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ORIGINAL ARTICLE

Factors associated with the risk of caries development after comprehensive dental rehabilitation under general anesthesia

Yai-Tin Lin, Yng-Tzer J. Lin*

Pediatric Dentistry, Kaohsiung Chang Gung Memorial Hospital, Chang Gung University College of Medicine, Taiwan, ROC

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KEYWORDS
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Abstract *Background/purpose:* The aims of this cross-sectional study were to determine the possible risk factors of caries development in children with early childhood caries (ECC) and to perform a caries risk assessment using Cariogram over a 12-month period. There is no report in examining caries risk assessment under 6 years old children in Taiwan.
Materials and methods: Seventy-nine children (mean age 48.80 ± 10.71 months) with ECC indicated for comprehensive dental reconstruction under general anesthesia were selected. A questionnaire was completed by the parents to assess the possible caries-related factors at a 12-month follow-up. Data were collected for caries index, plaque index, *Streptococcus mutans* (SM) and *Lactobacillus* (LB) counts, and salivary buffering capacity at the initial examination and at the 12-month follow-up. Children were divided into two groups: caries-free (decayed, extracted, and filled teeth = 0) and caries-recurrent (decayed, extracted, and filled teeth > 0). The children's caries risk was assessed using the Cariogram software program.
Results: At the 12-month follow-up, 79.7% of the children had developed new caries. No significant differences were found in parents' education levels, child's oral health practices, or parental knowledge and attitudes toward oral health ($P > 0.05$) between the caries-free group and the caries-recurrent group. The SM count ($P = 0.001$) and caries risk assessment (CRA) score ($P < 0.001$) were found to be significantly associated with new caries development.
Conclusion: This study has shown that SM count and CRA score were associated with new caries development in ECC children who needed to be treated under general anesthesia. The modified Cariogram used in this study is another significant tool for predicting new carries development in this particular population.

* Corresponding author. Pediatric Dentistry, Kaohsiung Chang Gung Memorial Hospital, Number 123, Ta Pei Road, Niao Sung Area, Kaohsiung, Taiwan, ROC.
E-mail address: Joe0430@ms13.hinet.net (Y.-T.J. Lin).

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Introduction

Early childhood caries (ECC) is a term used to describe rampant caries in infants and toddlers.[1] This type of caries generally affects the deciduous maxillary anterior teeth initially, followed by the involvement of deciduous posterior teeth. In view of the destructive characteristics of this condition, immediate and comprehensive treatment has been recommended to prevent further dental caries and to ensure the child's overall general health.[2] Most of these patients receive dental care in a conventional office environment even when immobilization is necessary. However, patients resistant to treatment, of young age, or requiring significant restorative treatment usually need general anesthesia.[3] Comprehensive dental treatment under general anesthesia for ECC can provide an immediate enhancement in the patients' oral health and quality of life.[4,5]

There have been relatively few studies that have investigated the outcomes after full mouth dental rehabilitation under general anesthesia. In spite of aggressive dental rehabilitation and preventive efforts in these patients, they still frequently experience recurrence of caries.[6–10] A retrospective study in 292 children treated under general anesthesia showed that of the 95% who returned for treatment, 55% had developed new caries within 2–4 years.[7] Almeida et al[10] found that 79% of 42 ECC children had detectable recurrent caries within 2 years compared with 29% of 31 caries-free controls. In order to achieve a further decrease in dental caries, it is important to identify cases with a higher risk for developing caries. A number of risk factors for caries development have been examined and include previous caries experience, diet, parents' education level, behaviors related to dental health, and socioeconomic status.[11,12] Köhler and Holst[13] investigated the dental health of 4-year-old children in Southern Sweden and found that their dental health was significantly associated with factors including infrequent between-meal eating, tooth brushing frequency, intake of fluoride tablets, and regular dental appointments.

