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A longitudinal study of early childhood caries in 9- to 18-month-old Thai infants

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Abstract – *Objective:* To examine the rate and pattern of early childhood caries (ECC) development and to investigate the transitional changes of the carious lesions during a follow-up period of 3–9 months. *Methods:* A longitudinal observational community-based survey of 599 children, 9–18 months old. The children's dental examinations were first carried out at the age of 9 months with re-examination at 12 and 18 months by five dentists using standardized methods. The affected rates of dental caries were determined for prevalence, incidence density for risk of caries per person (ID_p) and risk by surface (ID_s). Changes in dental status over time were explored from unerupted (U) to sound (S), including enamel caries (D1), dentine caries (D2) and caries involving pulp (D3) by computing transitional probabilities. *Results:* The prevalence of caries was 2.0%, 22.8% and 68.1% among 9-, 12- and 18-month olds, respectively. The ID_p observed for newly affected children 9–12 and 12–18 months old was 10.32 and 15.70 persons/100 person-months, respectively. The ID_s for children 9–12 months old was 2.17 newly affected surfaces/100 surface-months whereas it was 2.22 surfaces/100 surface-months for children 12–18 months old. The buccal surface of maxillary incisors was the most affected (44.9%) followed by lingual, mesial and distal surfaces, respectively. The transitional probability of caries progression ranged between 1.79% and 15.38% during the follow-up period from 9 to 12 months old. It was 3.43–39.60% from 12 to 18 months old. *Conclusions:* An extremely high caries-affected rate was found among the study children even before the age of 18 months. The buccal surface of the maxillary incisors was the most affected. The teeth acquired caries at 3–6 months after initial eruption and carious lesions developed continuously over time.

Key words: early childhood caries; epidemiology; incidence density; prevalence; Thailand; transitional probability

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It is widely accepted that deciduous teeth are important, as they can influence the growth and development of children (1, 2). The most obvious oral disease among young children is dental caries, now known as early childhood caries (ECC) (3–5). The etiology of ECC is known to be multi-factorial (6–8). In developed countries, ECC is most prevalent among infants from deprived groups (9–11). The ECC development in children under 3 years of age could lead to long-term caries risk (12, 13). Among children with a high prevalence of ECC, especially in developing countries, ECC mostly develops early in life (14–16). Most of the previous studies of ECC development have been cross-sectional in design and restricted to a single observation of subjects to determine caries prevalence. Although they contained some descriptions of the incremental rate of caries development, the prevalence was calculated at different chronological ages, and the time-period of observation of each individual tooth was not included in the analyses. A longitudinal study is better able to follow the changes of dental caries progression, which addresses clearly understanding the rate of caries progression of each individual tooth and the probability of transitional changes over time in order to find an appropriate access-time for ECC prevention. The aims of the present study were to examine the rate and pattern of ECC development and to investigate the transitional changes of the carious lesions during a follow-up period from 9 to 18 months of age.

Materials and methods

The study was a longitudinal observational community-based study. It was designed in association with the national child health research project, Prospective Cohort Study of Thai Children (PCTC). The PCTC intends to follow infants from birth to 24 years of age, and study changes in their physical and behavioral development. Among the five study regions participating in the PCTC, the present study was confined to a southern cohort, which is located in Thepa district of Songkhla province, Thailand.

Population and sample

The study site in Thepa district, Songkhla province is located about 1000 km south of Bangkok. It has a population of 66 990. Of its seven sub-districts, six could be categorized as rural. The other sub-district is urban. Ninety percent of the population lives in the rural areas. They are predominantly Muslims (68%), 32% are Buddhists. The average annual household income is 68 931 Baht (1681 US$). Forty-five percent of the population is employed in rubber plantations, rice growing and fishing. The remaining, 20% are employees of non-agricultural businesses, 19% are farmers working on their own land and 16% are merchants and government officers. The fluoride concentration of drinking water in this area is low, ranging from 0.1 to 0.2 ppm (17). Each sub-district is served by one to two of the total 11 health centers and a district hospital. Dental care is only available at the district hospital; all dental services are provided by two general dental practitioners and two dental nurses. A total of 1076 children born between November 2000 and October 2001 and registered at one of these health centers or at the district hospital were set as the study population. During the sampling process, seven health centers and the hospital were selected to cover all of the seven sub-districts. The 795 infants registered at these faculties were recruited. This study has been approved by the National Ethical Committee, at the Ministry of Public Health. All eligible guardians of the infants in the study area were invited to join the PCTC and provide their consent for the infants to participate in a series of assessments including the oral health study.

