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Caries risk profiles of Korean dental patients using simplified Cariogram models

JUNG-HYUN LEE[1], HO-HYUN SON[1], HAE-YOUNG KIM[2] & JUHEA CHANG[3]

[1]*Department of Conservative Dentistry and Dental Research Institute, School of Dentistry, Seoul National University, Seoul, Korea,* [2]*Department of Dental Laboratory Science and Engineering, College of Health Science, Korea University, Seoul, Korea, and* [3]*Clinic for Persons with Disabilities, Seoul National University Dental Hospital, Dental Research Institute, School of Dentistry, Seoul National University, Seoul, Korea*

Abstract

Objectives. The objective of this study was to compare the caries risk profiles obtained from the simplified Cariogram models and the conventional Cariogram model of Korean dental patients. ***Materials and methods.*** Data required for a caries risk assessment with the Cariogram were collected from 80 young adult patients (mean: 23 years old). Three different simplified Cariogram models were produced with exclusion of either or both salivary secretion rate and lactobacilli count: group 1, conventional model; group 2, both salivary secretion rate and lactobacilli count excluded; group 3, salivary secretion rate excluded; group 4, lactobacilli count excluded. ***Results.*** The mean chance of avoiding caries in group 1 (55.5%) was not significantly different from those in groups 2 and 3. Also four caries-related sectors of the Cariogram (diet, bacteria, susceptibility and circumstance) in group 1 were not significantly different than in groups 2 and 3. Group 4 showed significant differences from group 1 in the mean chance of avoiding caries and the diet, susceptibility and circumstance sectors ($p < 0.05$). Significant correlations were detected between all risk factors and their corresponding risk sectors ($p < 0.05$). Also there were significant correlations between each risk factor and the chance of avoiding caries, except for the amount of plaque, in groups 1, 2 and 3 ($p < 0.05$). ***Conclusions.*** The simplified Cariogram model without salivary secretion rate and lactobacilli count did not significantly change the outcome produced from the conventional model. However, single exclusion of lactobacilli count noticeably changed the caries risk profile.

Key Words: *caries risk assessment, cariogram, lactobacilli, salivary secretion*

Introduction

A caries risk assessment (CRA) is the evaluation of unique individual disease indicators, risk factors and protective factors to determine the presence of current and the risk of future dental caries [1]. A CRA involves gathering evidence relevant to the diagnosis of dental caries and decision making with regard to appropriate therapeutic intervention in the early stages of disease. Therefore, caries management based on a CRA can enhance health- and cost-effectiveness and facilitate the application of a customized treatment modality for individual patients [2].

A computer-based model, the Cariogram, has been developed for the practical application of a CRA. The program takes into account interactions among individually-assessed risk factors and evaluates the factors in a weighted way [3,4]. The Cariogram consists of four sectors: 'Diet', based on a combination of diet contents and diet frequency; 'Bacteria', based on a combination of the amount of plaque and mutans streptococci (MS); 'Susceptibility', based on a combination of the fluoride program, saliva secretion and saliva buffer capacity; and 'Circumstances', based on a combination of past caries experience and related diseases. This data, together with a fifth sector expressed as 'percentage chance of avoiding caries in the near future', is represented graphically in the form of a pie chart. A total of nine caries-related factors are entered into the program, but with a minimum seven factors, the Cariogram can still provide its outcomes. The computer algorithm estimates

Correspondence: Juhea Chang, Clinic for Persons with Disabilities, Seoul National University Dental Hospital, 101 Daehak-no, Jongno-gu, Seoul, 110-768, Korea. Tel: +82 2 2072 3831. Fax: +82 2 2072 2854. E-mail: juhchang@snu.ac.kr

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a hypothetical value using a weighted formula based on the combination of collected variables. Therefore, missing a certain risk factor with a relatively lower weight may not significantly affect the overall assessment outcome [5].

