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Validation of an age-modified caries risk assessment program (Cariogram) in preschool children

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Abstract

Objectives. (i) To validate caries risk profiles assessed with a computer program against actual caries development in preschool children, (ii) to study the possible impact of a preventive program on the risk profiles, and (iii) to compare the individual risk profiles longitudinally. ***Material and methods.*** Caries risk was assessed in 125 two-year-old children invited to participate in a 2-year caries-preventive trial with xylitol tablets. At 7 years of age, 103 were available for follow-up, 48 from the former intervention group and 55 from the control group. At baseline and after 5 years, 7 variables associated with caries were collected through clinical examinations and questionnaires, and scored and computed with a risk assessment program (Cariogram). ***Results.*** Children assessed as having a "low chance (0–20%) of avoiding caries" had significantly higher caries at 7 years of age compared to children with a lower risk in the control group ($p<0.05$) but not in the intervention group. Overall predictive accuracy and precision, however, were moderate in both groups. Less than half of the children remained in the same risk category at both ages, despite a largely unchanged consumption pattern of sugar. The majority of the children who changed category displayed a lowered risk at 7 years. The intervention program seemed to impair the predictive abilities of Cariogram. ***Conclusion.*** A modified Cariogram applied on preschool children was not particularly useful in identifying high caries risk patients in a low-caries community.

Key Words: *Caries risk, mutans streptococci, sugar, toothbrushing*

Introduction

Caries risk assessment is a key element in the comprehensive management of the disease and, consequently, has gained a great deal of attention in the recent literature. As dental caries has a multifactorial etiology, the procedure requires that information on demographic, social, behavior, and biological factors is taken together to form a caries risk profile or risk category [1]. As an aid for clinicians and a didactic tool for patients, a computer program (Cariogram) for caries risk assessment has been developed [2]. Basically, the scores of 10 caries-related factors are entered into the program to express, in graphical form, the likelihood of caries being avoided in the near future. The Cariogram has been validated in a longitudinal trial in 10 to 11-year-old schoolchildren and found to predict the 2-year caries increment more accurately than any of the single factors [3].

Several reviews of the literature have concluded that "past caries experience", especially of active initial lesions, is the most powerful single predictor of future caries development at practically all ages [4,5]. However, at young preschool ages, before the presence of clinically detectable lesions, the situation may be quite different. It has been suggested that prediction models with a combination of risk indicators, such as socio-demographic factors and dietary habits and mutans streptococci counts, can improve accuracy of the risk assessment at early ages [6–11]. In a previous study, we described the caries risk profiles in a group of 2-year-old children using modified and age-adapted scoring of the Cariogram [12]. A striking finding was that half of the subjects exhibited high caries risk, with sugar consumption as the dominant sector of the risk profiles. To our knowledge, the Cariogram has not yet been validated against actual caries development in the primary

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dentition and it is not known whether one particular risk category of an individual is likely to remain stable over the years. Another research question of interest was whether or not the estimated caries risk profile could be influenced by preventive measures. The aims of the present follow-up study were therefore threefold: (i) to validate the modified risk assessment tool Cariogram in preschool children, (ii) to investigate whether an 18-month xylitol tablet program could have an influence on the caries risk profiles established at 2 years of age, and (iii) to compare the risk profiles longitudinally at 2 and 7 years of age.

Material and methods

Study group

In 2002, all 2-year-old children ($n = 146$) born between January 2000 and March 2001, attending the Public Dental Clinic in Lycksele, a small municipality in northern Sweden with around 13,000 inhabitants, were invited to participate in a study for caries prevention with xylitol [13]. After exclusion of those with severe disabilities and children who did not cooperate in an oral inspection, 132 were included in the intervention study, as shown in Figure 1. A complete set of baseline data forming a Cariogram was available for 125 children. At 7 years of age, 22 children had moved out of the area and 103 (82%) were available for re-examination. The level of caries in the community is considered as low, and characteristics of the material have been published earlier [13].

