THE EFFECT OF XYLITOL CHEWING GUM ON MUTANS STREPTOCOCCI IN SALIVA AND DENTAL PLAQUE

Sroisiri Thaweboon[1], Boonyanit Thaweboon[1] and Surin Soo-Ampon[2]

[1]Department of Microbiology, [2]Department of Physiology and Biochemistry, Faculty of Dentistry, Mahidol University, Bangkok, Thailand

Abstract. Dental caries are one of the most common infectious diseases occurred in Thai children. The chewing of xylitol, sorbitol, and even sugar gum has been suggested to reduce caries rates. The aim of the present investigation was to evaluate the effect of xylitol chewing gum on mutans streptococci (MS) in saliva and dental plaque. Ninety-one children, aged 10-12 years, with more than 1×10^5 MS per milliliter of saliva were included in this study. They were divided into three groups balanced according to their MS counts at baseline: one control group (no supervised gum use), and two xylitol groups (supervised 55% and 100% xylitol gum use). Whole saliva and pooled plaque samples were obtained after 90 school days. When comparing the MS counts between the groups, those chewing 100% and 55% xylitol gum showed significant reductions ($p < 0.025$), but a dose response effect was not demonstrated. Chewing 100% xylitol gum caused significant reductions on salivary MS scores ($p < 0.025$) which was little different from the 55% xylitol group. The results suggest that the use of xylitol chewing gum can reduce the levels of MS in plaque and saliva.

INTRODUCTION

Dental caries are one of the most common infectious diseases in Thai children. The prevalence of dental caries in Thai children aged 5-6 years had been reported to be 87.4% in 2000 (Ministry of Public Health, Thailand, 2002). Mutans streptococci (MS), in particular *Streptococcus mutans* and *Streptococcus sobrinus*, are considered to be closely associated with dental caries (Emilson and Krasse, 1985; Loesche, 1986). These microorganisms possess a unique combination of properties rendering them more cariogenic than other plaque bacteria. MS synthesize water-insoluble glucans from sucrose that mediate irreversible adhesion and colonization the teeth. They also produce large amounts of acid, which is involved in tooth demineralization. Another interesting property is that the acid tolerance of these kinds of bacteria is extremely high, thus allowing colonization and persistence under cariogenic conditions (Freedman *et al*, 1978; Tanzer *et al*, 1984).

Xylitol, a five-carbon natural sugar alcohol

Correspondence: Sroisiri Thaweboon, Department of Microbiology, Faculty of Dentistry, Mahidol University, 6 Yothi Road, Bangkok 10400, Thailand.
Tel: 66 (0) 2644 8644-6 ext 4811-2; Fax: 66 (0) 2644 8634
E-mail: dtstw@mahidol.ac.th

has been shown to be a successful caries preventive agent both in animals and humans (Birkhed, 1994). It is not fermented or used as a growth substrate by MS or by other microorganisms (Edwardson, 1977). Xylitol occurs in small quantities in berries and other fruits, in products made from these materials, or from other plant parts (Makinen *et al*, 1989). In addition, it occurs in human carbohydrate metabolism as a normal intermediate. About 5-15 g of xylitol may be formed daily in our body, mostly in the liver cells (Bassler, 1976). Xylitol has been used in Europe as a sweetener in the diabetic diets and was approved by the Food and Drug Administration (FDA) in the United States for special dietary uses in 1963 (Senti, 1986). Several studies have demonstrated that the consumption of xylitol decreased the growth and metabolism of acidogenic and aciduric oral flora and stimulated salivary defense mechanisms (Makinen, 1988). Moreover, the caries occurrence figures have been shown to decrease significantly in association with the daily use of xylitol-containing gum (Isokangas *et al*, 1988; 1993; Makinen *et al*, 1995). Two clinical field trials on the use of xylitol gum indicated that 7-10 g daily xylitol intake per child reduced the incidence of dental caries by 30-80% compared with control children who received no gum

(Isokangas *et al*, 1988). Therefore, the use of xylitol chewing gum is today recommended in Finland and in many other countries.

MATERIALS AND METHODS

Subjects

Approximately 250 children, aged 10-12 years, from a school in Chachoengsao Province, Thailand, were screened for salivary levels of MS. Those having ≥ 10^5 CFU/ml saliva, 91 children in total, were recruited into this study. All the children were asked to maintain normal dietary and oral hygiene habits throughout the study and to refrain from the use of fluoride mouthrinse or tablets. No eating or drinking was allowed 2 hours before the appointment for specimen collection.