Clinical examination

Dental examination appointments were made for all eligible subjects at the ages of 9, 12, and 18 months old. A second appointment was arranged within 1 month if the first appointment was missed. As a result the children were examined at a ±1-month interval around the intended examination age. The examination took place at the health centers, the hospital or in the village depending on convenience for the subject's caretakers. The subjects were examined in a knee to knee position. The teeth were examined with a WHO probe (no. 621) under natural light using a scoring system adapted from the WHO's criteria, 1997. The dental status of each examined surface was categorized as:

U = Unerupted surface; no part of the surface emerges to the oral cavity.

S = Normal enamel surface/texture and no restoration.

D1 = Initial caries/caries limited in enamel; the lesion demonstrates whitish/yellowish opaque with/without micro-cavity but no softened floor/wall.

D2 = Caries to dentine; cavitated lesion is seen to extend beyond enamel that certainly catches the probe with softened floor/wall of undermined enamel.

D3 = Caries involving pulp; a deep lesion with probable pulpal involvement or deep lesion with present/history of spontaneous pain/swelling/fistula opening.

The dental status data were collected by five dentists using standardized methods. Prior to the data collection, all examiners and recorders participated in a meeting to discuss the process of data collection and to study the dental examination criteria. Later a practical standardization was carried out at the university daycare center. The standardization was performed at tooth surface level. The range of the Cohen's Kappa coefficients of overall intra-examiner standardization ranged from 0.75 and 0.91 and the overall inter-examiners coefficients ranged from 0.68 to 0.89. The Kappa coefficients of intra-examiner standardization, only in surfaces with S and D1, ranged from 0.66 to 0.79 whereas the inter-examiner coefficients fell between 0.49 and 0.78. The level of reliability was maintained over the study period.

Statistical analysis

The data were checked for accuracy and entered in the computer using the SPSS® statistical program (SPSS Inc., Chicago, IL, USA). Frequency counts and cross-tabulations of the data were used to check for errors in data entry. Analysis first resulted in the reporting of descriptive statistics. The rates of dental caries were presented in prevalence, incidence density and transitional probability of carious lesions from one stage to another. The prevalence was the number of persons with carious teeth divided by the population at a specified time. The incidence was the number of new caries-affected teeth in a defined population, within a specified period of time. Incidence in the present study was calculated as incidence density for risk of caries of a person (ID_p) and of a tooth surface (ID_s) summarized by the formula below:

$$ID_p = \frac{\text{Number of new caries-affected subjects}}{\text{Total person} - \text{time at risk for having at least one caries lesion (person} - \text{month)}}$$

$$ID_s = \frac{\text{Number of new carious surfaces}}{\text{Total surface-time at risk (surface-month)}}$$

Person-time in ID_p and surface-time in ID_s was calculated by summing the observation-time of individuals/surfaces having no caries. For simplicity, we assumed that the teeth had a uniform hazard rate within each follow-up interval. For teeth that were present as sound at t_0 and t_1, the time at risk was $= t_1 - t_0$. For teeth which were absent at t_0, the time of eruption was assumed to be $(t_1 - t_0)/2$. For teeth that were present as sound at t_0 and became carious teeth at t_1, the onset of caries was assumed to take place at $(t_1 - t_0)/2$. Similarly if the teeth were absent at t_0 and became carious teeth at t_1, the eruption time was calculated to be at $(t_1 - t_0)/2$ whereas the onset of caries was assumed to be at $t_0 + 3/4(t_1 - t_0)$. In other words, the caries-free duration of these teeth was one-fourth of the interval. When a carious lesion was detected that person/surface was considered to be a new case for the period. It was then excluded from the at-risk status.

