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Impact of caries onset on number and distribution of new lesions in preschool children

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Background. Caries in preschool children remains an important public health issue.

Aim. To determine (i) which teeth and tooth surfaces are most susceptible to dental caries by age 3, (ii) where do caries lesions develop during 2-year follow-up, and (iii) to evaluate the impact of caries onset on the distribution of new caries experience.

Design. One thousand and fifty seven consecutively born children were recruited in Flanders (Belgium). Parents completed validated questionnaires on oral health-related behaviour and trained dentists examined the children at ages 3 and 5.

Results. Children with visible caries experience at age 3 were significantly more vulnerable in developing additional caries during follow-up. In this group, new caries experience developed primarily in the occlusal and distal surfaces of the mandibular first molars and the occlusal surfaces of the maxillary second and first molars, whereas in the caries-free group, the occlusal surfaces of both mandibular and maxillary second molars ranked first.

Conclusions. This paper confirms the higher vulnerability for further caries development in those children with caries experience at age 3. Visible caries develops most frequently in the occlusal surfaces of the second molars: in high-risk children already by age 3 and in children who were caries free at baseline by age 5.

Introduction

Also in the 21st century, a considerable proportion of young children still suffer from dental caries and its consequences, as was documented in several countries[1–5]. Hence, dental caries remains an important public health issue nowadays.

In order for oral healthcare providers to deliver effective preventive (and restorative) treatment to young children in good time, it is not only necessary to have a basic understanding of the risk factors involved, but also to get an insight into the distribution of dental caries in the primary dentition. Earlier studies pointed out that especially primary molars and maxillary incisors are very susceptible[6–9]. Primary molars show the highest attack levels in pits and fissures, and when also the proximal surfaces are involved, the mesial surface of the second and the distal surface of the first molar are most frequently affected[7,10,11].

When children of different age groups are compared, it is apparent that in 3-year-olds, the most affected teeth are the maxillary central incisors, whereas in the 5-year-olds, it concerns the mandibular molars[12], which may suggest that early childhood caries corresponds to the order of tooth emergence[13].

So far, only few prospective studies on caries incidence in preschool children have been performed. They illustrate that children with caries experience at baseline are significantly more prone to subsequent caries development and hence should be considered high-risk children. But they also point out that children who were classified caries free at baseline may develop caries lesions during follow-up[14–16]. Up to now, it has not been well documented in which teeth and more precisely in which tooth surfaces new caries lesions develop over time in the primary dentition of preschoolers with and without caries at baseline. Therefore, the following research

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questions were addressed in this study: Which teeth and which tooth surfaces are most susceptible to dental caries development by age 3 and in which teeth and tooth surfaces do new caries lesions develop during a follow-up period of 2 years? Is there an impact of timing of caries onset on the distribution of lesions in primary teeth?

Material and methods

Study population

This study was imbedded in the 'Smile for Life – Tandje de Voorste' project, an oral health intervention programme that was implemented within the frame of the well-baby clinics organised in Flanders by the governmental organisation Kind & Gezin ('Child & Family'). The well-baby clinics offer preventive, medical, and educational guidance to parents of young children (from birth until the age of 3 years). The advantage of this study frame was that data were not only collected through oral examinations and questionnaires completed by the parents, but additional information was also obtained through registrations by the nurses and physicians of the well-baby clinics during the very first years of the participants' life. The study population presented here consisted of 1057 children, selected in two distant geographical areas in Flanders; these children served as control group for the evaluation of the intervention. As no intervention was offered to these children, the 'natural' evolution of oral health and related parameters could be investigated from birth up to the age of 5 years. Although attendance of well-baby clinics is not compulsory, the participation level in 2003 and 2004 (the years of recruitment for the study) was 97% for the home visits (n = 4) and ranged between 84% and 86% for attendance at consultation offices (n = 11).