There are no current literature reports examining caries risk assessment in children under the age of 6 years treated under general anesthesia and residing in Taiwan. We used a risk assessment model called Cariogram to evaluate several possible caries risk factors.[14,15] This model allowed us to simultaneously assess the relative importance of different factors allowing a more accurate determination of the caries risk than a single-factor model. The aim of the present study was to determine the possible risk factors of caries development in ECC children in Taiwan 12 months after treatment under general anesthesia. We used the Cariogram to analyze the risk of caries development by comparing caries-free with caries-recurrent children over a 12-month period.

Materials and methods

The study was approved by the Institutional Review Board of Chang Gung Memorial Hospital (IRB no: 100-3088A3). A total of 79 children with early childhood caries requiring full mouth dental rehabilitation under general anesthesia were recruited from the Children's Dental Clinic of Kaohsiung Chang Gung Memorial Hospital. The study group was comprised of 40 boys and 39 girls aged 27–71 (48.80 ± 10.71) months. The parents of the children were invited to participate in the study and signed a consent form.

Study design

Immediately after the participant had been anesthetized, dental examinations were conducted by two pediatric dentists (Lin JYT and Lin YT) using on-site dental chairs, mirrors, and explorers under focused flashlights. Caries were assessed using decayed, extracted, and filled teeth (deft) and decayed, extracted, and filled surfaces (defs) indices according to the World Health Organization diagnostic criteria (WHO, 1997).[16] The oral hygiene status was evaluated using the Silness–Löe Plaque Index and was based on an average of six assigned teeth (A, D, I, K, N, and S).[17] All teeth were isolated with a rubber dam and treated with operative restoration, pulpotomy with crown, pulpectomy with crown, or extraction according to the severity of the carious lesions.

The caries and plaque index examinations were repeated in the clinic 12 months after the initial treatment. Physical restraint with parent's permission was sometimes necessary when the child was uncooperative during the examinations. We divided the participants into caries-free (deft $= 0$) and caries-recurrent (deft > 0) groups according to the caries status at the 12-month follow-up. A questionnaire was completed by the parents or caregivers at this time to assess the possible caries-related factors including: (1) the child's demographic background (gender and age); (2) parents' education levels; (3) child's oral health practices; and (4) parental knowledge and attitudes toward oral health.

In addition, three biological parameters were measured in participants at the 12-month follow-up: salivary buffering capacity, *Streptococcus mutans* (SM) count, and *Lactobacillus* (LB) count. The Dentocult-buffer Strip, Dentocult-SM, and Dentocult-LB test kits (Orion Diagnostica, Espoo, Finland) were used to determine the salivary buffering capacity, SM count, and LB count respectively. Each participant was instructed not swallow their saliva for 1 minute of chewing paraffin pellets prior to SM collection using the Dentocult-SM kit. The participant was then instructed to continuously spit out all saliva into a plastic cup for the next 4 minutes. Immediately after collection, the saliva samples were poured into a Dentocult-LB tube. The Dentocult-SM and LB tubes were stored in an incubator at 37°C for 2 days and 4 days, respectively. The SM and LB salivary counts were obtained by comparing the colony density on the test strips against a standard chart provided by the manufacturer (Table 1). The buffering capacity test (Dentobuff, Orion Diagnostica) was performed by applying 1 drop of stimulated saliva to a test strip; the reading was taken 5 minutes after initiation of the stabilized chemical reaction.

Caries risk assessment (CRA) using Cariogram

Children's caries risk was assessed by using a multifactorial computational program called Cariogram.[14,15] We modified

Table 1 Caries-related factors/parameters used for the Cariogram.

