases	Rate of ECC	Mean dmfs	β (95% CI)	*p* value	*p* for interaction
Mean dmfs[b]	BD ≤24 and EBD <6	333	0.13	0.35	Ref	–	<0.001
	BD ≤24 and EBD ≥6	148	0.16	0.44	0.08 (−0.01, 0.18)	0.09	–
	BD >24 and EBD <6	18	0.26	1.09	0.70 (0.39, 1.00)	<0.001	–
	BD >24 and EBD ≥6	15	0.20	0.36	0.00 (−0.30, 0.30)	0.99	–

BD, breastfeeding duration by months of offspring age; EBD, exclusive breastfeeding duration by months of offspring age; dmfs, decayed, missing, and filled primary tooth surfaces. [a]Adjusted for maternal age at delivery, prepregnancy body mass index, residence, annual household income, education level, smoke exposure, parity, offspring sex, low birth weight, starting oral hygiene time. [b]β coefficients obtained from multivariable linear regression.

higher annual household income, smoke exposure, conception with ART, live in urban, and have offspring with low birth weight compared to those in the excluded population (online suppl. Table 14). These findings suggest the possibility of selection bias in this study.

Discussions

In this longitudinal birth cohort study, we observed a significant association between breastfeeding duration and both the rate and severity (mean dmfs) of ECC. Notably, an interaction between overall breastfeeding duration and exclusive breastfeeding duration was identified in relation to mean dmfs, though such an interaction was not evident in the prevalence of ECC. In offspring breastfed for over 24 months, exclusive breastfeeding for the initial 6 months was associated with less dmfs.

In line with the results from our study, some former studies found that breastfeeding for over 12 or 24 months was associated with ECC risk elevation [12–14, 25–27]. A few studies also indicated that children who were breastfed for over 6 or 12 months had a lower risk of developing ECC compared to those who were breastfed for a shorter duration [26–29]. We considered the protective effect may account for the initial exclusive breastfeeding, which was observed in current study. Four observational studies found that there were no significant associations between exclusive breastfeeding duration and ECC [20, 30–32]. These findings may overlook the real relationships due to the retrospective design [20, 31] or inaccurate ECC assessment as children older than 6 years might have exfoliated some primary dentition [30], or ECC data were reported from parents [32]. Besides, all these studies did not adjust for breastfeeding duration when investigating the relationship between exclusive breastfeeding duration and ECC, which was considered as a strong confounder in our study. Our study is the first population-based cohort study to provide evidence that exclusive breastfeeding for the first 6 months could diminish the high risk of ECC among children breastfed for over 24 months. This finding suggests that breastfeeding the children according to the recommendation by WHO did not elevate the risk of ECC.

There are several potential explanations for the associations observed in our study from the aspect of behavioral influence. First, breastfeeding for over 12 months is considered to be associated with nocturnal breastfeeding on demand [14], while elevated nocturnal breastfeeding frequency is reported to contribute to ECC risk [33] because when breastfed at night, the offspring are less likely to have their teeth cleaned, and the breast milk can be held against the surfaces of the teeth by tongue, prolonging the exposure to the cariogenic bacteria [27]. Second, high frequency of breastfeeding can contribute to ECC [34]. The long contact of breast milk with teeth due to high frequency of breastfeeding has been shown to result in acidogenic conditions, leading to softening of enamel [33, 35]. Third, it was supposed that offspring who are breastfed for longer durations also have more frequent cariogenic food intakes [27, 34], but the reason remained unclear.

The composition of human breast milk is another aspect to explain the associations observed in our study. Evidence based on desalivated rat model indicated that

human breast milk was more cariogenic than bovine milk [36]. The high concentration of lactose found in human breast milk can reduce the pH of dental plaque, leading to ECC [36, 37].