Some risk factors, such as past caries experience, plaque amount and fluoride availability can be easily determined during a routine clinical examination and patient interview. However, some factors require additional cost and time for measurement; moreover, patient compliance is an important consideration when attempting to establish a routine series of assessment procedures [3,5]. During the measurement of salivary secretion, patients must allow their saliva to pool in their oral cavity and spit it without swallowing for 5 min, which can be uncomfortable for some patients. Without the collection of secreted saliva, lactobacilli (LB) count cannot be obtained, since the saliva is used to inoculate the media used for LB culture. Furthermore, this technique is not suitable in young children or special needs patients. Many previous studies have examined the weight of each risk factor included in the Cariogram [6–8], but few studies have sought to determine whether the absence of some factors in the Cariogram would affect the overall profile of caries risk. Petersson et al. [5] compared a total set of the Cariogram-factors with a reduced set of factors lacking MS count, salivary secretion rate and buffer capacity, as a prediction model for 10–11-year olds. They found that the accuracy of the risk assessment significantly decreased when all three factors were omitted. In the present study, we assessed the caries risk among adolescent and young adult patients, using three simplified Cariogram models, which excluded either or both of the following two factors: salivary secretion rate and LB count. We compared the caries risk profiles obtained using the conventional Cariogram and those from the simplified models. We hypothesized that there would be differences in the risk profiles between the conventional Cariogram model and the simplified models.

Materials and methods

Study population

Participants in the study were recruited from among individuals who visited Seoul National University Dental Hospital, Department of Conservative Dentistry between December 2011 and February 2012. The inclusion criteria were: (1) 15–30 years of age and (2) in need of caries and/or root canal treatments. The study population consisted of 80 individuals with 41 women and 39 men [mean age (SD) = 23.0 (3.3)]. The study was approved by the Seoul National University Dental Hospital Institutional Review Board (CRI11034) and informed consent was obtained from all participants or their parents.

Questionnaire

Each participant was interviewed using a questionnaire based on the Cariogram manual. Information was obtained from the patients on their general health and oral hygiene maintenance. The dietary factor was scored on four levels ranging from a very cariogenic diet (foods with high fermentable carbohydrates and a sticky consistency) to a less cariogenic diet (foods with low fermentable carbohydrates and a flowing consistency) and the frequency of snacks was also determined. The fluoride factor was scored on four levels according to the availability of supplemental fluoride. No participant was taking medication on a regular basis, or suffering from symptoms suggestive of hyposalivation. No participant exhibited any signs of general diseases related to caries, and all cases were assigned a score of 0 for the related general disease factor of the Cariogram model.

The level of oral hygiene maintenance was assessed by using a 3-point scoring system based on self-reported brushing time as follows: 0, normal (>3 min); 1, insufficient (1–3 min); 2, very insufficient, (<1 min). In addition, a high frequency of brushing (more than twice a day) had one point subtracted from the original score to provide a more favorable outcome in the Cariogram (when the original score was 0, the final score was still the same).

Clinical and radiographic caries assessments

The clinical examination and subsequent tests were conducted by a single examiner (J.H.L). Using optimal light, a mirror and an explorer, caries lesions were examined both clinically and radiographically (if available). Established caries lesions, in a pit or a fissure or on a smooth surface, were defined as those lesions with a distinct cavity, undermined enamel, loss of enamel continuity or a detectably softened floor or wall. Approximal caries lesions had a detectable cavity (visually or tactilely) or discontinuity on an approximal surface or a discolored marginal ridge. Radiolucency reaching the outer dentin was also used as a cut-off for established lesions [9]. White spots and arrested and inactive lesions were excluded from the study. The number of decayed, missing and filled teeth (DMFT index) was recorded. The reference DMFT value was taken from the Korean National Oral Health Survey 2010 [10], in which the mean DMFT index was 6.06 for 18–24-year olds and 6.55 for 25–29-year olds. Consequently, caries experience factor was rated on a 4-point scale, with 0 indicating caries-free (DMFT = 0); 1, better than normal (DMFT = 1–4); 2, normal (DMFT = 5–7); and 3, worse than normal (DMFT ≥ 8).

