ARTÍCULOS ORIGINALES

Fermentable carbohydrate dietary consumption measured by a cariogenicity scoring system and caries experience in youth and adults

Consumo de carbohidratos fermentables en la dieta medido mediante un sistema de puntaje para la cariogenicidad y experiencia de caries en jóvenes y adultos

ABSTRACT

Aim: To evaluate if dietary fermentable carbohydrate consumption associates with caries experience of youths and adults when assessed by a scoring system of putative cariogenicity of the foods. Methods: Two hundred and seventy five subjects (12 to 67 years-old) were examined to assess caries experience by the DMFT Index (decay, missing and filled teeth) and radiographs. Subjects filled a weekly diet diary registering the type, frequency and time of consumption of foods. An arbitrary scoring system was used to determine cariogenic potential of the diet based on food consistency, frequency and occasion of consumption. Results: DMFT index significantly increased with age ($p<0.001$). Females showed higher cariogenic potential than males ($p=0.04$). When subjects were divided into four DMFT categories, no differences were detected in cariogenic potential of the diet in any caries group. No correlation between caries experience and cariogenic potential of the diet could be found. Conclusions: Arbitrarily assigned cariogenicity of dietary fermentable carbohydrates does not seem to associate with caries experience, when information was obtained through a cariogenicity scoring system.

Key words: Caries, weekly diet diary, cariogenic potential, sugar, carbohydrate consumption, DMFT.

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INTRODUCTION

Dental caries is a multifactorial disease with a diet high in fermentable carbohydrates considered as a primary etiological factor (1). Among dietary carbohydrates, sucrose is considered the most cariogenic sugar as it is readily fermentable by the cariogenic microflora to serve as substrate for exopolysaccharide synthesis, which in turn favor bacterial adhesion and colonization of the tooth (2). The effect of sucrose depends on the concentration and the frequency of the exposure (3,4). Thus, sucrose availability in the oral environment is associated with the etiopathogenesis of dental caries (5). Besides sucrose, processed starches have also a cariogenic potential (6). Combination of starch and sucrose are commonly found in western diets and they can have a synergistic effect (7,8). The intermittent exposure to dietary sugars (carbohydrates), involves periods of demin and remineralization (9) In fact, frequent exposure to fermentable sugars (carbohydrates) lowers pH leading to dental hard tissue (enamel or dentin) demineralization and to proliferation of cariogenic bacterial species in the oral biofilm (10,11).

It has long been thought that a diet containing high amounts and frequency of sugar would predispose to caries (12). Several investigations have confirmed this association (13). Despite the relative consensus in the dental profession on the cariogenic role of simple sugars, i.e., sucrose, increasing evidence has challenged this assertion. Indeed, even the classic and seminal Vipeholm caries and sweets study in which children from a mental institution received high amounts of sweets and chocolates for years (14), provides confusing evidence. In the study, 20 to 30% of the subjects

did not develop new caries lesions and individuals without supplements of refined sugar and with maximal avoidance of natural sugars and other carbohydrates continued to have new dental caries (15). The observations jeopardize a simplistic conclusion on the straightforward role of sugars on the onset of caries. Indeed, a study on fermentable carbohydrate consumption and dental caries demonstrated a poor correlation between the amount of sugar consumed by 10 to 15 year-old children and their caries experience (16). In fact, despite the many studies supporting an etiological role for fermentable carbohydrates in dental caries, many others argue for a rather weaker association (17,18).

Most of the available clinical evidence of the role of sugar-containing diet on caries has been obtained from studies performed in children. How fermentable carbohydrate consumption influences caries experience in adults has been less explored and requires further investigation. Thus, despite the apparent direct association on the deleterious effect of simple sugars, evidence reveals gaps and lack of clarity on the matter.

