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ORIGINAL ARTICLE

A seven-year survival analysis of caries onset in primary second molars and permanent first molars in different caries risk groups determined at age two years

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Abstract

Objective. To investigate in a group of children ($n = 183$) the effect of possible risk factors registered at the age of 2 years on caries development in 7 years of follow-up, and to study associations between risk groups. ***Material and methods.*** Consumption of candies, use of a nursing bottle at night, use of fluorides, toothbrushing, pacifier sucking, and prolonged breastfeeding (≥ 12 months) were recorded at the age of 2 years. The timing of caries onset in different groups was compared by applying a survival analysis method – the survival curves produced separately for selected teeth in different risk groups. ***Results.*** The survival curves of caries onset for both primary and permanent molars were consistently lower for children who consumed candies more than once a week, did not brush their teeth daily, were given a nursing bottle at night or a pacifier at age 2 years. The multivariate survival analysis confirmed that consumption of candies and lack of daily toothbrushing were the factors that had the major impact on caries onset in both primary and permanent molars. Prolonged pacifier sucking (≥ 2 years) was related only with short duration of breastfeeding. Children with prolonged use of a nursing bottle at night also consumed candies more than once a week, did not brush their teeth regularly, and did not use fluoride tablets. ***Conclusions.*** Consumption of candies and inadequate oral hygiene at age 2 years are important long-term risk factors for caries development in both primary and permanent molars.

Key Words: *Dental caries, feeding habit, oral hygiene, risk factor, sucking habit*

Introduction

Although many investigators have studied the risk factors for early caries development, only a few have examined how these factors materialize in a long-term follow-up. A recent longitudinal study in Finland has shown that early childhood risk factors of poor dental health, stable even at the age of 10 years, can be seen as high mean caries increments in the study groups [1]. In addition, a 6-years' prospective oral screening project in Belgium has confirmed the major impact of the caries status of the deciduous dentition and self-reported oral hygiene habits on the incidence of cavities in permanent 1st molars [2]. In shorter follow-up studies, similar findings have been reported of the effect of early lifestyle factors on caries development in primary teeth [3–5].

At the baseline of this longitudinal cohort study we found that pacifier sucking and use of a nursing bottle at night leads to increased caries activity in early primary dentition, as indicated by an increased occurrence of salivary caries-related micro-organisms [6]. A follow-up study later showed that this microbiologically determined caries activity was realized in terms of initial or manifest caries lesions in the following 2 years [7].

The aim of this study was to investigate, in the original study cohort ($n = 183$), the effect of possible risk factors determined at age 2 years for caries development in both primary and permanent dentition in a 7-year follow-up by applying a longitudinal survival analysis. Survival analysis methods provide summary curves of individuals, and make classical comparisons of the means of study cohorts more comprehensive (see Hannigan et al.) [8]. Development of caries in primary molars and in the 1st permanent molars was the indicator of the realization of caries risk. We also investigated the relationships between possible risk factors recorded at age 2 years, i.e. consumption of candies, use of a nursing

bottle at night, pacifier sucking, neglecting to use fluoride tablets, and a lack of toothbrushing.

Our hypothesis was that risk factors determined even in the early stages of development of dentition may lead to materialization of the risk in terms of caries development many years later, both in primary and permanent dentition, which should be clearly seen when novel survival analysis methods are applied.

Subjects and methods

Data collection and registration of caries

At baseline, this study was part of a large infection survey investigating the connection between pacifier sucking and susceptibility to otitis media infections. The size of the study population was determined on the basis of the prevalence of otitis media infections. One-hundred-and-eighty-three preschool children (aged 1–4 years) were entered in the study, which was conducted at 11 daycare centers in the town of Oulu, Finland. To control the wide age range, we did the baseline study separately in two age groups [6]. Age was also included in the multivariate analysis, both in the baseline study and in the first follow-up study [6,7]. In the present study, the status of risk factors was determined in the study population at the age of 2 years and the development of caries was examined annually as long as this was possible for each individual. In the analysis of our data we used the survival analysis method, which allows the use of different lengths of follow-up [9].

The Finnish dental care system enables re-analysis of the results of different clinical trials with a long follow-up time retrospectively, because all Finns under the age of 18 years are entitled to dental services in municipal health centers free of charge, and most avail themselves of this privilege. The dental records of all the subjects who participated in the cohort study are therefore available for retrospective analysis of the outcome as entered in the records of the health centers.