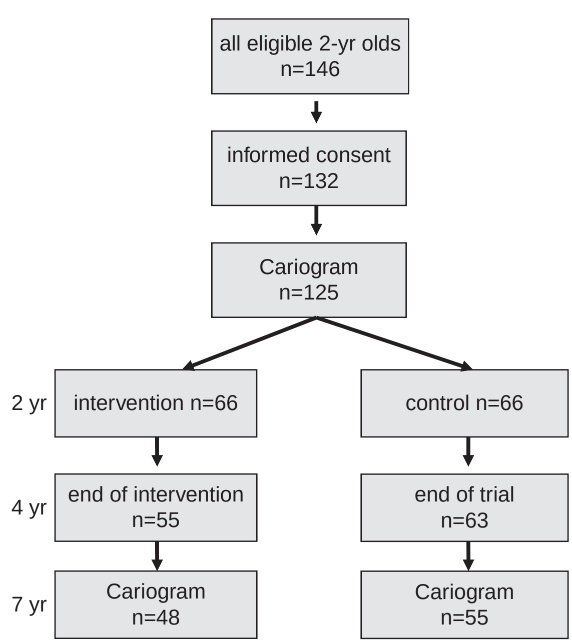

Figure 1. Flow chart of participants in the original intervention study and in the present follow-up.

Clinical procedures and questionnaire

The clinical and radiographic follow-up examinations were conducted by a single examiner (P.L.H.). Oral examination was by use of a mirror and probe, and caries was recorded in accordance with the guidelines of the Public Dental Service, which resemble the World Health Organization criteria [14], but modified for the primary dentition. At 7 years, primary and permanent teeth were examined and decayed (d/D, including enamel (non-cavitated) caries), missing (m/M), and filled (f/F) surfaces (s/S) were recorded. The criteria for enamel caries were a chalky, white spot with an unbroken surface or an approximal translucency within the enamel on the bitewing radiographs. The criteria for manifest caries were the minimal level that could be defined as a cavity visually detectable on smooth surfaces, a catch of the blunt probe under slight pressure for fissures, or an approximal translucency into the dentin on the bitewing radiograph. Radiographs were exposed when the approximal surfaces were not available for visual inspection (84% of the children). The same questionnaire was used at 2 and 7 years of age, and included questions on general health and medication, toothbrushing frequency with parental help, and use of fluoride toothpastes and supplements. Special efforts were made to note the dietary habits; the intake of sweet drinks between meals and the frequency of sugary snacks were scored as: 0 = never, 1 = once per month, 2 = 2–3 times per month, 3 = once per week, 4 = 2–3 times per week, 5 = daily, 6 = 2–3 times per day, 7 = >4 times per day.

Microbial procedures

Enumeration of oral mutans streptococci was carried out with the Strip mutans chair-side technique (Orion Diagnostica, Helsinki, Finland) as described by Jensen & Bratthall [15]. At 2 years, oral sampling was done according to Twetman & Grindefjord [16], while the manufacturer's instructions were followed at 7 years of age. The growth of mutans streptococci was identified based on morphology, and the colony forming units (CFU) were counted in a stereomicroscope with 12–25 times magnification and scored into 4 categories (see Table I).

Calculating the caries risk profiles

The caries risk profiles of each participating child were calculated with the Cariogram at 2 and 7 years of age [2]. In the original Cariogram, 10 different parameters were scored and entered in the computer, but only 7 were used in the present study; caries experience, mutans streptococci counts, answers from the questionnaire including relevant diseases or medication, frequency of sugar consumption, oral hygiene, use of fluorides and clinical judgment

Table I. Caries risk factors entered into the Cariogram and percentage distribution at 2 years ($n = 125$) and 7 years ($n = 103$). Chi square test was used to calculate the difference in distribution ($p < 0.05$, NS = non significant).