As in each region about 1000 children had been born annually in the years preceding the project, it was decided to recruit during one half-year to secure a study population of at least 500 consecutively born children in each region; recruitment started 1 October 2003. During the first home visit, shortly after birth, the nurses of Child & Family informed the parents about the project and invited them to participate, to sign an informed consent, and to complete a questionnaire. A child was not adopted in the study population if parental language skills were insufficient to complete the questionnaire, if the child had one of the predefined congenital and/or acquired general health problems with possible oral health impact (e.g., down's syndrome, congenital cleft of lip, and/or palate), if the parents did not attend the well-baby clinics, or if they moved out of the region shortly after birth. In addition, in case of twins, only the child whose name was alphabetically ranked first was adopted in the study population.

Questionnaire and/or clinical data were collected at three occasions: shortly after birth (October 2003–July 2004), at age 3 (February–June 2007), and a third time at age 5 (March–June 2009). For data collection at 3 and 5 years of age, kindergartens were the most convenient setting. In Flanders, children can attend kindergarten from 2.5 years on. Although attendance of kindergarten is not compulsory, over 99% of 3-year-olds and 98% of 5-year-olds living in Flanders attended kindergarten in the school year 2002–2003 (source: Ministry of the Flemish Community, Education Department). Hence, to retrieve as many toddlers as possible at ages 3 and 5, parents were asked during the last consultations at the well-baby clinic which kindergarten their child would attend.

Ethical approval

The study protocol was approved by the Medical Ethics Committee of the Katholieke Universiteit Leuven, Belgium.

Clinical examination

The oral health examinations were carried out at age 3 and 5 years in kindergarten, with the children sitting on an ordinary chair. Parents were not informed about the exact date of the oral examination, so that no extra brushing could be performed. Examinations were performed by six (2007) and five (2009) trained dentist examiners; all examiners participating in 2009 had been involved in

2007. In 2009 the examiners had no access to the 2007 data. Before each examination period, all examiners received a specific training and participated in a calibration session. Afterwards the examiners received individual feedback from the benchmark scorer (last author). The sensitivity and specificity for caries experience scoring were estimated for each dental examiner *versus* the benchmark scorer as in recent research, the use of sensitivity and specificity scores rather than kappa scores for reporting interexaminer reproducibility in the presence of a gold standard has been advocated[17]. At the d_1 level, sensitivity scores (at tooth level) ranged between 0.39 and 0.49 in 2007 and between 0.62 and 0.87 in 2009, and specificity scores ranged between 0.95 and 0.98 in 2007 and between 0.97 and 0.99 in 2009.

Teeth were examined using a mirror with a built-in light source (Mirrorlite™ by Defend® from Medident, Sint-Truiden, Belgium), and a blunt WHO/CPITN type-E screening probe was available for the examiners in case they wanted to clean debris from a pit or fissure or they wanted to confirm the absence of a cavity. If felt necessary, teeth were cleaned and/or dried with cotton rolls before caries experience was recorded. Caries experience was scored according to the guidelines published by the British Association for the Study of Community Dentistry (BASCD)[18]. Upon the suggestions of the Bethesda workshop on early childhood caries, both noncavitated (= d_1) and cavitated caries lesions (= d-component of WHO-index) were recorded[19]. Dental caries lesions at the d_1 level were scored according to the criteria described by Fyffe *et al.*[20] No radiographs were taken as the screenings were not the part of routine oral examinations.

The examiners were assisted by a nurse or dental assistant, who entered the clinical data on site into an electronic database (Dental Survey Plus version 4.50B; Providence software).

Questionnaires

Parents completed questionnaires that rendered data on socio-demographical variables, and children's and parental oral health behaviours at birth (2003–2004), when the child was three (2007) and 5 years old (2009). The questionnaires also contained a letter explaining the purpose of the study; at the same time, permission was asked for an oral examination when the child had reached the age of 3 and 5. Questionnaire data were entered in excel files with data validation to minimise invalid data entry.