To assess dietary habits and specific food consumption, a weekly diet diary is often used in nutrition (19). Likewise, many Dental Schools and private practices use similar questionnaires to determine fermentable carbohydrate consumption. In Chile and in some other places in Latin America, a weekly diet diary is used in combination with an instrument that intends to assess the cariogenic potential of the diet (20). The instrument scores sugar-containing food based on their putative cariogenicity from its stickiness and from consistency. Also, the tool scores higher if the intake is between meals than with main meals and based on the frequency of consumption. A final cariogenic potential of the diet score is obtained and categorized as high, moderate or low caries risk. Little evidence has been shown on the correlation of the tool's scores and the actual caries experience of a population, nonetheless. The aim of this study was to determine if cariogenic potential of the diet associates with caries experience, in youth and adults.

SUBJECTS AND METHODS

Subjects. Clinical records from three hundred and fifty patients attending the Dental Clinics of the University of Talca in Talca, Chile were randomly selected to participate in the study. Patients with low salivary flow (<1 mL/min stimulated and <0.25 mL/min unstimulated) obtained from the record data, were excluded. A final sample of records from two hundred and seventy five patients aged twelve to sixty seven years, 64,4% females and 33,6% males, participated in the study. Education level was not considered to enter the study. Each participant signed an informed consent to release their information for research purposes.

Dietary assessment. To obtain information on type, frequency and habits of fermentable carbohydrate consumption, each subject was instructed on how to fill out a weekly diet diary at home. Written instructions were also included. During the entire week, subjects had to write everything they ate at breakfast, lunch and dinner and also between main meals.

Once the forms were received, the cariogenic potential of the diet was calculated, as follows (table 1). Each carbohydrate was assigned an arbitrary value based on its putative cariogenic properties. Thus, non-sticky complex carbohydrates scored lower than adhesive sugary foods. Moreover, frequency and occasion of consumption, which was scored low if sugar was consumed with or high if it was between main meals, were registered. If the sugar-containing food was consumed occasionally, two or more times a week, daily or more than twice per day, it was assigned a score of 0, 1, 2 or 3, respectively. Likewise, if a cariogenic food was consumed with meals or between meals, it was assigned a score of 1 or 5, respectively. Frequency and occasion scores were multiplied each by the food type values and the resulting numbers were the Frequency Score (FS) and the Occasion Score (OS). The Cariogenic Potential (CP) of the diet of a person, therefore, was the sum of FS and OS. The scores obtained from each variable were converted into a scale of three categories, as described in table 1.

TABLE 1

Scoring system of food type, frequency and occasion of consumption to obtain the cariogenic potential of the diet.

A. Carbohydrate type

Beverages with sucrose	Sugared soda	1
	Tea, coffee with 2 or more spoons of sucrose	1
Doughs without sucrose	Bread, whole weat bread, sugarless cookies	2
Sweets	Candy, ice cream, jam, chocolate	3
Dough with sucrose	Cake, cookies with sugar, sugared pastry	4
Sticky candies or sugar	Honey, sugared cereals, toffee, sticky candy	5

B. Frequency

Occasionally	2 or more per week	daily	More than 2 per day
0	1	2	3

C. Occasion

With main meals	Between Meals
1	5

D. Cariogenic potential of diet

Scores	Interpretation
10 - 33	Low
34 - 79	Moderate
80 - 144	High

Caries assessment. Subjects were divided into 5 age categories (table 2). Caries experience, measured by DMFT, were obtained from the clinical record of each participant. Clinical information was obtained by an exam performed by means of a mouth mirror and a probe on a dental chair. To obtain the DMFT index (decayed, missing and filled teeth), only teeth with current caries or with history of having had caries were included, according to WHO criteria (21). Additionally, the Significant Index Caries (SiC) (22) was calculated. This index corresponds to the DMFT of the most affected third of the population. Data were registered on the dental record under a faculty member supervision. Additionally, bitewing radiographs were taken to detect proximal lesions as a supplement for the diagnosis.

Statistical analysis. Shapiro-Wilk test was used to test for normality of the data. Since all data showed normal distribution, they were analyzed with parametric tests (t-student and ANOVA). Several multinominal logistic regression models were adjusted to find associations. A significance level of 95% was used and considered significant if $p<0.05$. Analysis was performed using SSPS software, version 14.0.

RESULTS

Patients were grouped into 5 age categories, as follows: 12–15; 16-19; 20–34; 35-49, and 50 and older (table 2). Mean age was 25.83±11.29 years.