In addition to the ID analysis, we employed transitional probabilities computation dividing each tooth into five stages as unerupted tooth (U), sound tooth (S), enamel caries (D1), dentine caries (D2) and caries involving pulp (D3) in a series from U > S > D1 > D2 > D3. In this analysis, all the durations were ignored and the calculation was carried out for the whole mouth and broken down by tooth type, that is, incisors, canines and molars. The distribution of carious surfaces is presented in bar charts.

Results

Of the 795 recruited subjects, 196 (24.7%) were absentees. This was due to the unwillingness of their parents to participate in the study, inconvenience, the family moved out of the study area or the uncooperativeness of the children. Out of 599 attending the dental examination, 42 (7.0%) had only one examination; therefore this data was used only for the prevalence analysis. The remaining 557 (93.0%) were used for incidence density analysis. For transitional analysis only, 406 (67.8%) subjects who completed all follow ups were used (Table 1).

The prevalence of caries, which included all D1, D2, and D3 was 2.0%, 22.8%, and 68.1% among 9, 12 and 18 month olds, respectively. The average number of teeth in children of 9, 12 and 18 months was 2.2 ± 2.1, 5.5 ± 2.6 and 10.4 ± 3.6 teeth/child, respectively. The number of caries-affected teeth was 0.05 ± 0.39, 0.73 ± 1.6, and 2.82 ± 2.69 teeth/child, respectively. The incidence of caries, D1, D2 and D3, affected persons (ID_p) observed from the age of 9 to 12 months was 10.32 persons/100 person-months of observation whereas it was 15.70 person/100 person-months from the period of 12 to 18 months. The rate of new caries-affected tooth surfaces (ID_s) in the period from 9 to 12 months was 2.17 surfaces/100 surface-months of observation, whereas the ID_s in the period from 12 to 18 months was 2.22 surfaces/100 surface-months (Table 2).

Figure 1 shows the percentage of unerupted, sound and decayed lesions by tooth surfaces and tooth types. Decayed surfaces included all D1, D2 and D3. At the age of 9 months a few carious surfaces (0.3%) were observed on the buccal surface of upper incisors. At 12 months, 10% of the erupted surfaces were affected by caries. The majority of the lesions were located on the upper incisors, where 60% of the buccal surface and 30% of lingual surfaces were affected. By 18 months, 35.0% of the teeth and 14.9% of the surfaces were affected by caries. Buccal surfaces were the most affected surfaces (44.9%), followed by lingual

Table 1. Distribution of children by examination ages

Examination age (months)			Children attending examination *N*	%	Data analysis
9	12	18	406	67.78	Incidence density, transitional probability of caries attacked and prevalence of dental caries
9	12		75	12.52	Incidence density and prevalence of dental caries
9		18	62	10.52	Prevalence of dental caries
9			23	3.84	Prevalence of dental caries
	12	18	14	2.34	Incidence density and prevalence of dental caries
	12		5	0.83	Prevalence of dental caries
		18	14	2.34	Incidence density and prevalence of dental caries
		Total	599	100.00	

Aggregate totals for 9, 12 and 18 months = 566, 500 and 496, respectively.

Table 2. Frequency, incidence and rates of risk of caries-affected children/surfaces

	Observation period (months) 9–12	12–18
N (persons)	463	396
No. of new caries-affected cases	105	249
Person-months of observation	1 017.25	1 585.50
ID_p/100 persons at risk	10.32	15.70
N (surfaces)	11 315.00	23 159.00
No. of new caries-affected surfaces	504.00	2 107.00
Surface-months of observation	23 271.00	94 774.50
ID_s/100 surfaces at risk	2.17	2.22

(24.2%), mesial (20.0%) and distal surfaces (8.9%). The only posterior teeth present were first molars, 10.7% of them were carious teeth. Occlusal surfaces were the most affected surfaces (50.7%), followed by buccal (39.6%), lingual (8.4%) and distal surfaces (1.3%).