The socio-economic status of the child's family was assessed based on the reported maternal and paternal educational level; these data were collected at birth. Two categories were made: parents who did not continue educational training after primary and/or secondary school ('Primary or secondary school') and parents who completed higher education at the level of college, nonuniversity or university ('Higher education or University').

Data analysis

Clinical and questionnaire data were first converted and then merged into SAS® data files for further analyses (version 9.2)[21]. The difference in the development of new caries experience on the different surfaces of the primary molars and the maxillary incisors between children with and without caries experience at age 3 was analysed using Fisher's exact tests. In addition, *P*-values were adjusted for multiple testing to control the false discovery rate using the linear step-up method of Benjamini and Hochberg[22].

Results

Study population

Although recruitment had been scheduled to last only 6 months, it took eventually 8 months in one region and 10 months in the other to collect respectively 547 and 510 children meeting the inclusion criteria and whose parents consented to participate. During that time span, 768 and 886 babies had been born in these regions. In the two regions, 15 and 25 parents meeting the inclusion requirements refused collaboration in the study; the major reasons were indifference and lack of time. A flow chart with the number of children who entered the study and their

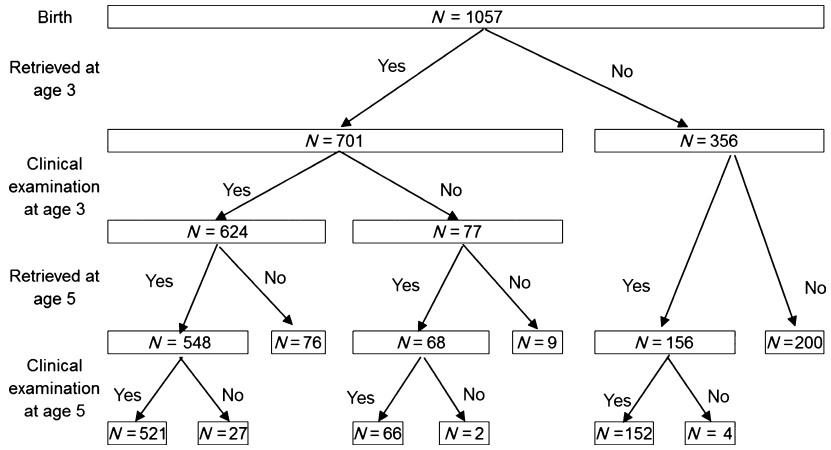


Fig. 1. Number of children who entered the study and their follow-up (retrieval and clinical examination) over the 5-year study period.

follow-up over the 5-year study period is documented in Fig. 1. Sixty-six per cent (n = 701) of the 1057 originally selected children were retrieved at age 3 and 73% (n = 772) at age 5. The main reason for missing data at follow-up was failure to identify the kindergarten the child attended; other reasons were illness or absence on the day of the examination. At age 3, oral examinations were performed in 624 (59%) children; 521 (49%) of them were also examined at age 5.

Responders versus nonresponders

To evaluate possible attrition bias because of missing data, baseline questionnaire data, collected shortly after birth of the child, were compared for responders (i.e., clinical examination performed at age 3 and/or 5) and nonresponders (i.e., no clinical examination at age 3 and/or 5). Significantly more parents responders reported a higher paternal educational level (i.e., higher education or university) and the use of interdental cleaning aids (e.g., dental floss, proximal brushes), whereas significantly more parents nonresponders reported the current use of a nursing bottle by their child. In addition, significantly more children who were examined at age 5 had mothers with a higher educational level compared with their peers who could not be retrieved for clinical examination.

Caries experience at age 3

Enamel and/or dentinal caries experience (i.e., $d_1mft > 0$) was observed in 139 (22%) 3-year-olds. The distribution of caries experience scores was very skewed: 70 children (11% of the total study population of 624) were responsible for 75% of all 335 teeth affected at the d_1 level (i.e., $d_1mft > 0$). In 26 of 31 children with overt caries experience (i.e., $d_3mft > 0$), no restorations were observed; no teeth had been extracted because of caries.