Plaque scoring

The Silness-Löe plaque index was assessed, with 0 indicating no plaque; 1, film of plaque adhering to the free gingival margin and adjacent area of the tooth; 2, moderate accumulation of soft deposits in the gingival pocket or on the tooth gingival margin; and 3, abundance of soft matter within the gingival pocket and/or on the tooth gingival margins.

Salivary and microbiological tests

For an assessment of MS count, plaque was obtained using a microbrush (Applicator Tips, Dentsply DeTrey BmbH, Konstanz, Germany) from the tooth surfaces and spread thoroughly on the rough surface of a strip (Dentocult SM Strip Mutans, Orion Diagnostica, Espoo, Finland). When the amount of plaque was insufficient for collection, an alternative method was used according to the manufacturer's directions. Briefly, after the participant chewed paraffin pellets for 1 min, the rough surface of the strip was pressed against the saliva remaining on the participant's tongue [11]. Participants were classified into one of four classes based on their MS and LB scores according to the Cariogram manual; the lowest class had a score of 0. Salivary secretion rates were measured in ml/min, while paraffin-stimulated whole saliva was collected for 5 min with the participants in an upright position. The fresh saliva sample was then used to inoculate selective LB culture media (Dentocult LB, Orion Diagnostica). The buffer capacity of the saliva was also determined using a buffer strip (DentobuffStrip, Orion Diagnostica).The scoring of the salivary buffer capacity was determined by the color of the strip as follows: 0, blue (pH > 6.0); 1, green (4.5 < pH < 5.5); and 2, yellow (pH < 4.0).

Risk assessment using the Cariogram

Information based on each caries-related factor was collected and entered into the Cariogram (Table I). Each factor has a score ranging from 0–2 (or 3), with 0 being the most favorable score. The 'clinical judgment' factor was set to 1 (normal setting). In the Cariogram, an individual caries risk profile is generated for each of five sectors expressed with a percentage value. In the simplified Cariogram models, either or both the salivary secretion rate and lactobacilli count were excluded. The following four groups were recognized: group 1, conventional model; group 2, both salivary secretion rate and LB count excluded; group 3, salivary secretion rate excluded; group 4, LB count excluded (Table II).

Statistical methods

Descriptive statistics were expressed as either a mean (standard deviation, SD) or frequency (percentage), as appropriate. The distribution of risk avoidance was approximately symmetric ($|\text{skewness}| < 0.5$). Repeated measures analysis of variance (ANOVA) was applied to determine whether there were statistically significant differences in risk avoidance, diet (%), bacteria (%), susceptibility (%), and circumstance (%) among the four models. Since the assumption of sphericity was rejected ($p < 0.001$) and the Greenhouse-Geisser epsilon was below 0.7, the Greenhouse-Geisser adjustment was applied to modify the obtained p-values (0.05). Spearman correlation coefficient analysis was used to assess the degree of correlation between the risk factors and the risk sectors and between the risk factors and the chance of avoiding caries. The type one error rate of 0.05 was applied to determine the statistical significance. SPSS version 12.0 (SPSS Inc., Chicago, IL, USA) was used for the analysis.

Table I. Caries-related factors included in the Cariogram.

Factors	Cariogram information	Collection methods
Diet (content)	A. Consumption of fermentable carbohydrates B. Lactobacillus (LB) test	A. Questionnaire B. Dip-slide LB test (Dentocult LB)
Diet (frequency)	Frequency of daily dietary intake	Questionnaire
Plaque amount	Plaque Index (PI) according to Silness-Löe	Clinical examination
Mutans streptococci (MS)	MS count	Strip Mutans test (Dentocult SM)
Fluoride	Availability of fluoride	Questionnaire
Saliva secretion rate	Secretion rate on stimulated saliva	Paraffin & measuring cup
Salivary buffering	Buffering capacity of saliva	pH indicator kit (Dentobuff Strip)
Caries experience	DMFT (decayed, missing and filled teeth)	Clinical examination, Radiography
Related disease	General disease, medication	Questionnaire

Table II. Caries-related factors included in the conventional and the simplified Cariogram models.