Factor	Data	Cariogram scores	2 years (%)	7 years (%)	
Caries experience	Clinical examination	2: No caries (normal for the age group)	94	65	NS
		3: Caries (above the average for the age group)	6	35	$p < 0.05$
Related diseases	As recorded in questionnaire	0: Healthy	95	87	NS
		1: Caries-related diseases or medication	5	13	NS
Diet, frequency	Sum of scores for intake of sweets, sweet drinks, and ice cream	0: ≤ 8	5	15	NS
		1: 9	13	18	
		2: 10	37	32	
		3: ≥ 11	45	35	
Oral hygiene	As recorded in questionnaire	1: 1–2 times/day with parental help	78	62	$p < 0.05$
		2: Almost every day with parental help	17	24	$p < 0.05$
		3: Irregularly	5	14	$p < 0.05$
Mutans streptococci	Enumeration using the Strip mutans test	0: No detectable CFU	82	25	
		1: 1–10 CFU	5	14	NS
		2: 11–100 CFU	4	36	$p < 0.05$
		3: ≥ 101 CFU	9	25	$p < 0.05$
Fluorides	Data from questionnaire	0: Fluoride toothpaste and extra fluorides regularly	0	4	
		1: Fluoride toothpaste and extra fluorides irregularly	0	51	
		2: Fluoride toothpaste only	98	44	
		3: Not fluoride toothpaste	2	1	$p < 0.05$
Clinical judgment	Clinical impression	0: More positive than the result of the Cariogram	3	5	Not tested
		1: Normal	38	67	
		2: Worse than the result of the Cariogram	21	10	
		3: Convinced that caries will occur	38	18	

(Table I). The parameter "sugar frequency" was formed by summarizing the scored consumption of ice cream, soft drinks, and candies for each child. A summarized score above the mean value was regarded as frequent intake (score 3), the mean value as moderate intake (score 2), while a value below the mean was scored as low intake (score 1 or 0). A clinical judgment was made based on the clinical impression at the examination. The caries risk profile was calculated for each child and presented in a pie chart with five different sectors expressed in percent: (i) diet, based on the frequency of sugar intake, (ii) bacteria, based on a combination of oral hygiene and number of mutans streptococci, (iii) susceptibility, based on fluoride program, and (iv) circumstances, based on past caries experience and general diseases. The fifth sector (v) represented the chance of avoiding caries and was scored in four groups: 0–20% = low; 21–40% = fairly low; 41–60% = moderate; 61–100% = fairly high and high.

The intervention

The intervention study between 2 and 4 years of age had a single-blinded design and the children were randomly assigned to either an intervention group or a control group [13]. The children in the intervention group were provided with sucking tablets with a daily dose of 0.5–1 g xylitol. Children in the control group were not given any tablets. During the intervention period, the children in both groups were recalled to a dental hygienist semi-annually and received individually tailored diet-counselling as well as additional preventive and restorative care based on individual need. After 4 years, both groups received the same preventive-oriented dental care at the local Public Dental Clinic.

Statistical methods

All data obtained were processed using the SPSS software (v. 12.0, 15.0, SPSS Inc., Chicago, Ill., USA). The distribution of data from the questionnaire was presented descriptively. For prediction calculations, the highest risk category (0–20% chance of avoiding caries) was regarded as a "positive test", while any new enamel or dentine lesion (dmfs/DMFS > 0) was considered as "disease". The chi-square test was used to check the difference in caries between the Cariogram groups and between distribution of scores for different factors at 2 and 7 years. Spearman's rank correlation was used to test individual correlation between the scored Cariogram results at 2 years of age with the corresponding value at 7 years of age. Linear regression was analysed to study the relative impact on caries experience at 7 years from the single factors as well as the Cariogram values at 2 years. A p-value <0.05 was considered statistically significant.

Results

Validation of Cariogram at 7 years of age

Actual caries development among the children in the control group at 7 years in relation to the estimated caries risk at age 2 years is presented in Table II; the predictive values are given in Table III. At baseline, 3 children (5%) exhibited caries lesions compared to 20 (36%) at age 7 years. Practically all new caries lesions appeared in the group assessed with a low likelihood of avoiding caries at baseline ($p<0.05$). The sensitivity and the negative predictive values were 90%, while the specificity and positive predictive values were low, around 50%. The percentage of correctly classified children (true positive and true negative) was 63.

Effect of intervention on risk profiles

In the intervention group, 3 children (6%) had decayed teeth at the age of 2 years, this prevalence increasing to 38% at 7 years. There was no statistically significant difference in caries development between the different risk categories at the follow-up (Table II). Sensitivity was lower than in the control group, while specificity was generally slightly higher, but still at a very moderate level (60%). Only 37% of the children in the intervention group were classified correctly (Table III).

A regression analysis of the single factors and the Cariogram model established at 2 years, with the caries prevalence at 7 years of age as dependent variable (Table IV), showed that the strongest single factor associated with caries development in the control group was the presence of salivary mutans streptococci ($p<0.05$). The strongest single factor in the intervention group was past caries experience. The Cariogram model was stronger than any single factor among children in the control group ($p<0.01$), but failed to reach statistical significance in the intervention group.