Caries experience: DMFT was 12.16 (±5.04) in a range from 0 to 27. The SiC for this sample of patients was 17.91(±2.57). DMFT significantly increased with age ($p<0.001$) (table 3).

Frequency Score. When FS was calculated, a decreasing trend in the scores with age groups could be observed (table 4). Females showed higher FS than males ($p<0.05$) (Table 5).

Occasion Score. Like for FS, there was a declining trend

TABLE 2

Patient distribution by age and gender

Age	n	Female (%) (n=177)	Male (%) (n=98)
12 - 15	36	10.2	10.2
16 - 19	44	17.5	17.5
20 - 34	145	52.0	52.0
35 - 49	35	14.7	14.7
>50	15	5.7	5.7
Total	275	64.4%	33.6%

TABLE 3

DMFT and SiC by age groups.

Age	DMFT Mean SD	SiC Mean SD
12 - 15	8.64 ± 4.82	17.33 ± 1.15
16 - 19	11.91 ± 4.12	16.73 ± 1.27
20 - 34	12.00 ± 4.90	18.13 ± 2.58
35 - 49	15.31 ± 3.98	17.54 ± 2.28
>50	15.53 ± 5.62	20.67 ± 4.03
Total	12.16 ± 5.04	17.91 ± 2.57

TABLE 4

Frequency score, occasion score and cariogenic potential of the diet by age groups (n=275).

Age	Frequency score Mean SD	Occasion score Mean SD	Cariogenic potential Mean SD
12 - 15	20.75 ± 8.29	48.94 ± 19.18	69.97 ± 24.54
16 - 19	22.64 ± 9.15	53.48 ± 21.58	76.23 ± 27.67
20 - 34	17.69 ± 7.32	45.27 ± 18.87	63.21 ± 23.85
35 - 49	16.54 ± 5.71	37.26 ± 17.52	53.51 ± 19.41
>50	14.67 ± 6.65	31.13 ± 17.67	46.47 ± 23.11
Total	18.58 ± 7.84	45.27 ± 19.83	64.03 ± 25.10

in the OS with age (table 4), but no difference by sex was detected (table 5).

Cariogenic potencial of diet. CP of the diet was calculated from the scores of diet type, frequency and occasion of consumption, according to the formula described above. Moreover, CP for the entire group was 64.03(±25.10), which corresponds to a moderate level. 60% of the participants had moderate CP, followed by 30.2% with high and 9.8% with low CP (data not shown). Although not significant (p>0.05), CP of the diet of the participants in this study decreased with age (table 4). The CP for women was significantly higher than for men (table 5).

Association between caries experience and CP. To compare if patients with higher caries experience had higher FS, OS or CP scores, subjects were divided into 4 categories using the quartiles of the DMFT (table 6). Neither FS, nor OS, or CP showed significant differences at any quartile of DMFT. In order to determine whether an association between cariogenic diet and caries history existed, several multinominal linear logistic regression models were adjusted. No association between the variables was found (p=0.52). On a dispersion plot, the distribution of the cases by cariogenic potential of the diet and DMFT indicates lack of any trend (r=0.014; p=0.51) (figure 1).

DISCUSSION

Although it is widely acknowledged that diet plays a role in the etiology of caries, our results failed to show association between consumption of fermentable carbohydrates and caries experience. When different habits of consumption of sugars (frequencies and occasion) were considered, no differences were found in the DMFT index. Indeed, patients who referred a high consumption of sugared beverages did not show differences in respect of those who reported very rare or no consumption. For example, while 17.2% of the population occasionally drinks sugared soda and experience a DMFT 13.26 ±3.94, DMFT of the population that drank this type of beverages twice or more a day was 12.24±5.32 (p=0.178). Importantly, the lack of association between DMFT and CP of the diet shown here refers only to that resulting from arbitrarily scoring sugars in the diet according to their putative cariogenicity. Net fermentable carbohydrate consumption was not evaluated in this study.