Factor	Cariogram scores
1. Past caries experience	0: deft $\leq$ 1 1: deft $\leq$ 2 2: deft $\leq$ 3 3: deft $>$ 3
2. Related diseases	0: No general diseases of importance related to dental caries. 1: Mild degree disease/conditions indirectly influencing caries process, or other conditions, which can contribute to higher caries risk. 2: Severe degree, long-lasting disease/conditions. Patient could be bed-ridden or may need continuous medication for example affecting the saliva secretion.
3. Diet content (based on LB count)	0: LB amount: $< 10^4$ CFU/mL saliva 1: LB amount: 10^4–10^5 CFU/mL saliva 2: LB amount: 10^5–10^6 CFU/mL saliva 3: LB amount: $> 10^6$ CFU/mL saliva
4. Diet frequency	0: Maximum 3 meals per day 1: 4–5 meals per day 2: 6–7 meals per day 3: $>$ 7 meals per day
5. Plaque index	0: Averaging Silness–Löe plaque index: 0–0.50 1: Averaging Silness–Löe plaque index: 0.5–1.5 2: Averaging Silness–Löe plaque index: 1.51–2.5 3: Averaging Silness–Löe plaque index: 2.51–3.0
6. *Streptococcus mutans*	0: SM amount: $< 10^4$ CFU/mL saliva 1: SM amount: 10^4–10^5 CFU/mL saliva 2: SM amount: 10^5–10^6 CFU/mL saliva 3: SM amount: $> 10^6$ CFU/mL saliva
7. Fluoride program fluoride measures	0: Fluoride toothpaste plus constant additional 1: Fluoride toothpaste plus inadequate additional fluoride measures 2: Fluoride toothpaste only 3: Not using fluoride toothpaste or other fluoride measures
8. Buffer capacity	0: Adequate. Dentobuff blue, end-pH $\geq$ 6.0. 1: Reduced. Dentobuff green, end-pH 4.5–5.5. 2: Low. Dentobuff yellow, end-pH $\leq$ 4.0

CFU = colony forming units; Deft = decayed, extracted, and filled teeth; LB = *Lactobacillus*; SM = *Streptococcus mutans*.

the study for use in young children, using eight of the 10 original parameters including scores for the child's baseline caries experience, relevant diseases or medication, dietary content (based on LB count) and frequency, oral hygiene status (plaque index), use of fluorides, SM count, and buffering capacity (Table 1). The child's caries risk was estimated and expressed as the "% chance of avoiding caries". The chance varies on a scale from 0% to 100%. A 0% chance of avoiding caries means that lesions will definitely occur over time (high caries risk). Correspondingly, a 100% chance of avoiding caries means that there is no risk of future caries (low caries risk).

Statistical analysis

Two examiners (Lin JYT and Lin YT) participated in a pilot study that involved10 cases. The interexaminer reliability tested using a kappa score was 0.83 (P = 0.0002). Comparisons of caries-related categorical variables between caries free and caries recurrent groups were determined using the Chi-square test. Variables with P values $\leq$ 0.05 under the Chi-square test were included in the multiple logistic regression analysis using the stepwise forward procedure. CRA score was tested using Student *t* test. Data were analyzed using statistical software (Statistical Package for Social Sciences 19 for Windows, Chicago, IL, USA). A P value $<$ 0.05 was considered to be significant.

Results

At the 12-month follow-up, 79.7% of the children had developed new caries (deft = 2.58 $\pm$ 2.57, defs = 5.76 $\pm$ 6.79). There were no significant differences between caries-free and caries-recurrent groups in terms of gender, age, parents' education levels, child's oral health practices, or parental knowledge and attitudes toward oral health (P $>$ 0.05) (Table 2). Table 3 shows that the SM count (P = 0.001) and CRA score (P = 0.000) were found to be significantly associated with the recurrence of dental caries. The multiple regression analysis revealed that the

Table 2 Comparisons of social, diet, and behavioral factors between caries-free (deft = 0) and caries-recurrent (deft > 0) groups.