In our study, we found that the cariogenic influence of breastfeeding became statistically significant at 12 months of offspring age. As most children have their first tooth erupted before the age of 12 months [38], breastfeeding beyond this point becomes a potential risk factor for ECC. Besides, we found insignificant associations between exclusive breastfeeding for the initial 6 months after birth and ECC. This was in line with a cluster randomized trial, where the intervention group received home-based individual peer counseling to support exclusive breastfeeding for 6 months and was not affected on the prevalence of ECC [39]. With the average age of the first primary tooth eruption being around 6 months [17, 38, 40], it is less probable for the human breast milk consumed by offspring before this age to contribute to the development of ECC.

The mechanisms through which exclusive breastfeeding in early age mitigates the risk of ECC caused by breastfeeding for over 24 months have yet to be fully understood. First, breast milk is known to contain immunomodulatory factors along with a rich microbiome, which can help establish the gut microflora of offspring and enhance metabolic health [41]. Notably, breast milk contains only lactose, without other free sugars like sucrose or glucose. Therefore, exclusive breastfeeding for the initial 6 months may offer a protective effect by promoting the development of a healthy oral microbiome in offspring [27]. In addition, previous studies have shown that a longer duration of exclusive breastfeeding is associated with a delayed introduction of foods or drinks containing free sugars [42, 43]. This delay in introducing free sugars may mediate the protective effect of exclusive breastfeeding duration on ECC.

The major strength of our study is the precisely evaluated breastfeeding status. We measured breastfeeding from two dimensions, duration and exclusivity. The three questionnaires administered at 6 months, 1 year, and 3 years of offspring age were designed with appropriate options to gather relevant information, and the study subjects were categorized based on their responses using a logical approach. Besides, the prospective design of our study avoids the recall bias, especially when evaluating breastfeeding status. Given the large sample size and precise evaluation of exposure and outcomes, the conclusions of our study are expected to have broad applicability.

The results of our study must be seen in light of some limitations. First, we did not collect data on offspring sugar consumption, which may be a significant confounding factor in the association between breastfeeding and ECC. Although the main results were compared before and after adjusting for sugar consumption before sleeping, this key limitation remains in our study. This is due to the limited data on sugar consumption before sleeping for only a small portion of the offspring, and the possibility that this data may not accurately reflect sugar consumption throughout the day. Future studies are recommended to use a validated dietary assessment method to collect data on sugar consumption. It is meaningful to fully investigate the role of sugar consumption in the associations between breastfeeding and ECC. Moreover, the observed differences in baseline characteristics between the included and excluded populations suggest the potential presence of selection bias in this study. The reasons for dropout could be multifaceted, including factors such as respondent migration and other circumstances. In addition, the data on nocturnal feeding and fluoride exposure were not taken into account, which may influence the results. However, since nocturnal feeding was considered to be on the causal path of breastfeeding status and ECC and fluoride exposure hardly could have an impact on the breastfeeding status, we supposed the results were still valid.

This study showed that breastfeeding duration over 12 months was associated with increased risk of ECC. Preventive interventions for dental caries should be implemented as early as possible, as breastfeeding is beneficial to children's health. The associations between breastfeeding duration and exclusivity with ECC should be investigated more thoroughly, particularly with adjustments for accurately measured sugar consumption.

Statement of Ethics

Ethical approval was obtained from the Institutional Review Board of Nanjing Medical University (protocol number NJMUIRB (2016) 311). All the adult participants had provided written informed consent at enrollment, and for the participants under the age of 18 years, written informed consent was obtained from the participants' legal guardian in the study.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

C.Z. conceptualized and designed the study, conducted statistical analysis, and wrote the manuscript. K.K. and K.Y. conceptualized and designed the study. H.L., S.T., R.Q., X.X., Y.D., B.X., and X.H. conducted research and collected the data. Y.J., T.J., H.Y., H.M., G.J., H.S., Z.H., and Y.L. critically reviewed the manuscript. J.D., H.W., and Q.H. had primary responsibility for final content. All authors have read and approved the final manuscript.

Data Availability Statement

The data underlying this article cannot be shared publicly due to the data protection and privacy of individuals who participated in the study. Further inquiries can be directed to the corresponding author.

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