As is illustrated in Fig. 2, tooth surfaces most frequently affected by caries experience at the d_1 level were the occlusal surfaces of the mandibular (6%) and maxillary (5%) second molars, the occlusal surfaces of the mandibular first molars (3%), and the buccal sites of the maxillary central incisors (3%).

Caries experience at age 5

At age 5, enamel and/or dentinal caries experience was observed in 213 (41%) children. The distribution of caries experience scores was also skewed at this age: 76% of all 660 teeth with caries experience at the d_1 level were recorded in 100 children (i.e., 19% of the study population). In 73 of 134 children (54%) with caries experience at the d_3 level, no restorations were observed. In 11 (2%) children, teeth had been extracted because of caries experience.

Increment of caries experience between the examinations at age 3 and 5

Of the 521 children with clinical data at age 3 and 5, 404 children (78%) presented without visible caries experience at the d_1 level at age 3; these children will further in the text be

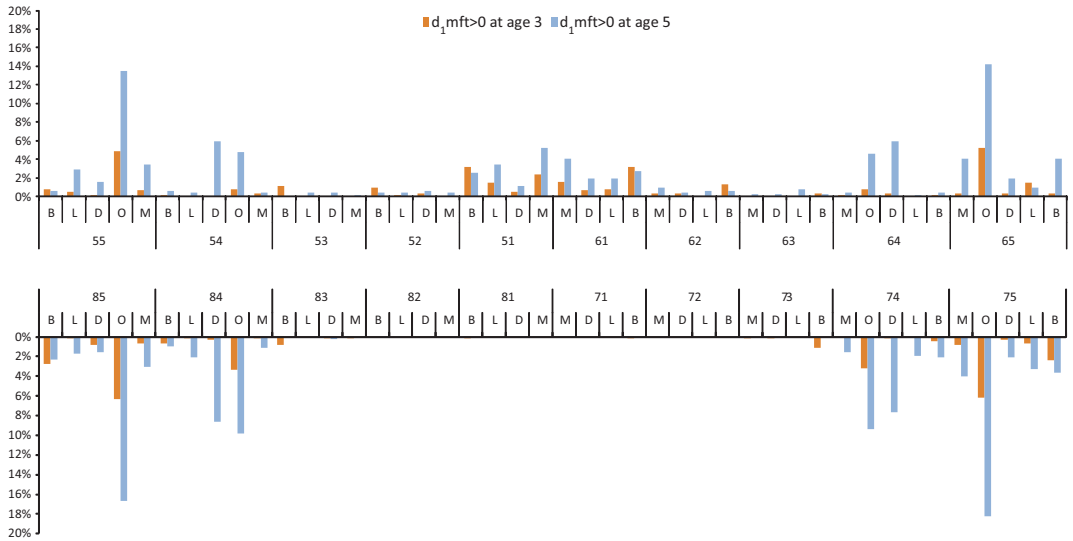


Fig. 2. Proportion of tooth surfaces affected by caries experience at the d_1 level (i.e., $d_1mft > 0$) at age 3 (n = 624) and at age 5 (n = 521).

denominated as caries-free children. In 136 (34%) of these children, visible caries experience (at the d_1 level) was scored at the age of 5; in 121 (30%) of them 1–4 teeth were affected and in 15 (4%) 5–8 teeth (Fig. 3). Caries experience was primarily recorded at the occlusal surfaces of the mandibular (13–14%) and maxillary (9–10%) second molars (Fig. 4). The prevalence of affected occlusal and distal surfaces in the mandibular (6% and 4–5%, respectively) and maxillary (2% and 4%, respectively) first molars was much lower.