Table 3 shows the transitory changes in dental status over the 9- to 12- and 12- to 18-month periods. The calculation was based on a total number of 20 deciduous teeth. The dental status of the majority of cases in both periods remained unchanged while the probability of one-step progression from 9 to 12 months ranged between 12% and 18% but doubled at second follow-up at 18 months. The major transitory change with a two-step progression was observed from S at 12 months to D2 at 18 months (8.38%). A three-step progression was rare.

The transitional probability calculation by tooth type shows that from 9 to 12 months, 69.8% and 44.2% of maxillary and mandibular incisors had erupted, whereas the percentage of erupted canines and molars of both jaws ranged between 0.9% and 2.6%. Among newly erupted maxillary incisors, 9.5% had changed from U to D1 whereas 0.6% had changed to D2. In respect of sound teeth (S) at 9 months, 68.0% were still sound teeth whereas 27.1% and 4.9% had changed to D1 and D2, respectively. Of D1 teeth at 9 months, 77.8% had no progression, whereas 22.2% had changed to D2. For mandibular incisors, 0.9% of unerupted teeth were later seen to be D1 whereas 3.1% with normal enamel surface developed to D1.

The transitory changes during the second follow-up period at 12–18 months were in line with those from 9 to 12 months (Table 4). The majority of transitional changes were observed among maxillary and mandibular incisors. One-step changes among incisors ranged from 24.1% to 78.1%. Maxillary incisors suffered the highest caries attack rate. One-step caries progressions, S to D1 and D1 to D2, were observed in approximately 40% of the cases. The probabilities of two-step progressions among maxillary incisors were also high; and the transitions from U to D1 and S to D2 were 28.0% and 15.8%, respectively.

Discussion

The results of this study on prevalence of dental caries correspond with the results of many previous epidemiological studies (14–16). However, detailed dental caries development measurements in particular deciduous teeth have previously been less available. The rate of caries in the study population was extremely high. The prevalence of ECC rose sharply from 2.0% at 9 months to 68.1% at 18 months. These results raise similar concerns from a previous epidemiological study in Thailand where the prevalence of ECC among children in Suphan Buri province was 83% (14). As previously stated, early eruption may pose a higher risk of