Sectors	Cariogram models			
	Conventional Group 1	Simplified_SL[a] Group 2	Simplified_S[b] Group 3	Simplified_L[c] Group 4
Diet	Contents Frequency LB count	Contents Frequency	Contents Frequency LB count	Contents Frequency
Bacteria	Plaque amount MS count	Plaque amount MS count	Plaque amount MS count	Plaque amount MS count
Susceptibility	Fluoride Salivary secretion Saliva buffer	Fluoride Saliva buffer	Fluoride Saliva buffer	Fluoride Saliva secretion Saliva buffer
Circumstance	Caries experience Related disease	Caries experience Related disease	Caries experience Related disease	Caries experience Related disease

[a]Salivary secretion rate and LB count were excluded.
[b]Salivary secretion rate was excluded.
[c]LB count was excluded.

Results

Figure 1 shows the distribution of the high caries risk group according to the level of oral hygiene maintenance. Of the total patients, 44 (55.0%) belonged to the normal maintenance group, 34 (42.5%) were in the insufficient maintenance group and two (2.5%) were in the very insufficient group.

There was no significant difference in the chance of avoiding caries between age groups (15–23 years and 24–30 years) or between males and females (Table III). However, for oral hygiene maintenance, the insufficient or very insufficient group had a lower chance of avoiding caries than the normal group over all the different Cariogram settings ($p < 0.05$).

The mean chance of avoiding caries in the conventional Cariogram model (group 1) was 55.5% (Table IV). In the simplified_SL model (group 2) and the simplified_S model (group 3), the chance of avoiding caries was 55.4% and 54.0%, respectively. The three groups were not significantly different. The simplified_L model (group 4) showed a significant difference in the chance of avoiding caries (57.0%) compared to group 1 ($p < 0.05$). In the dietary sector, group 4 was significantly different compared to group 1 ($p < 0.05$). In the bacteria sector, no significant difference was detected among all the groups. In the susceptibility sector, group 4 significantly differed to group 1 ($p < 0.05$). In the circumstance sector, group 4 was significantly different from the other three groups ($p < 0.05$). Significant correlations were detected between each risk factor and its corresponding risk sector (Table V). All risk factors and the chance of avoiding caries were also significantly correlated, except for the amount of plaque in all the groups and MS count in group 4 (Table VI).

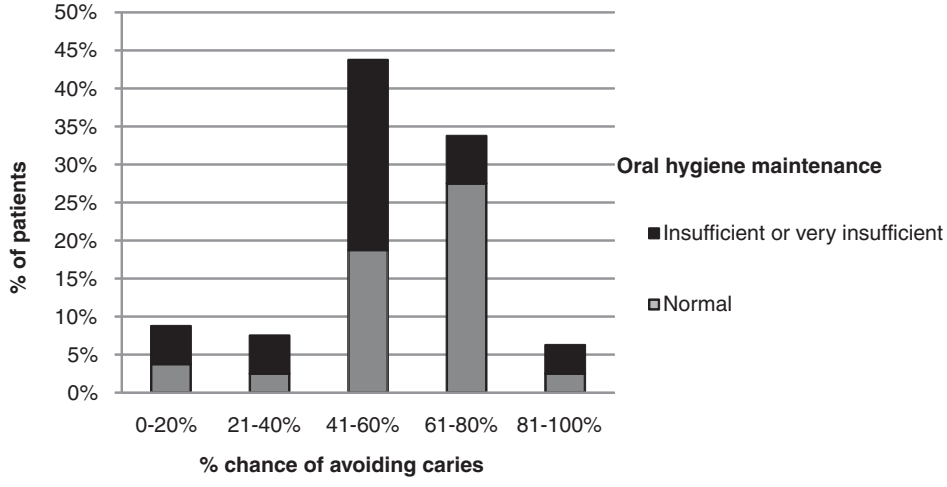

Figure 1. Distribution of caries risk groups according to the level of oral hygiene maintenance: normal, brushing time > 3 min; insufficient, brushing time 1–3 min, very insufficient, brushing time < 1 min.