In the present cohort study, the information on the development of caries during the follow-up was collected from the children's dental health records in the files of dental health-care clinics in Oulu. The data on 183 children were collected first at baseline, when the children in the study cohort were 2.5 years of age (range 0.7–4.3 years), and then after about 7 follow-up years (range 2.0–8.9 years), when the mean age of the children was 9.6 years (range 3.1–12.7 years). Personnel at the clinics were unaware that this follow-up re-analysis was in progress. Dental examinations were carried out annually by the local health center dentists in accordance with normal routines, and the findings were recorded on standard national oral health patient documents. X-ray pictures were not taken routinely, but only

when considered necessary. The criteria used for caries diagnosis were those given by the National Board of Health in Finland following the criteria of the World Health Organization [10]. According to those instructions, caries was recorded as initial when it was restricted to the enamel and could probably be stopped with preventive means. Manifest caries lesions were defined as those that had extended to the dentin and needed restorative dental care.

The information on the possible risk factors was collected from questionnaires filled in by the parents at the baseline of this cohort study and also from the children's dental health records in the files of dental health centers in Oulu. Consumption of candies, use of fluoride tablets, toothbrushing, pacifier sucking, and use of a nursing bottle at night at the age of 2 years were recorded. Breastfeeding was defined as prolonged when lasting for 1 year or more.

The socio-economic status of the study population determined in our earlier study had no effect on caries development at the follow-up [7], so we did not re-record it in the present study.

The Municipal Health Board of Oulu approved the study protocol and granted us permission to use the children's dental health records.

Statistical analysis

Survival probabilities, i.e. time to caries onset leading to dental restoration, were estimated using the Kaplan-Meier survival analysis method. Information for the survival analysis was available for 175 of the original 183 children. The survival time for each individual tooth was the time elapsing between the birth of the child and the first restoration due to dental caries, i.e. the time caries had progressed to a stage when the dentist made the decision to perform a restoration [11–13]. In order to avoid the dependence problem inside the oral cavity, the Kaplan-Meier estimates for survival time were produced separately for each tooth in different risk groups. These represented the proportion of new restorations at a certain point in time and are expressions of the speed and timing of caries attacks.

Because the exact onset of caries initiation is not known, since it may have occurred at any time between birth and the first dental examination, we recorded it as having taken place at the first examination ("interval-censored"), if recorded then. All sound teeth were "right-censored" after the last examination. Survival analysis provides a summary curve of individuals at their actual ages as long as they are followed, instead of means of a group of subjects during the follow-up of these groups.

One tooth on one side of each mouth was chosen to represent the individual in the significance tests. In primary dentition we investigated the 2nd molars on the right side of the maxilla and on the left side of

the mandibula as indicators of the oral health of the subject. Likewise, in permanent dentition the right maxillary 1st molar and the left mandibular 1st molar were used as indicators. High caries suscept-ibility of those teeth [11] justifies their value as indicators of oral health.

The survival analyses were performed using the SAS statistical package (v. 9.1) and comparisons between the survival curves were tested using the log-rank test. The statistical significance was set at $p < 0.05$ (5%). The outcome variable evaluated was time from birth of the subject to caries, defined as the first restoration due to caries in the primary 2nd molars and permanent 1st molars. To examine the covariates simultaneously, the data were also ana-lyzed using Cox proportional hazards regression analysis with the survival time of an individual tooth as the outcome.

The relationships between different possible risk factors were studied by cross-tabulation. Risk factors recorded at age 2 years were determined as follows: consumption of candies more than once a week, use of a nursing bottle at night, use of a pacifier, lack of daily toothbrushing, and non-use of fluoride tablets. The borderline of breastfeeding was speci-fied as 1 year or less. Direct univariate associa-tions were analyzed by cross-tabulation of the dichotomous variables. Possible associations were analyzed by calculating the odds ratios (OR) and 95% confidence intervals (CI). The Fisher exact test and the chi-square test were used to compare differences. The data for all subjects for whom

information about risk factors was available were used in the univariate analysis. Information about pacifier sucking at age 2 years was available for 164 children, as was use of a nursing bottle at night for 171 children. The statistical analyses were carried out using SPSS statistical software (v. 11.5; Chicago, Ill., USA).