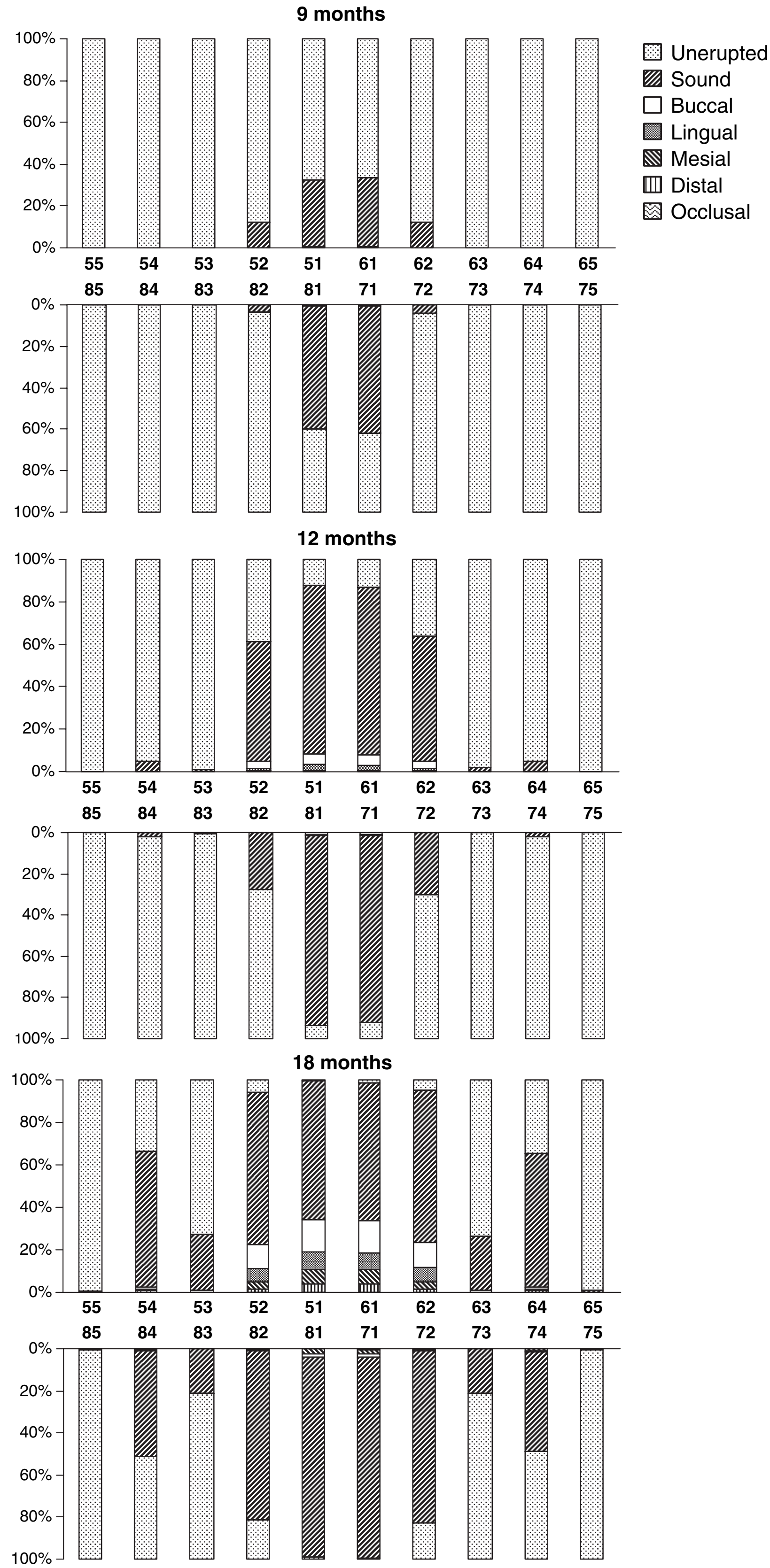

Fig. 1. The distribution of carious surfaces at the ages of 9, 12 and 18 months.

ECC (18). However, in this study population the average age of first tooth eruption was 8.53 months, whereas the average age of first tooth eruption among children in Bangkok is 7.5 months (19). Thus, tooth eruption did not occur early but the caries attacked rate was still very high.

Table 3. Transitional probability (%) of dental status of the whole mouth observed in the same children aged 9–12 and 12–18 months ($N = 406$)

Transitional status	Observation period (months)	
	9–12	12–18
U → U	79.96	60.39
U → S	18.13	35.51
U → D1	1.79	3.43
U → D2	0.11	0.67
U → D3	0.00	0.00
S → S	84.93	67.99
S → D1	12.86	23.62
S → D2	2.20	8.38
S → D3	0.00	0.00
D1 → D1	84.61	55.60
D1 → D2	15.38	39.60
D1 → D3	0.00	2.00
D2 → D2	100.00	77.42
D2 → D3	0.00	22.58
D3 → D3	0.00	0.00

U, unerupted; S, sound; D1, enamel caries; D2, dentine caries; D3, caries involving pulp.

Therefore, the higher risk is not explained by early eruption. By the age of 9 months an average of 2.2 teeth had already erupted; among these 0.05 teeth were affected by caries. The increasing number of caries-affected teeth was considerably higher than the increasing number of newly erupted teeth in the same period. This implies that the caries process starts as soon as the teeth emerge into the oral cavity. This is of significant interest and needs further investigation as a factor.

A cohort study is suitable for the calculation of an incidence rate and better characterizes the incremental rate of disease events. Incidence density was used in the study, as this more precisely estimates the rate of disease occurrences as it accounts for the varying times of follow up where the prevalence and incidence rates do not (20, 21). This is of importance as the length of follow up was not consistent for all participants. Some participants lost contact during the follow-up period, and some entered the study later than others. Moreover, the length of time between the two examinations was also different (3 versus 6 months) for the two periods.