Table III. Predictive values (95% CI) in per cent as estimated with Cariogram at 2 years versus actual caries development in children participating in a 2-year xylitol trial and in children with no intervention.

	Control group	Intervention group
Prevalence (%)	71	38
Sensitivity	46 (31–62)	61 (39–84)
Specificity	88 (71–104)	47 (29–65)
PPV	90 (77–103)	41 (22–59)
NPV	40 (24–56)	67 (47–87)
PLR	3.7 (1.0–14.1)	1.1 (1.1–1.1)
NLR	0.6 (0.4–0.9)	0.8 (0.8–0.8)

PPV = positive predictive value; NPV = negative predictive value; PLR = positive likelihood ratio; NLR = negative likelihood ratio.

Individual caries risk profiles at 2 and 7 years of age

The distribution of the scored variables at 2 and 7 years of age is presented in Table I and the corresponding average is shown in Figure 2. Since no significant differences were displayed between the intervention and control groups ($p>0.05$) for any of the variables, the data were merged. The sector "chance of avoiding caries" was clearly increased at 7 years of age compared with baseline. Toothbrushing frequency was significantly lower at 7 years compared to 2 years ($p<0.05$), and the presence of salivary mutans streptococci increased from 19% to 75% between 2 and 7 years of age ($p<0.05$). The relative impact of these variables was reflected by an increased "bacterial" sector in the average Cariogram at 7 years. At 2 years of age, 97% of the children were given candies at least once a week; this situation remained high at 7 years. Sweet drinks were given to 20% of the children once a day or more at 2 years, a habit that decreased to 11% five years later.

There was a statistically significant correlation between the individual risk profiles assessed at 2 and 7 years of age among the children in the control group ($r=0.34$ ($p<0.05$), but not in the intervention group ($r=0.24$). A flow-chart with the distribution of children with respect to the risk category at 2 and 7 years of age is given in Table V. In the control group, 40% remained in the same risk category, 13% exhibited an increased category, and 47% were assessed with a decreased category. The corresponding values in the intervention group were 35%, 23%, and 42%, respectively.

Table II. Mean caries experience (dmfs/DMFS (SD)) at 7 years of age in the Cariogram groups assessed at 2 years.

	Control group		Intervention group	
Chance of avoiding caries 2 years	n	Mean (SD)	n	Mean (SD)
0–40%	38	2.4 (3.2)	27	1.4 (2.1)
41–100%	17	0.1* (0.4)	21	0.9 (1.4)

*Statistically significant difference from 0–40% category ($p<0.05$).

Table IV. Linear univariate regression analysis of single factors and the Cariogram scores at 2 years of age.Caries experience at 7 years of age was the dependent variable.

	Control group		Intervention group	
Factor	Standardized β-coefficient	Significance	Standardized β-coefficient	Significance
Caries experience	0.141	0.301	0.554	0.000
Related diseases	0.073	0.575	0.193	0.200
Diet	−0.185	0.174	−0.040	0.804
Oral hygiene	−0.223	0.091	−0.184	0.266
Mutans streptococci	0.311	0.021	0.291	0.056
Cariogram	−0.389	0.003	−0.191	0.194

Discussion

The most important challenge in pediatric dentistry is in maintaining children's teeth healthy, and reliable caries risk assessment is essential for early oral health promotion and disease management. The Cariogram was originally developed to assess the future caries risk in adults in the event that the entered factors remained unchanged [17]. Thus, our present attempt to modify the scoring of the variables for growing and developing individuals was a real challenge. Longitudinal evaluations of predictive models present an ethical dilemma because risk-based action through preventive measures may obscure the true predictive ability of potential risk factors. In this case, the design of the original trial offered a non-treated control group for prospective validation of the Cariogram. Although the majority of the eligible families gave their consent for participation, it has to be kept in mind that the number of available children in the geographic area was limited and that the general caries level in the community was low. In particular, the small number of children calls for caution when drawing conclusions. Considering the long follow-up period over 5 years, the 18% attrition due to relocation was acceptable. Moreover, the baseline Cariogram profiles of the drop-out children did not differ substantially from those that remained in the study.