Since diet is only one of the multiple factors involved in the pathogenesis of caries (23), other factors present in the subjects may have played a role, as well. Actually, the modulating role of fluoride exposure (24,25) and oral hygiene (26-28) may obscure the relation between diet and caries experience. Fluoride therapy seems to diminish the net influence of simple sugars on caries etiology, elevating the threshold for demineralization. Hence, the effect of sugars in caries would be less relevant (17). In vitro experiences have shown that when fluoride is present, higher frequencies of sucrose are needed to produce a significant enamel demineralization (3). The population of the present study has been exposed for several years to 0.7 ppm of fluoride in drinking water. Also, other fluoride sources may have been present, such as fluoride-rich food and fluoridated toothpastes (29).

The population of this investigation was mostly adults and young adults (table 1). Most of the research on this topic has been performed in children (30-34). It is possible that the impact of sugars on caries history is more evident in children than adults. Age may weaken the effect of sugar on caries. An interesting issue is the fact that caries experience using DMFT does not portrait current caries activity. Thus, fermentable carbohydrate consumption may be related with higher incidence of new lesions, but not with caries activity occurred in the past. New studies using caries lesion assessment, for example, ICDAS II (35), are suggested to better characterize

TABLE 5

Frequency score, occasion score and cariogenic potential of the diet by gender (n=275).

Gender	Frequency score Mean SD	Occasion score Mean SD	Cariogenic potential Mean SD
Male	17.02 ± 7.53	41.03 ± 19.92	58.24 ± 25.75
Female	19.44 ± 7.88	47.61 ± 19.44	67.23 ± 24.22
p-value	0.014*	0.08	0.04*

* Statistical differences (p<0.05)

TABLE 6

Frequency score, occasion score and cariogenic potential of the diet by DMFT index (n=275).

	Frequency score Mean ±SD	Occasion score Mean ±SD	Cariogenic potential Mean ±SD
DMFT≤9	19.65 ±9.05	44.57 ±20.85	64.20 ±26.70
9<DMFT≤12	17.13 ±7.67	47.40 ±18.60	64.91 ±23.31
12<DMFT≤15	17.74 ±5.98	43.67 ±21.45	62.27 ±26.28
DMFT>15	19.77 ±8.10	45.64 ±18.09	64.84 ±24.13
Total	18.58 ±7.84	45.27 ±19.83	64.03 ±25.10

the lesion status.

Our results jeopardize the use of a scoring system to intuitively assign levels of cariogenicity to sugars contained in food (20). A food that is retained longer in the mouth is supposedly more cariogenic. Likewise, a food that contains a higher proportion of sucrose is considered to be more acidogenic than a food that contains a lower proportion of simple sugars. While the latter appears reasonable, whether those foods remain actually longer in the mouth or if they really lower the pH more than others is merely an educated guess. Regardless of the reasonable that such scoring may seem, individual cariogenicity resulting from experimentation might be the only way to categorize cariogenicity of the different forms of sugars. Moreover, one of the clinical studies showing a direct association between sugar intake and caries found the association only with sugared beverages, which are scored as the least cariogenic by the instrument used in this research (table 1). Furthermore, the amount of sugar is not considered in this instrument and it could be also of importance to determine cariogenicity of the diet. Given its popularity in Chile and other countries, mainly at universities, we decided to test how well this scoring system portraits caries experience. Our results clearly show a lack of association between the putative cariogenic potential of the diet measured by the questionnaire and the caries experience of the individuals. Since the instrument is not validated, but largely used, faculty and clinicians should be aware that it is not a reliable tool to assess cariogenicity of the food consumed. New instruments capable to associate dietary habits with caries experience appear as necessary. The latter is in the assumption that food type and/or dietary habits actually constitute risk factors for caries, which in light of these results seems uncertain, and deserves more research.

The association between fermentable carbohydrate consumption and caries experience may derive from more specific aspects of the food or the habits of consumption. Although, the contribution of diet in lowering oral biofilm pH has been extensively demonstrated (36), carbohydrate availability, per se, appears not to be totally responsible for the microbiological shift during caries. Rather, pH drop from carbohydrate metabolism seems more strongly linked to changes in composition and metabolism of the oral biofilm (37,38). Experiments, though, have used standard foods that do not discriminate food molecules and all contain high

FIGURE 1

Correlation between DMFT and the cariogenic potential of the diet.