Of the 117 children presenting with caries experience (at the d_1 level) at age 3, 68 (58%) had developed additional caries experience by the examination at age 5 (Fig. 3). These children will be called the high-risk group. Forty-three (37%) of them developed new caries lesions or received restorations in 1–4 teeth, 21 (18%) in 5–8 teeth, and 4 (3%) in more than eight teeth. In this group of children, the tooth surfaces most frequently affected by new caries experience (i.e., on tooth surfaces that were recorded as caries free at age 3) were the following: the distal and occlusal surfaces of the mandibular first molars (18–19% and 13–15%, respectively), the occlusal surfaces of the maxillary second molars (14–15%), the distal and occlusal surfaces of the maxillary first molars (11–14% and 13%, respectively), and the occlusal surfaces of the mandibular second molars (11–15%) (Fig. 4). Also on the maxillary central incisors, new caries experience was recorded on up to 8% of some tooth surfaces.

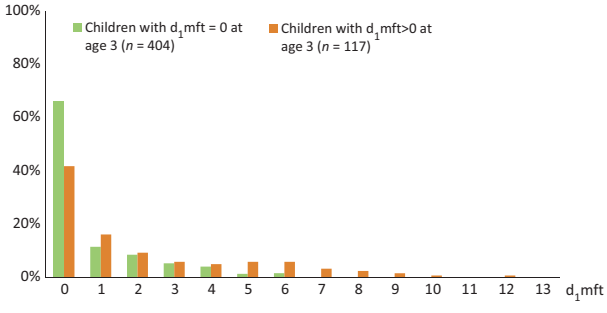
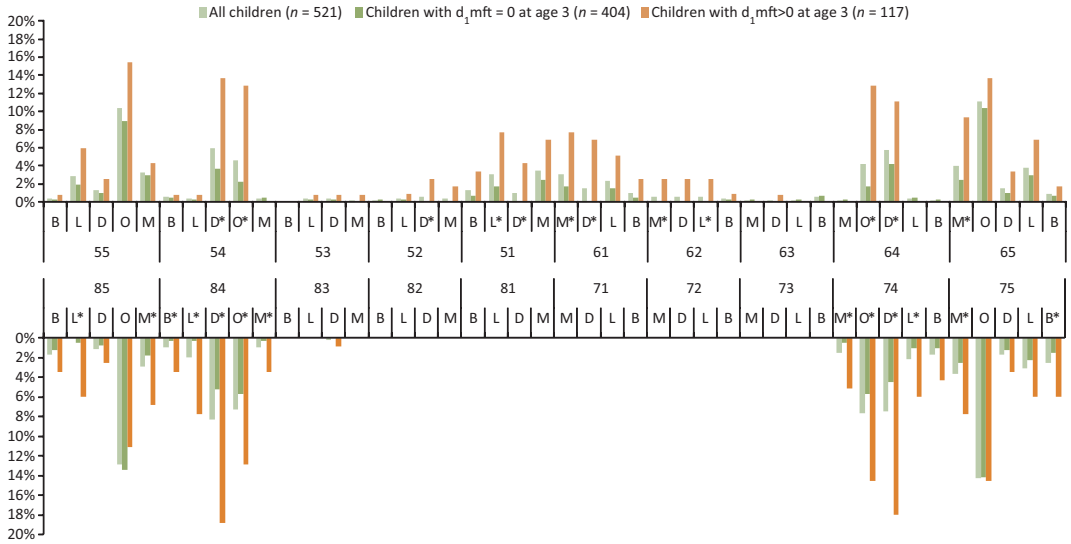


Fig. 3. Increment in caries experience at d_1 level between age 3 and 5 (n = 521).