	Caries-free (%) $N = 16$	Caries-recurrent (%) $N = 63$	P
Gender			
Male	9 (56.3)	31 (49.2)	0.615
Female	7 (43.8)	32 (50.8)	
Age			
≤ 4 y	1 (6.3)	8 (12.7)	0.677
> 4 y	15 (93.8)	55 (87.3)	
Father's education level			
≤ Polytechnic	9 (56.3)	37 (58.7)	0.857
≥Bachelor	7 (43.8)	26 (41.3)	
Mother's education level			
≤ Polytechnic	6 (37.5)	31 (49.2)	0.402
≥ Bachelor	10 (62.5)	32 (50.8)	
Diet frequency per day			
≤ 3 meals	0 (0.0)	3 (4.8)	0.148
4–5 meals	12 (75.0)	29 (46.0)	
6–7 meals	4 (25.0)	23 (36.5)	
> 7 meal	0 (0.0)	8 (12.7)	
Snacks/drinks between			
Meals			
0–1 time	5 (31.3)	17 (27.0)	0.760
≥ 2 times	11 (68.8)	46 (73.0)	
Bedtime sweet without brushing			
Never/occasionally	14 (87.5)	60 (95.2)	0.265
Frequently/almost every night	2 (12.5)	3 (4.8)	
Brushing by whom			
Children themselves	10 (62.5)	33 (52.4)	0.468
Parents/caregivers	6 (37.5)	30 (47.6)	
Frequency of tooth brushing			
0–1 time	3 (18.8)	15 (23.8)	1.000
≥ 2 times	13 (81.3)	48 (76.2)	
Main reason for tooth decay			
Brushing			
Yes	7 (43.8)	15 (23.8)	0.128
No	9 (56.3)	48 (76.2)	
Main reason for tooth decay			
Sugar			
Yes	0 (0.0)	6 (9.5)	0.338
No	16 (100.0)	57 (90.5)	
Main reason for tooth decay			
Bacteria			
Yes	0 (0.0)	3 (4.8)	1.000
No	16 (100.0)	60 (95.2)	

Deft = decayed, extracted, and filled teeth.

CRA level in caries-recurrent children was associated with a 1.076 [odds ratio (OR) 95%, confidence interval (CI) 1.025–1.129, P = 0.003] times greater chance of new caries development when compared with caries-free children at 12-month follow-up (Table 4).

Discussion

Previous reports have shown a high recurrence of caries, ranging from 53% to 80%, for children treated with dental rehabilitation under general anesthesia.[6,10,18–20] Almeida et al[10] reported results similar to ours, showing that 33 of 42 (79%) ECC children had detectable carious lesions at a 24-month follow-up. In addition, of the 42 patients treated for ECC under general anesthesia, seven (17%) required retreatment under general anesthesia within 2 years of the initial full-mouth rehabilitation.[10] In another study by Worthen and Mueller,[21] 20% of patients treated under general anesthesia before the eruption of primary second molars required additional dental rehabilitation within 38 months. It can be concluded that the ECC group of

Table 3 Comparisons of caries-related biological factors between caries-free (deft = 0) and caries-recurrent (deft > 0) groups.

	Caries-free (%) N = 16	Caries-recurrent (%) N = 63	P
Buffer capacity			
0: High-blue	8 (50.0)	31 (49.2)	0.835
1: Medium-green	7 (43.8)	30 (47.6)	
2: Low-yellow	1 (6.3)	2 (3.2)	
SM count			
Score 0	9 (56.3)	9 (14.3)	0.003*
Score 1	3 (18.8)	10 (15.9)	
Score 2	1 (6.3)	14 (22.2)	
Score 3	3 (18.8)	30 (47.6)	
LB count			
Score 0	13 (81.3)	34 (54.0)	0.128
Score 1	3 (18.8)	13 (20.6)	
Score 2	0 (0.0)	12 (19.0)	
Score 3	0 (0.0)	4 (6.3)	
Oral hygiene status (plaque index)			
0: 0.00—0.50	2 (12.5)	3 (4.8)	0.679
1: 0.51—1.50	10 (62.5)	42 (66.7)	
2: 1.51—2.50	4 (25.0)	17 (27.0)	
3: 2.51—3.00	0 (0.0)	1 (1.6)	
Score of CRA	74.81 ± 14.32[a]	57.76 ± 18.36	0.000**

* Significant difference (P < 0.01).
** Significant difference (P < 0.001).
CRA = caries risk assessment; Deft = decayed, extracted, and filled teeth; LB = *Lactobacillus*; SD = standard deviation; SM = *Streptococcus mutans*.
[a] Mean ± SD.