Results

At the onset of this dental health follow-up, 23.8% of the children in the cohort consumed candies more than once a week, 21.1% used a nursing bottle at night, 55.4% were still sucking a pacifier, 73.7% were using fluoride tablets, and 88% brushed their teeth daily. Thirteen per cent of children were breastfed 1 year or more. At age 2 years, the caries prevalence of the subjects was 10.8% ($n = 17$), but as many as 16 had initial caries and only 1 had manifest caries. Four years later, at age 6 years, 33.7% of the children exhibited one or more manifest ($n = 57$) carious lesions in the primary dentition. The mean DMFT was 0.2 (SD $= 0.90$) at age 7 years and 1.1 (SD $= 1.7$) at age 10.

The survival curves for the primary 2nd molars decreased faster during the whole follow-up for children who consumed candies more than once a week, used a nursing bottle at night, and whose teeth were not regularly brushed at the age of 2 years (Figure 1). The probability of survival for the primary 2nd molars was about 70% at age 6 years in the group that consumed candies, compared with
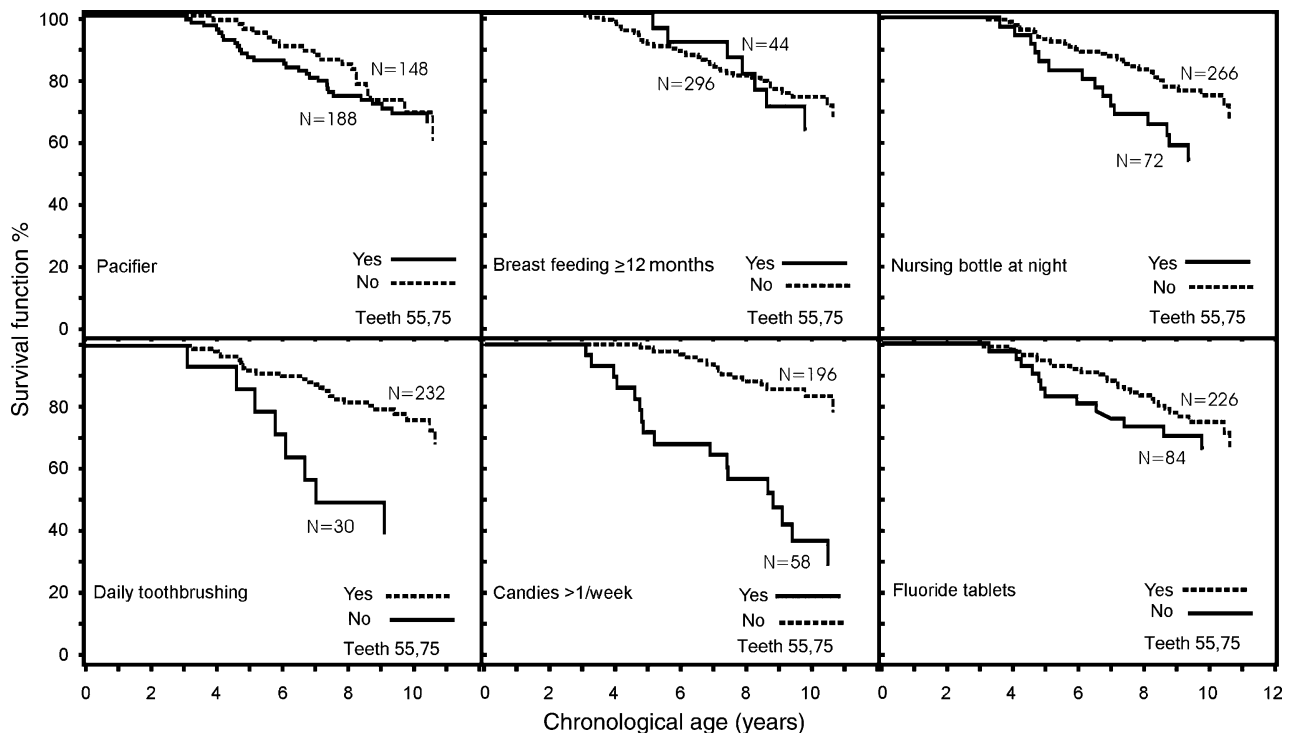

Figure 1. Survival curves for caries onset in primary 2nd molars calculated by chronological age in different risk groups registered at age 2 years.

97% in the children who did not (Figure 1). There were significant differences in the survival curves of the children who used a nursing bottle at night ($p = 0.002$), or whose teeth were not regularly brushed ($p < 0.001$). Shorter survival times were also seen in the children who used a pacifier or who did not use fluoride tablets. Those differences were not statistically significant. Prolonged breastfeeding (≥ 12 months) had no effect on caries onset in terms of survival estimates.