Impact of caries onset on caries increment

When new caries experience in the two subgroups was compared, the proportion of affected teeth in the high-risk group (322/2334 or 13.80%) was triple that in the caries-free group (338/8053 or 4.20%) ($P < 0.0001$). Also at tooth surface level, in all but one surface (i.e., occlusal surface of the mandibular right second molar), the prevalence was substantially higher in the high-risk group. The differences between



*Indicates surface with statistically significant difference in new caries experience between those children with $d_1$mft = 0 versus $d_1$mft > 0 at age 3. *P*-values were adjusted to control for the false discovery rate using the linear step-up method of Benjamini and Hochberg (1995). The following *P*-values were obtained:tooth 54: distal surface: $p = 0.0019$, occlusal surface: $p = 0.0002$; tooth 52: distal surface: $p = 0.0284$; tooth 51: lingual surface: $p = 0.0129$, distal surface: $p = 0.0038$; tooth 61: mesial surface: $p = 0.0129$, distal surface: $p = 0.0001$; tooth 62: mesial surface and lingual: $p = 0.0284$; tooth 64: occlusal surface: $p = 0.0001$, distal surface: $p = 0.0284$; tooth 65: mesial surface: $p = 0.0113$; tooth 85: lingual surface: $p = 0.0038$; mesial surface: $p = 0.0284$; tooth 84: buccal surface: $p = 0.0284$, lingual surface: $p = 0.0001$, distal surface: $p = 0.0002$, occlusal surface: $p = 0.0339$, mesial surface: $p = 0.0284$; tooth 74: mesial surface: $p = 0.0113$, occlusal surface: $p = 0.0129$, distal surface: $p = 0.0001$, lingual surface: $p = 0.0137$; tooth 75: mesial surface: $p = 0.0459$, buccal surface: $p = 0.0309$.

Fig. 4. Proportion of tooth surfaces where new caries experience (at the d_1 level) developed between age 3 and 5 ($n = 521$).

subgroups were statistically significant in the mandibular first molars and in some surfaces of the maxillary first molars and incisors and the mandibular second molars (which is indicated with * in Fig. 4).

In addition, the analyses further disclosed that in the high-risk group, 18% (73/398) of new lesions were recorded in incisors and canines and 82% (325/398) in the primary molars; in the caries-free group, the respective proportions were 9% (45/490) and 91% (445/490).

Discussion

Enamel and/or dentinal caries experience was observed in 22% of 3-year-olds, overt caries experience (i.e., $d_3$mft > 0) in 5%. At the d_1 level, the most affected tooth surfaces were the occlusal surfaces of the mandibular and maxillary second molars, followed by the occlusal surfaces of the mandibular first molars and the buccal and mesial surfaces of the maxillary central incisors. Previously it was suggested that first primary molars were more frequently affected than second primary molars because they emerge earlier and consequently have a longer exposure time[4,23]; obviously, this hypothesis could not be confirmed in this study population. At follow-up after 2 years, tooth surfaces with the highest frequencies of new caries experience in the high-risk subgroup were the distal and occlusal surfaces of the mandibular first molars, followed by the occlusal surfaces of the maxillary and mandibular second molars and the distal and occlusal surfaces of the maxillary first molars. In the caries-free group, this ranking was slightly different with second molars showing higher caries experience than the first. These results illustrate that visible caries develops in the primary dentition most frequently in the occlusal surfaces of the second molars: in the high-risk group already detectable at age 3 and in the caries-free group by age 5. In high-risk children, particular attention should go to the distal and occlusal surfaces of the first molars and the mesial surfaces of the maxillary central incisors. These surfaces should be inspected carefully during clinical examination and may benefit from the application of a fluoride varnish; parents should also be instructed to brush these areas thoroughly.

In a prospective study in Swedish 2.5-year-old children, 92% of the children with caries experience at baseline developed new lesions during 1-year follow-up, compared with 29% of the children who were caries-free at baseline[14]. In this study, the differences between the two subgroups were not as extreme (58% *vs* 34%), yet they confirm earlier publications that children with early caries development are at higher risk for further caries development[14,16,24-26]. Other risk factors that may have a profound impact on the incidence of caries experience in preschool children, like socio-economic background, plaque accumulation, dietary, and oral hygiene habits, were not considered in this paper, because they were the main focus of a previous study performed in the same study population[26].