Table III. Comparisons of the chance of avoiding caries according to age, gender and oral hygiene maintenance among the conventional and the simplified Cariogram models.

	Age, years			Gender			Oral hygiene maintenance		
Models	15–23	24–30	*p*-value	Male	Female	*p*-value	Normal	Insufficient or very insufficient	*p*-value
Conventional, group 1	57.4 (20.0)	52.8 (20.7)	0.321	57.7 (20.0)	53.5 (20.6)	0.360	60.1 (19.9)	49.9 (19.6)	0.024
Simplified_SL, group 2	53.1 (19.2)	57.0 (18.2)	0.363	58.4 (17.2)	52.6 (19.6)	0.162	59.5 (18.0)	50.5 (18.4)	0.030
Simplified_S, group 3	55.6 (18.6)	51.6 (18.5)	0.347	56.9 (17.7)	51.3 (19.0)	0.173	58.2 (17.7)	49.0 (18.5)	0.026
Simplified_L, group 4	58.8 (19.8)	54.2 (21.4)	0.327	59.2 (19.8)	54.8 (20.1)	0.345	61.4 (20.2)	51.5 (19.7)	0.029

Discussion

Performing a CRA in an efficient and practical way is crucial not only in public health screenings, but also in ordinary clinical practices [3]. Determining the risk level of an individual patient can inform the selection of treatment options and prediction of prognosis to establish a definitive treatment plan and post-care program. The application of assessment models should not have usage barriers for clinicians and data collection systems need to be simple and inexpensive with a limited armamentarium [12]. More importantly, the procedures should be acceptable and convenient for patients. Among the risk parameters included in the Cariogram, saliva secretion rates may be the least attainable in clinical settings, because the measurement procedure deviates from the routine examination and requires special patient guidance. After measurement, the collected saliva sample is used to inoculate LB culture media, while MS can be alternatively gathered from plaque on the tooth surfaces. We hypothesized that the saliva collection procedure could be excluded from the Cariogram without significant changes in the caries risk profile generated by the program.

In groups 2 and 3, the chance of avoiding caries was not significantly different compared to controls (group 1, Table IV). In group 4, however, the chance of avoiding caries differed significantly compared to the values in the other three groups. In the diet sector, group 4 showed a significant difference than the other three groups. Considering the fact that a high level of LB correlates with increased sugar consumption [13], the role of fermentable carbohydrates may have been under-estimated in the high sugar-intake group, when only dietary questionnaires were included in the diet sector. When salivary secretion rate and LB count were both excluded (group 2), the disparity between the simplified model and the conventional model seemed to decrease, resulting in no significant difference between the two groups in the diet sector. The questionnaire results were highly correlated (0.72–0.82) with the diet sector in all groups and the correlation coefficients were similar to those generated by the analysis of the questionnaire results and LB count combined (0.74–0.81) (Table V). There was no significant difference among all four groups in the bacteria sector. This was an intuitive outcome because no variables belonging to the bacteria sector were excluded. In the susceptibility and the circumstance sector, group 4 showed significantly different values compared to the other groups. Additionally, a certain individual factor (MS count) was inconsistently correlated with future caries risk in group 4 compared to the other groups. Overall, among the three simplified Cariogram models, only the single omission of LB count noticeably altered the risk profiles. Therefore, our research hypothesis was not fully rejected.

Our statistical analysis was performed after adjusting for age, gender and oral hygiene maintenance. Age and gender did not affect the risk of future caries throughout the four different settings of the Cariogram. The three-point scoring system for oral hygiene

Table IV. Mean values (SD) of the chance of avoiding caries and the sectors of diet, bacteria, susceptibility and circumstance (%) obtained with the conventional and the simplified Cariogram models.