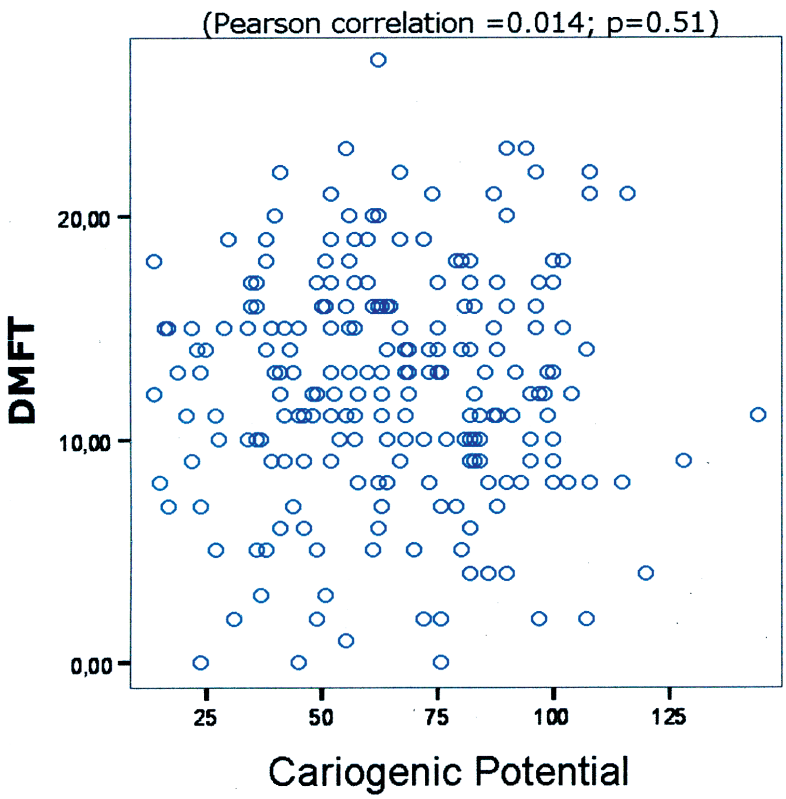

Figure shows the distribution of scores resulting from the weekly diet diary (n=275).
Vertical axis indicates caries experience (DMFT) and horizontal axis shows the cariogenic potential of the diet. Pearson correlation 0.014; p= 0.51.

amounts of sucrose (36). Furthermore, pH measurements in these experiments were made after 30 minutes after the food was ingested and therefore, time for bacteria to reorganize and create a more cariogenic biofilm was not allowed. The net cariogenic potential of the food requires considering all the nutrients, resembling the way they are presented to the oral environment during normal feeding.

Dietary habits and patterns remain important to explain caries, but the tools to assess intake or a certain bias in scoring the food consumed darken the association. Although diet is undoubtedly crucial, other risk factors may contribute to caries and may influence the final pH produced by food: buffer capacity of the saliva, calcium and phosphate concentration in saliva, flow rate and viscosity of saliva, presence of plaque in susceptible sites of the tooth, components of the biofilm affecting diffusion, anatomy of the teeth, enamel microstructure, fluoride content of enamel and plaque, pattern of mastication, sucking, rinsing and swallowing and frequency of food ingestion (39). As a way of controlling the salivary factor, patients with altered salivary flow were excluded from the study. Altered salivary flow may delay oral clearance for sugars and the time that that pH remains low to demineralize the enamel (40).

In conclusion, the study failed to find an association between intake of fermentable carbohydrates measured by a weekly diet diary combined with a cariogenicity scoring system and caries experience in adults. More research appears needed to clarify this topic.