Chewing gum

The children were divided into 3 groups: 55% xylitol group, 100% xylitol group, and non-gum group. They were assigned to chew 2 pieces of gum for a period of 5 minutes, 3 times per day (at 8.00 AM, 11.00 AM and 3.30 PM), under the supervision of their class teachers, for 90 schooldays. Children in the 55% xylitol group received the dosage of 5.76 g/day and those in the 100% xylitol group received the dosage of 11.88 g/day.

Microbiological assay

Paraffin-stimulated whole saliva was collected by the spatula method as described by Kohler and Bratthall (1979). Plaque specimens were collected by sterile curette from supragingival plaque at the buccal surface of teeth numbered #15, #16, #35, and #36. The wet weight of the sample was determined immediately. One mg of plaque was transferred into a tube containing 5 ml reduced transport fluid. All the specimens were obtained at baseline and after 90 days and cultured for MS on Mitis-Salivarius Bacitracin (MSB) agar in 5% CO_2 at 37ºC for 48 hours.

The identification of MS was based on colony morphology and Gram staining. The salivary MS score was divided into 3 categories: 1=0-20 CFU, 2=21-100 CFU, and 3 ≥100 CFU. The amount of MS was expressed as CFU/mg plaque (wet weight).

Statistical analysis

Three groups were compared with each other at various intervals by non-parametric Kruskal-Wallis and Mann Whitney *U*-tests. Changes over time within a group were compared using the non-parametric Wilcoxon signed-rank test.

RESULTS

At baseline, there were no statistical significant differences between the groups in levels of salivary and dental plaque MS. The mean values of plaque MS in the three groups at baseline and at 90 days are presented in Table 1. At 90 days, statistical analysis revealed differences between the non-gum and 100% xylitol groups ($p < 0.025$) and between the non-gum and 55% xylitol groups ($p < 0.025$). Significant decreases in the number of MS in dental plaque was found in the 55% and 100% xylitol chewing-gum groups, compared with baseline ($p < 0.025$). Although a dose response effect was not found, children in the high dose group (100% xylitol) tended to have lower plaque MS counts compared with the low dose group (55% xylitol) (3.44 ± 1.42 *vs* 3.96 ± 1.99). The mean values of the salivary MS scores in the three groups at each time interval are presented in Table 2. Statistical analysis revealed significant differences between the non-gum and 100%

Table 1
Plaque level of MS (log CFU/mg plaque) at baseline and 90 days (mean ± SD).

Group	N	Baseline	90 days
Non-gum	30	5.36 ± 2.12	5.00 ± 1.55
55% xylitol	29	5.97 ± 1.74	3.96 ± 1.99[a]
100% xylitol	32	5.94 ± 1.60	3.44 ± 1.42[a]

[a]Statistically different from baseline (p<0.025)

Table 2
Salivary level of MS (scores) at baseline and 90 days (mean ± SD).

Group	N	Baseline	90 days
Non-gum	30	1.82 ± 0.88	1.96 ± 0.86
55% xylitol	29	1.95 ± 1.06	1.91 ± 0.84
100% xylitol	32	1.90 ± 0.80	1.50 ± 0.82[a]

[a]Statistically different from baseline (p<0.025)

xylitol groups (p < 0.025) and between55% and 100% xylitol groups (p < 0.025) at 90 days. No significant difference was observed between the non-gum and 55% xylitol groups (p ≥ 0.05). Chewing 100% xylitol gum caused a significant reduction in the salivary MS score (p < 0.025) but there was little change in the 55% xylitol group.

DISCUSSION

Chewing sugar-free gum has potentially beneficial effects on dental health (Edgar and Geddes, 1990). During the past 10 years, interest has been focused on using such gum after meals and snacks. Chewing resulted in the neutralization of low pH by increasing the buffer capacity of the saliva and by enhancing the clearance of fermentable carbohydrates from the oral cavity (Dodds *et al*, 1991). Many bacteriologic, animal, and experimental studies in man have been carried out on several sugar substitutes (Wennerholm *et al*, 1991). Studies evaluating the cariogenic potential of sweeteners have yielded substantial evidence that xylitol is the most promising sweetener (Makinen, 1992). The mode of action of xylitol is that it is not fermented by most dental plaque bacteria and it has an effect on two other factors that cause disease. Evidence to date indicates that the mechanisms of action of xylitol include: absence of significant degradation into acidic end-products by dental plaque, stimulation of salivary flow and increased buffering capacity, inhibition of plaque accumulation and of cariogenic bacteria, remineralization of decalcified sites and inhibition of the demineralization of sound enamel (Makinen, 1992).