Differences in the rate of caries onset were also seen in permanent 1st molars (Figure 2). The survival times were significantly shorter in the children who used a pacifier ($p = 0.049$), a nursing bottle at night ($p = 0.001$), or who did not brush their teeth daily ($p < 0.001$). The survival estimate was also shorter in children who consumed candies, but the difference was not statistically significant. The use of fluoride tablets and breastfeeding for more than a year did not affect the Kaplan-Meier estimates of caries onset in the 1st permanent molars (Figure 2).

The differences in survival times among different risk groups are summarized in Tables I and II. The occurrence of caries in children with certain risks was significantly different from children without risks for both primary and permanent teeth; children with low risks remained caries-free for a longer period than children with risks at baseline. For the primary 2nd molars, the mean survival time for the children who consumed candies at the baseline was 7.8 years, and for children who did not, 10.1 years.

Table I. Summary of mean survival times for primary 2nd molars in different risk groups with p-values tested by log-rank test

Risk at baseline	Mean survival time in years	p-value
Pacifer		
Yes	9.10	0.588
No	9.61	
Breastfeeding		
Yes	9.01	0.576
No	9.47	
Nursing bottle at night		
Yes	8.01	0.002
No	9.63	
Daily toothbrushing		
No	7.28	<0.001
Yes	9.65	
Candies		
Yes	7.83	<0.001
No	10.06	
Fluoride tablets		
No	8.53	0.196
Yes	9.65	

This difference was statistically significant for the log-rank test: $p < 0.001$. If a child's teeth were not brushed daily, the mean survival time was 7.3 years compared to 9.7 years for children whose teeth were brushed daily ($p < 0.001$). Shorter survival times for the permanent 1st molars in certain risk groups are given in Table II.

The results of the Cox proportional hazards regression analysis showed that statistically most
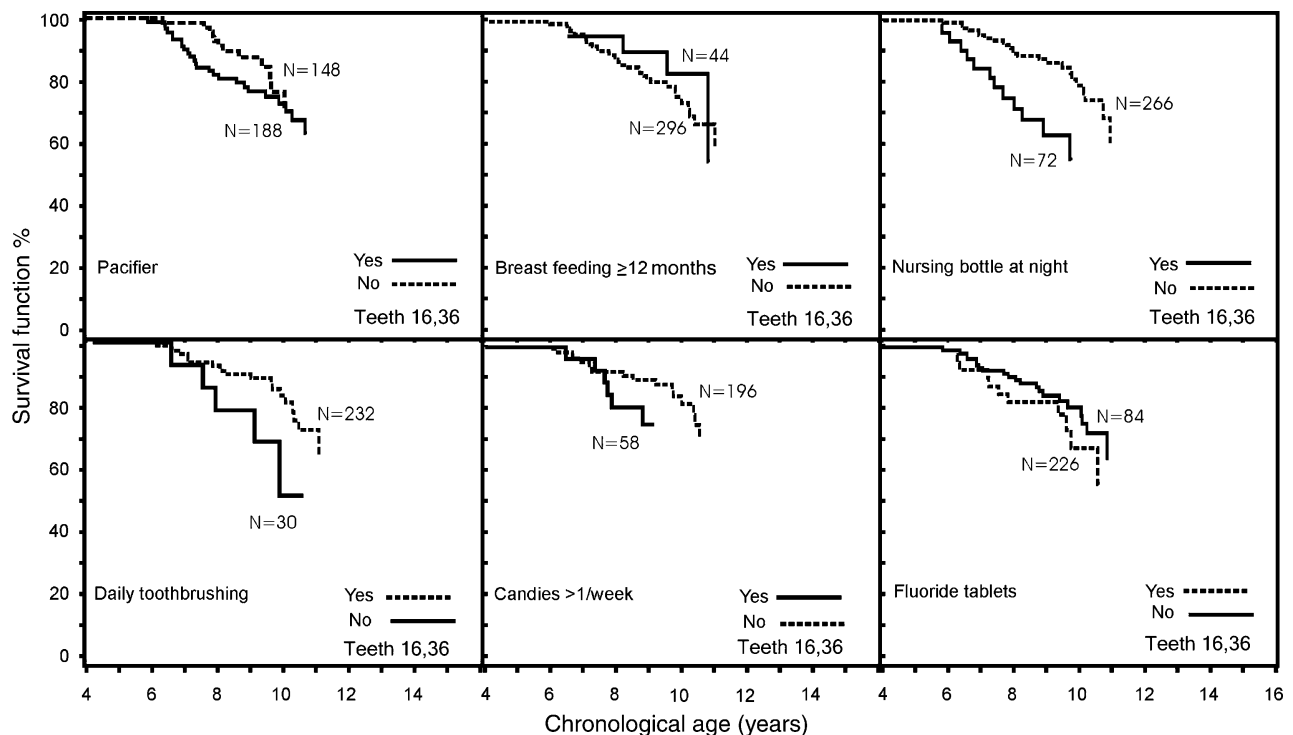