RESUMEN

Objetivo: Evaluar si el consumo de carbohidratos fermentables se asocia con la experiencia de caries en jóvenes y adultos, cuando es medido por un sistema de asignación de puntajes a los alimentos según su presunta cariogenicidad. Metodología: 275 sujetos (12 a 67 años) fueron examinados para determinar su experiencia de caries mediante el índice COPD (dientes cariados, obturados y perdidos) y radiografías. Los sujetos llenaron un diario dietético semanal. Se utilizó un sistema arbitrario para asignar puntajes y determinar el potencial cariogénico de la dieta basado en la consistencia, frecuencia y ocasión de consumo. Resultados: Las mujeres mostraron mayor potencial cariogénico que los hombres (p=0,04). Cuando los sujetos fueron divididos en 4 categorías de COPD, no se detectaron diferencias en su potencial cariogénico en ningún grupo de caries. No se observó correlación entre la experiencia de caries y el potencial cariogénico de la dieta (p>0,05). Conclusiones: La cariogenicidad arbitrariamente asignada a los carbohidratos fermentables de la dieta no parece asociarse con la experiencia de caries en adultos.

Palabras clave: Caries, diario dietético semanal, potencial cariogénico de la dieta, azúcar, consumo de carbohidratos fermentables, COPD.

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REFERENCES

1. *Fejerskov O. Changing paradigms in concepts on dental caries: consequences for oral health care. Caries Res. 2004;38:182-91.*
2. *Paes Leme AF, Koo H, Bellato CM, Bedi G, JA. C. The role of sucrose in cariogenic dental biofilm formation-New insight. J Dent Res 2006; 85:878-87.*
3. *Ccahuana-Vasquez RA, Tabchoury CP, Tenuta LM, Del Bel Cury AA, Vale GC, Cury JA. Effect of frequency of sucrose exposure on dental biofilm composition and enamel demineralization in the presence of fluoride. Caries Res 2007;41:9-15.*
4. *Aires CP, Tabchoury CP, Del Bel Cury AA, Koo H, Cury JA. Effect of sucrose concentration on dental biofilm formed in situ and on enamel demineralization. Caries Res 2006; 40:28-32.*
5. *dos Santos MN, dos Santos LM, Francisco SB, Cury JA. Relationship among dental plaque composition, daily sugar exposure and caries in the primary dentition. Caries Res. 2002; 36:347-52.*
6. *Lingström P, van Houte J, Kashket S. Food starches and dental caries. Crit Rev Oral Biol Med 2000; 11:366-80.*
7. *Ribeiro CC, Tabchoury CP, Del Bel Cury AA, Tenuta LM, Rosalen PL, Cury JA. Effect of starch on the cariogenic potential of sucrose. Br J Nutr 2005; 94:44-50.*
8. *Firestone AR, Schmid R, Muhlemann HR. Cariogenic effects of cooked wheat starch alone or with sucrose and frequency-controlled feedings in rats. Arch Oral Biol 1982; 27:759-63.*
9. *Longbottom CL, Huysmans MC, Pitts NB, Fontana M. Glossary of key terms. Monogr Oral Sci 2009; 21:209-16.*
10. *Marsh PD. Are dental diseases examples of ecological catastrophes? Microbiology. 2003; 149:279-294.*
11. *Takahashi N, Nyvad B. Caries ecology revisited: microbial dynamics and the caries process. Caries Res 2008; 42:409-18.*
12. *Rypins R. Studies on the Relations of Types of Diet to Dental Caries: A Statistical Survey of Children Under School Age Relating to two Dietetic Theories on the Etiology of Dental Caries. J Dent Res 1922; 4:405-33.*
13. *Zero DT. Sugars - the arch criminal? Caries Res 2004; 38:277-85.*
14. *Gustafsson BE, Quensel CE, Lanke LS, et al. The Vipeholm dental caries study; the effect of different levels of carbohydrate intake on caries activity in 436 individuals observed for five years. Acta Odontol Scand 1954; 11:232-64.*
15. *Krasse B. The Vipeholm Dental Caries Study: recollections and reflections 50 years later. J Dent Res 2001; 80:1785-8.*
16. *Burt BA, Szpunar SM. The Michigan study: the relationship between sugars intake and dental caries over three years. Int Dent J. Jun 1994; 44:230-240.*
17. *Burt BA, Pai S. Sugar consumption and caries risk: a systematic review. J Dent Educ 2001; 65:1017-23.*
18. *Levine RS, Nugent ZJ, Rudolf MC, Sahota P. Dietary patterns, toothbrushing habits and caries experience of schoolchildren in West Yorkshire, England. Community Dent Health 2007; 24:82-7.*
19. *Bellisle F, Dalix AM, Mennen L, et al. Contribution of snacks and meals in the diet of French adults: a diet-diary study. Physiol Behav 2003; 79:183-9.*
20. *Lípari A, Andrade P. Factores de Riesgo Cariogénico. Rev Chil Odontopediatr. 2002;13:7-8.*
21. *WHO. World Health Organization. Oral health surveys: basic methods. Geneva. 4th ed1997.*
22. *Campus G, Solinas G, Maida C, Castiglia P. The 'Significant Caries Index' (SiC): a critical approach. Oral Health Prev Dent 2003; 1:171-8.*
23. *Jurgensen N, Petersen PE. Oral health and the impact of socio-behavioural factors in a cross sectional survey of 12-year old school children in Laos. BMC Oral Health*