An important finding was that the Cariogram was associated with caries increment more accurately than any of the single factors during preschool age in children with no preventive intervention. This agrees with an earlier evaluation in schoolchildren that resulted in predictive values of the same magnitude [3]. The high sensitivity was expected, since almost half of the children were assessed with high risk at the age of 2 years, but overall accuracy and precision did not meet expectations. The modified Cariogram was therefore not particularly useful as a tool for predicting future caries in the present study groups. The combined value of sensitivity and specificity reached 139%, which was considerably lower than the 170% obtained in a previous multivariate prediction model evaluated in immigrant children [7]. The relatively high negative predictive value may suggest a possible role of the Cariogram in selecting those with a low probability of developing caries in the future.

In concert with the review by Thenisch et al. [18], the presence of mutans streptococci in the oral cavity at 2 years of age was the most pertinent single factor predicting caries experience at 7 years of age among children in the control group. With this in mind, it was interesting to find that the Cariogram model appeared to be weaker in children who had participated in a xylitol-based intervention with the aim of counteracting mutans streptococci colonization. In this intervention group, the "past caries experience" was the strongest single variable associated with caries development at the age of 7 years. This was also logical, since it is likely that this variable reflects relatively well both the past and present interplay between the various etiologic factors [5]. Dental caries at 2 years represents an advanced stage of progression of the disease and was detected in 3 children in the intervention group. With so few cases, the outcome at 7 years may be more chance than methodical correlation. It has to be emphasized, however, that the variables "diet", "oral

Table V. Risk categories assessed with Cariogram ("percent chance of avoiding caries") at the age of 2 and 7 years in children participating in a xylitol intervention program and in a control group. Figures in the table represent the numbers of subjects.

	Cariogram 7 year							
Cariogram 2 year	Control group				Intervention group			
	0–20%	21–40%	41–60%	61–100%	0–20%	21–40%	41–60%	61–100%
0–20%	14	7	13	1	7	3	5	3
21–40%	1	–	2	–	3	2	3	1
41–60%	–	5	8	3	2	6	8	5
61–100%	–	–	1	–	–	–	–	–
Sum	15	12	24	4	12	11	16	9

hygiene", and "mutans streptococci colonization" exhibited a weaker association with caries development at 7 years of age in the intervention group compared to the control group. It thus seems possible, at least to some extent, to influence individual risk profiles with the implementation of a preventive program.

The question whether or not the children assessed at 2 years would remain in the same risk category 5 years later was answered by a clear "no". Less than half of the children displayed the same risk category on both occasions, and, most importantly, the majority exhibited an increased likelihood of avoiding caries, which means a lowered risk. However, there was a significant correlation within the sectors of the Cariogram on the two occasions, especially in respect of the consumption of sugar-containing between-meal products. The pattern at 7 years reflected consumption at 2 years. Thus, the consumption of candies established at an early age seemed to remain a habit, and the consumption of soft drinks continued to be high. Similar findings have been demonstrated by others [19,20], who stress the importance of early health promotion in the establishment of healthy dietary habits. A notable finding from the questionnaire was that only 78% of the 2-year-old children received parental help with toothbrushing once or twice a day, a figure that decreased to 62% at 7 years. Alm et al. [21] recently showed that early establishment of toothbrushing provided the foundation for a low experience of approximal caries during adolescence. Likewise, Adair et al. [22] demonstrated the importance of an early start with toothbrushing before the age of 1, and that brushing twice a day with adult involvement may double the odds of being caries-free. The caries preventive effect of fluoride toothpaste is well established, but with few studies in preschool age children [23,24]. Additional dental health effects could therefore be expected if an increasing proportion of children were to benefit from adult involvement in the brushing procedure.

In conclusion, validation of a modified Cariogram in 2-year-old preschool children resulted in high sensitivity for future caries, but the method lacked accuracy and precision. More than half of the children changed risk category over the years, with the majority displaying a decreased caries risk at 7 years. Sugar consumption habits were set at a very early age, however, and remained fairly stable from 2 to 7 years of age. Moreover, a preventive program had a certain impact on the individual caries risk profiles and impaired the predictive ability of the program. The findings call for strategies for early oral health promotion to involve and encourage parents to establish and maintain healthy dietary and oral hygiene habits from an early age.

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