Figure 2. Survival curves for caries onset in permanent 1st molars calculated by chronological age in different risk groups registered at age 2 years.

Table II. Summary of mean survival times for permanent 1st molars in different risk groups with *p*-values tested by log-rank test

Risk at baseline	Mean survival time in years	*p*-value
Pacifer		
Yes	9.99	0.049
No	10.50	
Breastfeeding		
Yes	10.42	0.283
No	10.28	
Nursing bottle at night		
Yes	9.48	0.001
No	10.45	
Daily toothbrushing		
No	9.73	<0.001
Yes	10.47	
Candies		
Yes	10.03	0.067
No	10.21	
Fluoride tablets		
No	10.43	0.888
Yes	10.07	

significant hazard ratios (HR) with onset of caries in tooth 55 were use of candies more than once a week (HR = 6.83, *p* < 0.001) and absence of daily toothbrushing (HR = 4.39, *p* = 0.009). The same risk factors were significant also in tooth 75; with candies, HR = 8.18 (*p* < 0.001) and with toothbrushing, HR = 2.74 (*p* = 0.043). According to Cox's multivariate model, use of candies was the most significant risk factor in tooth 16 (HR = 3.80, *p* = 0.025) and lack of daily toothbrushing in tooth 36 (HR = 3.39, *p* = 0.011).

Analysis of the relationships between different risk factors showed that use of a pacifier was significantly associated with breastfeeding. The children who still used a pacifier at the age of 2 years were breastfed for less than 1 year (Table III).

When prolonged use of a nursing bottle at night was analyzed, more associations with other caries-related habits were found. According to the univariate analysis, children who still used a nursing bottle at night at the age of 2 years consumed candies more often, did not use fluoride tablets, and did not brush their teeth daily (Table IV).

Discussion

We used a survival analysis method to demonstrate the materialization of caries risk in primary and permanent 1st molars. The benefits of this method, especially in longitudinal caries research, have been shown in many studies [11–14]. The possibility of censoring the data is one of the main benefits of survival analysis [9]. The exact timing of the onset of caries is impossible to determine; it can be either left-censored at onset of the follow-up or interval-censored to have occurred on that occasion, regardless of its correct timing. If the birth of the subject is the first "examination", interval-censoring is often appropriate in young children because the real onset and censored onset are so close to each other. Censoring also occurs when incomplete information about survival time is available for some individuals. Survival analysis has an advantage over conventional statistical methods, as it includes censored observations in the analysis of the data [8]. In our study the right-censored observations comprised subjects who did not reach a disease endpoint, i.e. they did not develop caries during the 7-year period of the study or they were left out of the follow-up.

In our study, survival analysis was used in the 7-year follow-up to longitudinally describe when caries onset occurred in the indicator teeth in the different risk groups. Recently, other investigators have used the same method when investigating risk factors for caries development in children [15,16]. Our results are in line with those of a recent study by Leroy et al. [2], where the survival model was also applied. Brushing frequency, consumption of sweets, sugar-containing drinks, and fluoride use were the main factors influencing caries risk in permanent 1st molars in a 6-year follow-up.

The main factor associated with shorter survival times in both dentitions was consumption of candies at age 2 years. This concurs with the results of a previous Finnish study reporting that the main risk factor for caries development in primary dentition in children from 3 to 6 years of age was daily sucrose intake that had started as early as 3 years of age [5]. In an earlier Swedish study, consumption of candies more than once a week was also an important

Table III. Associations between prolonged pacifier sucking and other risk factors reported at the age of 2 years with odds ratios (OR), 95% confidence intervals (CI) and *p*-values