2009;9:29.
24. Aires CP, Del Bel Cury AA, Tenuta LM, et al. Effect of starch and sucrose on dental biofilm formation and on root dentine demineralization. Caries Res 2008; 42:380-6.
25. Hicks J, Garcia-Godoy F, Flaitz C. Biological factors in dental caries: role of remineralization and fluoride in the dynamic process of demineralization and remineralization (part 3). J Clin Pediatr Dent 2004; 28:203-14.
26. Mascarenhas AK. Oral hygiene as a risk indicator of enamel and dentin caries. Community Dent Oral Epidemiol 1998; 26:331-9.
27. Sgan-Cohen HD. Oral hygiene: past history and future recommendations. Int J Dent Hyg 2005; 3:54-8.
28. Maltz M, Jardim JJ, Alves LS. Health promotion and dental caries. Braz Oral Res 2010; 24 Suppl 1:18-25.
29. Casals E, Boukpessi T, McQueen CM, Eversole SL, Faller RV. Anticaries potential of commercial dentifrices as determined by fluoridation and remineralization efficiency. J Contemp Dent Pract 2007; 8:1-10.
30. Lee JG, Messer LB. Intake of sweet drinks and sweet treats versus reported and observed caries experience. Eur Arch Paediatr Dent 2010; 11:5-17.
31. Palmer CA, Kent R, Jr., Loo CY, et al. Diet and caries-associated bacteria in severe early childhood caries. J Dent Res 2010; 89:1224-9.
32. Shenkin JD, Heller KE, Warren JJ, Marshall TA. Soft drink consumption and caries risk in children and adolescents. Gen Dent 2003; 51:30-6.
33. Burt BA, Kolker JL, Sandretto AM, Yuan Y, Sohn W, Ismail AI. Dietary patterns related to caries in a low-income adult population. Caries Res 2006; 40:473-80.
34. Zohouri FV, Maguire A, Moynihan PJ. Sources of dietary fluoride intake in 6-7-year-old English children receiving optimally, sub-optimally, and non-fluoridated water. J Public Health Dent 2006; 66:227-34.
35. Ismail AI, Sohn W, Tellez M, et al. The International Caries Detection and Assessment System (ICDAS): an integrated system for measuring dental caries. Community Dent Oral Epidemiol 2007; 35:170-8.
36. Jensen ME, Schachtele CF. The acidogenic potential of reference foods and snacks at interproximal sites in the human dentition. J Dent Res 1983; 62:889-92.
37. Bradshaw DJ, McKee AS, Marsh PD. Effects of carbohydrate pulses and pH on population shifts within oral microbial communities in vitro. J Dent Res 1989; 68:1298-1302.
38. Marsh PD. Dental diseases--are these examples of ecological catastrophes? Int J Dent Hyg 2006; 4:3S-10S.
39. Schachtele CF, Jensen ME. Comparison of methods for monitoring changes in the pH of human dental plaque. J Dent Res 1982; 61:1117-25.
40. Dawes C. Salivary flow patterns and the health of hard and soft oral tissues. J Am Dent Assoc 2008; 139:18S-24S.