Models	Chance of avoiding caries	Diet	Bacteria	Susceptibility	Circumstance
Conventional, group 1	55.5 (20.3)$a^{\star}$	13.3 (7.9)^{a}	11.8 (7.1)^{a}	13.5 (8.2)^{a}	5.7 (3.0)^{a}
Simplified_SL, group 2	55.4 (18.6)^{ab}	12.5 (7.7)^{ab}	11.8 (6.6)^{a}	14.5 (5.8)^{ab}	5.8 (3.0)^{a}
Simplified_S, group 3	54.0 (18.5)^{ac}	13.3 (7.6)^{ac}	12.0 (6.6)^{a}	14.8 (5.7)^{ab}	5.9 (3.1)^{a}
Simplified_L, group 4	57.0 (20.4)^{b}	12.4 (7.9)^{bc}	11.6 (7.1)^{a}	13.3 (8.2)^{b}	5.6 (2.9)^{b}
p-value$^{\#}$	0.004	0.005	0.109	0.011	0.001

*Different alphabetic superscripts represent a statistical difference at a type one error rate of 0.05.
$^{\#}$*p*-values obtained after adjusting for age, gender and oral hygiene status.

Table V. Correlations (p-value) between the risk sectors and the risk factors in the conventional and the simplified Cariogram models.

Sectors	Factors	Cariogram models			
		Conventional Group 1	Simplified_SL Group 2	Simplified_S Group 3	Simplified_L Group 4
Diet	Diet contents (questionnaire)	0.72 ($p < 0.001$)	0.82 ($p < 0.001$)	0.80 ($p < 0.001$)	0.75 ($p < 0.001$)
	Diet contents (questionnaire + LB count)	0.74 ($p < 0.001$)	—	0.81 ($p < 0.001$)	—
	Diet frequency	0.41 ($p < 0.001$)	0.47 ($p < 0.001$)	0.40 ($p < 0.001$)	0.46 ($p < 0.001$)
Bacteria	Plaque amount	0.49 ($p < 0.001$)	0.57 ($p < 0.001$)	0.57 ($p < 0.001$)	0.49 ($p < 0.001$)
	MS count	0.69 ($p < 0.001$)	0.69 ($p < 0.001$)	0.69 ($p < 0.001$)	0.69 ($p < 0.001$)
Susceptibility	Fluoride	0.41 ($p < 0.001$)	0.55 ($p < 0.001$)	0.56 ($p < 0.001$)	0.41 ($p < 0.001$)
	Saliva secretion	0.65 ($p < 0.001$)	—	—	0.65 ($p < 0.001$)
	Salivary buffer	0.51 ($p < 0.001$)	0.65 ($p < 0.001$)	0.64 ($p < 0.001$)	0.51 ($p < 0.001$)
Circumstances	Caries experience	0.87 ($p < 0.001$)	0.90 ($p < 0.001$)	0.90 ($p < 0.001$)	0.87 ($p < 0.001$)
	Related disease*	—	—	—	—

*The general disease factor was scored as 0 for all cases.

maintenance was based on self-reports (normal, insufficient and very insufficient). There are conflicting reports with regard to the direct influence of tooth brushing habits on the degree of caries risk [14–16]. Also, the plaque amount factor was not significantly correlated with the future caries risk in this study (Table VI). However, extended duration of brushing can induce intra-oral fluoride retention; in addition, it implies good oral hygiene maintenance [17]. We intended to relate a CRA to patients' self-awareness of oral hygiene, because a CRA can be an educating and explanatory tool for patients along with clinical intervention. We evaluated an adolescent and young adult population (mean age: 23.0 ± 3.3 years) that visited the dental hospital for caries and/or root canal treatments in the present study. Since information based on CRA studies in children or the elderly is abundant, evidence-based caries management protocols for these groups have been widely proposed. In another way, adults almost never encounter school-based preventive programs and are prone to neglecting their potential caries risk. Among the participants, 4% reported that they spent less than 3 min for tooth brushing per each brushing session (Figure 1). This self-defined status of oral hygiene maintenance was significantly correlated with future caries risk (0.32 to 0.28). A remarkably higher proportion of participants among the normal-maintenance group belonged to the low caries risk group, while the opposite trend was noted among the insufficient or very insufficient maintenance group. The participants commonly sought treatments related to past or current caries lesions or endodontic problems. A recent study [18] showed that the lower the chance of avoiding new caries was, the higher the percentage of recurrent caries would be. According to another study on the