	Pacifier in use		OR	CI	*p*-value
	Yes, % (*n* = 91)	No, % (*n* = 73)			
Candies more than once a week	30	18	2.0	0.8–4.6	0.117
Nursing bottle at night in use	25	18	1.6	0.7–3.4	0.251
Breastfeeding <12 months	96	75	7.3	2.4–22.8	<0.001
Non-use of fluoride tablets	29	24	1.3	0.6–2.6	0.542
No daily toothbrushing	11	15	0.7	0.3–2.1	0.584

Table IV. Associations between prolonged use of a nursing bottle at night and other risk factors reported at the age of 2 years with odd ratios (OR), 95% confidence intervals (CI), and p-values

	Nursing bottle at night in use				
	Yes, % ($n = 91$)	No, % ($n = 73$)	OR	CI	p-value
Candies more than once a week	38	19	2.5	1.0–6.6	0.054
Pacifier in use	64	53	1.6	0.7–3.4	0.251
Breastfeeding <12 months	92	86	1.8	0.5–6.6	0.346
Non-use of fluoride tablets	43	23	2.6	1.1–6.0	0.021
No daily toothbrushing	25	8	3.6	1.2–11.4	0.021

predictor for developing manifest caries between 2.5 and 3.5 years of age [4].

Prolonged use of a nursing bottle at night was a significant risk factor for caries development in both primary and permanent molars in our study. Similar findings in primary teeth have been reported by other researchers in different countries [3,17,18].

According to the multivariate analysis, caries onset was significantly associated with lack of daily toothbrushing in both primary and permanent molars. The findings of the present study are in line with the results of other studies showing that oral hygiene is strongly related to caries development in children [3–5,19,20].

The present study confirms investigations in other studies showing that the effect of fluoride tablets is associated to some extent with caries onset in primary molars, but no associations were found in permanent molars [21,22]. Perhaps the positive fluoride effect at 2 years of age is not as long-lasting as are the negative effects of the risk factors.

Prolonged breastfeeding (≥12 months) did not have a pronounced impact on the survival times in our study. The results of other studies concerning the association between breastfeeding habits and caries prevalence are contradictory. In some earlier studies no correlation has been found between breastfeeding and caries prevalence [23,24], whereas others have demonstrated an association between prolonged breastfeeding and caries [25,26].

In our earlier studies we found that prolonged use of a pacifier was a risk factor for higher caries activity [6] in preschool children and for early caries development, too [7]. In the present study, shorter survival curves were shown for children who used a pacifier at the age of 2 years. Larsson [27] was one of the first to find an association between the use of a pacifier and higher caries development. Later, Wendt & Birkhead [26] found that a pacifier may have an effect on higher caries development in infants and toddlers.

Prolonged use of a pacifier was associated only with the duration of breastfeeding, a fact also seen in the study by Paunio et al. [28], who found that children who had been breastfed for a shorter time had a significantly higher need to suck a pacifier.

Since pacifier sucking was not associated with other behavioral caries risk factors, it may be an independent factor that alters the circumstances in the oral cavity in a more caries-active direction, as was the case with the present study cohort at age 2 years, when aciduric lactobacilli and candida increased in saliva [6]. In contrast to pacifier, prolonged use of a nursing bottle at night was related to several other risk factors, confirming that dental caries in children is mainly a lifestyle disease caused by various caries-promoting habits [1–4].

In Finland, radiographs are not routinely taken of children for caries examination. As our study had a practice-based research approach, this arrangement may be accepted. However, we know that X-rays have been shown to improve the diagnosis of approximal lesions [29,30]. Lack of radiographic examination naturally reduces the prevalence of caries and may have lengthened the survival times.

In the present study, information on caries development was collected from the public health records. Several dentists carried out the examinations, and intra- and inter-examiner differences were naturally not calculated. This may have had an effect on the results. On the other hand, Hausen et al. [31] showed that the data collected from public health records are not decisively inferior to those obtained from examinations by trained examiners. As the criteria for caries onset in our study were manifest caries and the dentist's decision to restore it, this may provide assurance that the prevalence of caries is not too high and is clinically significant.

We conclude that consumption of candies more than once a week at the age of 2 years and inadequate oral hygiene are important risk factors for caries development in both primary and permanent molars. Prolonged (≥2 years) use of a nursing bottle at night, pacifier sucking, and non-use of fluoride tablets are also possible risk factors, seen as shorter survival times.

Clinically, it is important to know that it is possible to determine significant risk factors for caries development in both primary and 1st permanent teeth in children as early as at age 2 years. Information collected at toddler age is therefore of great value when making plans for the future of children's dental health care.

Acknowledgments

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