children is highly predisposed to caries incidence in later years.[10] The best outcomes following dental rehabilitation under general anesthesia may result from aggressive treatment of the caries, active follow-up, and education of the parents.[9]

The present study assessed the biological, social, dietary, and behavioral risk factors associated with the prevalence of the recurrent dental caries in preschool children, and found that the SM count level and CRA score were significantly related at a 12-month follow-up. No significant difference between two groups in oral hygiene status (plaque index) was probably due to the impact of general anesthesia that parents were willing to improve their children's oral hygiene. Children with high counts of SM often exhibit higher decayed, missing, and filled permanent teeth (DMFT) values.[22—25] This is because SM is able to survive in an acidic environment, and has the ability to increase their rate of acid production, decrease the pH in the oral cavity, and form a cariogenic plaque.[26] Our finding is in agreement with previous studies that a higher level of SM in the recurrent group appears to be a significant caries risk factor compared with the caries-free group.[22—25] However, some studies have indicated that SM and LB counts were not associated with the increase in caries suggesting that dental caries is a multifactorial disease in which the cumulative and combined interactions of different risk factors should be evaluated.[27,28]

Table 4 Multiple logistic regression analysis with caries experience.

Variable	OR (95% CI)	P
Score of CRA	1.076 (1.025—1.129)	0.003*

* Significant difference (P < 0.001).
CI = confidence interval; CRA = caries risk assessment; OR = odds ratio.

Another important factor in the development of caries is the presence of bacterial plaque on the teeth. It has long been supposed that the development of caries is reduced by the mechanical removal of plaque from tooth surfaces. Some studies have reported a strong, consistent relationship between brushing and other oral hygiene procedures, and a reduction in the caries prevalence,[29—31] although results from other studies have not supported this association.[32,33] Gibson and Williams[33] found that the benefit of tooth brushing frequency was not significant for children from families where the head of the household was employed in manual labor. A possible explanation for this is that the overall benefits of frequent brushing does not outweigh the damage of higher sugar consumption in the manual labor group.[33] In our study, there were no significant differences in the child's gender and age, parents' education levels, child's oral health practices, or parental knowledge and attitudes toward oral health between the caries-free and caries-recurrent groups. This suggests that social, dietary, and behavioral factors were not important when the two groups of ECC patients who were highly susceptible to caries were compared.

Cariogram is a computer program that assesses and illustrates the caries profile for an individual graphically, simultaneously taking into account the cumulative and combined interactions of the 10 different caries risk factors/parameters in the adult patient.[14,15] This a straightforward and comprehensive model, which includes the three principal etiological factors of dental caries: diet, microbial pathogens, and host susceptibility. It was devised as an educational model that aimed to demonstrate the multifactorial etiology of dental caries in a simple manner. We have adapted this model by modifying the scoring of risk factors to make it suitable for use in children treated under general anesthesia by eliminating two parameters: clinical judgment and stimulated saliva secretion rate. These two factors were excluded because it was not possible to objectively access caries status and social factors, and stimulated saliva is difficult to collect from young children. A reduced Cariogram model without saliva parameters has been evaluated in schoolchildren and it has been found that exclusion of the saliva parameters had little impact on Cariogram in predicting new caries lesions.[28,34]

In the present study, the CRA level in caries-recurrent children was associated with a 1.076 (OR 95% CI 1.025 − 1.129, P = 0.003) times greater chance of new caries development when compared with caries-free children at 12-month follow-up. We believe that the modified Cariogram used in our study is another significant tool for predicting the new caries development in young ECC patients who had previously required treatment under general anesthesia. The multifactorial caries risk assessment model

is a better predictor for the future development of dental caries than any single caries risk factor.[34] It is also a useful teaching tool for dentists facilitating discussion with parents regarding their children's caries risk.

In conclusion, this study has shown that SM count and CRA score are associated with recurrent dental caries in ECC children who required general anesthesia. Social, dietary, and behavioral factors were not relevant in this particular ECC population. The modified Cariogram model used in this study is another significant tool for predicting the new carries development in this particular population.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

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