Table VI. Correlations (p-values) between the caries-related factors and the chance of avoiding caries in the conventional and the simplified Cariogram models.

Factors	Cariogram models			
	Conventional Group 1	Simplified_SL Group 2	Simplified_S Group 3	Simplified_L Group 4
Oral hygiene maintenance	0.32 ($p = 0.004$)	0.28 ($p = 0.011$)	0.30 ($p = 0.007$)	0.30 ($p = 0.007$)
Diet contents (questionnaire)	0.32 ($p = 0.003$)	0.43 ($p < 0.001$)	0.40 ($p < 0.001$)	0.38 ($p < 0.001$)
Diet contents (questionnaire + LB count)	0.34 ($p = 0.002$)	—	0.41 ($p < 0.001$)	—
Diet_frequency	0.31 ($p = 0.006$)	0.40 ($p < 0.001$)	0.40 ($p < 0.001$)	0.40 ($p < 0.001$)
Plaque_amount	0.19 ($p = 0.096$)	0.20 ($p = 0.081$)	0.17 ($p = 0.134$)	0.05 ($p = 0.622$)
MS count	0.49 ($p < 0.001$)	0.51 ($p < 0.001$)	0.53 ($p < 0.001$)	0.04 ($p = 0.722$)
Fluoride	0.34 ($p = 0.002$)	0.33 ($p = 0.003$)	0.33 ($p = 0.003$)	0.27 ($p = 0.015$)
Saliva secretion	0.42 ($p < 0.001$)	—	—	0.49 ($p < 0.001$)
Salivary buffer	0.42 ($p < 0.001$)	0.39 ($p < 0.001$)	0.37 ($p < 0.001$)	0.38 ($p < 0.001$)
Caries experience	0.40 ($p < 0.001$)	0.40 ($p < 0.001$)	0.41 ($p < 0.001$)	0.41 ($p < 0.001$)

survival of teeth with extensive restorations [19], failed teeth and surviving teeth differed with regard to some caries-related factors, such as bacterial levels, dietary frequency per day and salivary buffer capacity. When the level of risk is adequately evaluated, clinicians can work with patients to modify the contributing risk factors, which will then enhance the preservation of tooth structure and longevity of the restorations.

There are some restrictions to the interpretation of our results. First, the outcome of this study may be valid only for young adults with uncompromised saliva-secretory function. The results would likely be different in an elderly group with an increased prevalence of hyposalivation. Second, the Cariogram serves as both a prediction model and a risk model [3] and the present study focused on the latter function of the program. We attempted to evaluate the patients' current risk factors to allocate them into various risk groups in an everyday practice setting. As Petersson et al. [5] have already emphasized, it is more important to proceed with a CRA incorporating the best available evidence than to not attempt it due to a lack of firm evidence. Future studies involving longitudinal observations and linear regression analysis could facilitate the development of simpler CRA models with greater accuracy and accessibility for both clinicians and patients.

In conclusion, within the limitations of our study, our findings indicate that the simplified Cariogram with the exclusion of two risk factors (i.e. salivary secretion rates and LB count) may be used in clinical practice, when a full inclusion of risk factors is not achievable. The Cariogram can be used to determine individual risk profiles of patients in need of preventive and/or restorative dentistry.

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