The incidence density of caries-affected children sharply increased from 9 to 18 months. Among children unaffected by caries at 9 months, 22.7% were affected at the age of 12 months. Further, for those who were caries free at 12 months, 62.9% had acquired caries 6 months later at the 18-month follow up. This shows that susceptibility to caries in study children occurred in the first 3–6 months after the teeth had erupted into the oral cavity. To counteract the high caries rate among this high-risk population, a preventive program must be implemented early in life. To obtain the greatest benefit from the preventive program, it should commence at the time of tooth eruption or even before.

The analysis of carious surface distribution revealed that buccal surfaces of maxillary incisors were most affected. Lingual surfaces were next most affected, followed by mesial and distal surfaces. This confirmed the results of previous studies of caries manifestation of ECC (12, 13, 22). The high rate of caries attacks on buccal surfaces of maxillary incisors is known to be associated with both biological mechanisms and psychosocial behaviors (7, 8, 23). The mandibular teeth were less affected which is consistent with the findings of previous studies (14, 16).

Table 4. Transitional probability (%) categorized by tooth types observed in the same children aged 12–18 months ($N = 406$)

Transitional status	Maxillary teeth			Mandibular teeth		
	Incisors	Canines	Molars	Incisors	Canines	Molars
U → U	10.40	64.01	65.53	19.39	74.94	73.56
U → S	5.52	33.97	31.39	78.09	24.31	24.98
U → D1	28.00	1.90	2.50	1.65	0.76	1.32
U → D2	6.40	0.13	0.58	0.33	0.00	0.13
S → S	43.06	84.62	79.07	92.23	1.00	73.68
S → D1	41.12	15.38	16.28	6.63	0.00	15.79
S → D2	15.82	0.00	4.65	1.14	0.00	10.53
D1 → D1	52.73	0.00	0.00	76.67	0.00	0.00
D1 → D2	43.64	0.00	0.00	10.00	0.00	0.00
D1 → D3	2.27	0.00	0.00	0.00	0.00	0.00
D2 → D2	75.86	0.00	0.00	100.00	0.00	0.00
D2 → D3	24.14	0.00	0.00	0.00	0.00	0.00

U, unerupted; S, sound; D1, enamel caries; D2, dentine caries; D3, caries involving pulp.

Analysis of the transitional changes probability of caries susceptibility for the whole mouth shows that among study children there is a tendency for all teeth to demonstrate a rapid rise in caries susceptibility. These results demonstrate that new lesions develop not only as the child ages but more importantly, that the progression of caries lesions continues in the child's early years. Although the observation period of the subjects was limited to only 18 months of age, it is noteworthy to observe that during the 6-month follow up, a third of the enamel caries (D1) developed to be dentine caries (D2) and a fifth of dentine caries (D2) developed further to involve pulp tissue (D3). Based on this pattern, we would expect to see some of these D3 lesion teeth to be missing in the near future. As this study was carried out among children of 9–18 months, unerupted teeth accounted for the majority of the probability.

Maxillary teeth are more susceptible than mandibular teeth. Analysis by tooth type demonstrated that a rapid rise in caries susceptibility occurred in a rather short time as seen with maxillary incisors where around 9% of those unerupted teeth (U) at 9 months were enamel caries (D1) affected at 12 months. Although the nature of all caries development cannot be inferred from the present analysis, investigation is certainly needed to identify important associated factors in this rapid caries progression. A previous cross-sectional study among pre-school children in southern Thailand found that the high caries rate was related to oral hygiene, consumption of sweet milk, use of non-fluoride toothpaste, whether mothers or caretakers examined the child's teeth and socioeconomic status (24). Early colonization with mutans streptococci seems also to be an important risk factor as shown in a study by Bratthall et al. (25). It demonstrated that children in Bangkok who had oral streptococcus mutans colonization were more caries affected than remote hill tribe children who were mutans-free. The major route of the mutans streptococci transmitted to the children is from mothers (26, 27). Therefore, preventing cariogenic bacteria transmission from mothers to children would prevent ECC (28, 29).

An extremely high caries-affected rate was found among study children. The buccal surfaces of the maxillary incisors were the most affected. Generally, the teeth acquired caries at 3–6 months after initial eruption into the oral cavity and the carious lesions developed continuously over time. By the age of 18 months, a large proportion of children were affected by caries. Further investigation to identify risk factors of ECC development is needed.

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