In the cited Swedish study, it was also pointed out that the subgroup with caries at baseline developed as often new lesions on anterior teeth as on molars, whereas in the group who was caries free at baseline, 67% of new lesions were recorded on molars and 33% on incisors and canines[14]. In this study, different proportions were observed: in the high-risk group 18% of new lesions were recorded in incisors and canines and in the caries-free group only 9%. Differences in disease levels, in socio-economic status of study samples, in dietary and/or hygiene habits, in patterns of fluoride application, in patterns of (preventive) dental attendance, in applied detection levels (d_3 *vs* d_1), in length of follow-up, and in applied methodology may be responsible for observed differences.

The observation that the distribution of caries experience scores in this sample of preschool children was very skewed (e.g., at age 3, 11% of the study population was responsible for 75% of all 335 teeth affected at the d_1 level), is in line with previous reports[15,27-29]. In Scandinavian studies, immigrant children comprised the majority of the group with affected teeth[15,29]. In this study, it was not possible to determine the ethnic background of the participants. Actually, as part of the data were collected through questionnaires, it was a prerequisite for participation in the study that at least one parent had sufficient language skills in Dutch (the language spoken in the northern part of Belgium). Hence, many children from immigrant background may for that reason have been excluded. So, although care was taken to collect within each region a study population of at least 500 consecutively born children to represent the population as well as possible, the sample may not be truly representative for the population of 3- and 5-year-olds living in those regions and certainly not for all children of that age living in Flanders.

In this study population of preschool children, the major parts of the $d_3$mft scores were made up of untreated caries lesions; the care index was equal to zero in 84% of children at age 3 and in 54% at age 5. These data are comparable to the data obtained in age-matched children in the same regions in 2003, when baseline information before the start of the intervention was collected[30]. They indicate that although since 2005 preventive and restorative dental treatment for young children is fully reimbursed in Belgium, the oral health of many preschool children with overt caries lesions did not benefit from this subsidy scheme. In the same study group, 62% and 21% of parents reported that their 3 and 5-year-old child had never visited the dentist[31]. Hence, there are more than just financial barriers that keep children away from professional oral care. These barriers should be further explored.

In this study caries experience was diagnosed at the d_1 level. Theoretically, teeth should be dried before caries experience is recorded at this threshold. Unfortunately, the field conditions (i.e., a class room in kindergarten) made it impossible to comply with this instruction. Moreover, it could be argued that the use of an airline to dry the teeth could lead to a reduced cooperation of the preschool children. As a result, caries experience may have been underscored and the differential diagnosis with enamel hypoplasia may have been hampered. In addition, it can be speculated that the number of affected posterior proximal surfaces would have been higher if bitewings had been taken. In a sample with low caries experience, it was estimated that 33% of 5-year-olds had at least one approximal enamel or dentin caries lesion that would not have been detected with-

out bitewing examination[32]. Furthermore, the exclusion of non-Dutch-speaking children and the higher loss to follow-up of lower socio-economic groups may also have contributed to an underestimation of the prevalence and incidence of caries experience.

In conclusion, children who presented with visible caries experience at age 3 were more vulnerable in developing new caries lesions during a 2-year follow-up period. At age 3, the most frequently affected tooth surfaces were the occlusal surfaces of the second molars. By age 5, new caries experience was primarily seen in the distal and occlusal surfaces of the first molars in the high-risk children and in the occlusal surfaces of the second molars in caries-free children.

Why this paper is important to paediatric dentists

- This paper confirms the sustained vulnerability for further caries development in those children who presented already at age 3 with caries experience.
- Visible caries (incl. initial lesions) develops in the primary dentition most frequently in the occlusal surfaces of the second molars: in ''high-risk'' children already at age 3 and in ''caries-free'' (at baseline) children by age 5.
- In ''high-risk'' children, distal and occlusal surfaces of first molars and mesial surfaces of maxillary central incisors need particular attention during clinical examination and may benefit from additional preventive interventions.

Conflict of interest

The authors declare no conflict of interest.

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