Chewing gum sweetened with 100% and 55% xylitol was well accepted by all the children who were participants in this study. No adverse reactions, such as gastrointestinal discomfort or transient loose stools were reported. Our data confirm earlier observations that xylitol reduces the number of MS in dental plaque and saliva (Loesche *et al*, 1984; Makinen *et al*, 1989). Although a dose-response effect was not shown in this study, children in the 100% xylitol group tended to have lower MS counts in the dental plaque compared to the 55% xylitol group. A dose-response effect has been recently reported in a 3-week crossover study by Wennerholm *et al* (1994). An increased concen-

tration of xylitol in the gum resulted in a significant decrease in saliva MS only. In our investigation, we found a significant reduction of MS in the saliva samples of children who consumed 100% xylitol, but no significant decrease of salivary MS levels was found in the 55% xylitol group. This was not in agreement with a study by Loesche *et al* (1984) which showed that the chewing of 58.8% xylitol resulted in up to a 90% reduction of MS in saliva. The difference may be because the subjects selected for our study had rather high levels of MS ($\geq 10^5$ CFU/ml saliva), whereas children participating in their study had $\geq 10^4$ CFU/ml saliva. The time period they observed the effect was only 4 weeks; whereas our test period was 90 days. The most effective dosage used in children who were considered to be at high risk for caries was reported to be 7-10 g/day (Makinen *et al*, 1989). This dosage is comparable to the 100% concentration that provided 11.88 g of xylitol, whereas the use of the 55% concentration provided only 5.76 g.

Wennerholm and Emilson (1989) confirmed a significant decrease in salivary *S. mutans* after 2 months of chewing xylitol-containing gum, but they also found that levels of *S. mutans* in the saliva return to baseline values after 3 months of chewing. Longer periods of xylitol consumption did not appear to significantly decrease the number of MS in the saliva compared with a control group of non-consumers (Soderling *et al*, 1991) in contrast to the results obtained with short periods of use (Masalin, 1992; Loesche *et al*, 1984). The level of MS in plaque seem to be significantly reduced in xylitol consumers in both short- and long-term studies, regardless of original values (Soderling *et al*, 1991; Loesche *et al*, 1984). Drean and Trahan (1990) reported an increased amount of xylitol-resistant *S. mutans* strains in the saliva of some subjects. Such an increase has been reported in many studies (Drean and Trahan, 1990; Trahan, 1992). The authors concluded that xylitol consumption modifies the MS distribution between the dental plaque and the saliva. Regular use of xylitol along with other factors allows the xylitol-resistant mutants to be more easily shed into the saliva from the plaque than the xylitol-sensitive wild-type strains. An easier shedding of xylitol-resistant cells from the plaque, and subsequent elimination from the saliva through swal-

lowing can result in a reduction in plaque MS only, usually observed in xylitol consumers in long term studies.

In conclusion, chewing of 55% and 100% xylitol gum caused a reduction in the amount of MS in the dental plaque. However, a significant decrease of MS in saliva was observed only in 100% xylitol use. These data suggest that the use of xylitol chewing gum can be a method of caries prevention in Thai children.

REFERENCES

Bassler KH. Quantitative aspects of the metabolism of glycerol, fructose, sorbitol and xylitol. In: Ritzel G, Brubacher D, eds. Monosaccharides and polyalcohols in nutrition, therapy and dietetics. Bern-Stuttgart-Wien: Hans Huber, 1976: 22-30.

Birkhed D. Cariological aspects of xylitol and its use in chewing gum-a review. *Acta Odontol Scand* 1994; 52: 1-12.

Dodds MWJ, Hsieh SC, Johnson DA. The effect of increased mastication by daily gum-chewing on salivary gland output and dental plaque acidogenicity. *J Dent Res* 1991; 70: 1474-8.

Drean MF, Trahan LA. New method for the detection and enumeration of xylitol resistant (fructose-PTS) strains of *Streptrococcus mutans* pure cultures and human saliva. *Microb Ecol Health Dis* 1990; 3: 113-20.

Edgar WM, Geddes DAM. Chewing gum and dental health-a review. *Br Dent J* 1990; 168: 170-7.

Edwardson S, Birkhed D, Majare B. Acid production from lycasin, maltitol, sorbitol and xylitol by oral streptococci and lactobacilli. *Acta Odontol Scand* 1977; 35: 257-63.

Emilson CG, Krasse B. Support for and implications of the specific plaque hypothesis. *Scand J Dent Res* 1985; 93: 96-104.

Freedman ML, Birkhed D, Granath D. Analysis of glucans from cariogenic and mutans streptococci. *Infect Immun* 1978; 21: 17-27.

Isokangas P, Alanen P, Tiekso J, Makinen KK. Xylitol chewing gum in caries prevention: a field study in children at caries active age. *J Am Dent Assoc* 1988; 117: 315-20.

Isokangas P, Makinen KK, Tiekso J, Alanen P. The long-term effect of xylitol chewing gum in the prevention of dental caries: a follow up 5 years after termination of a prevention program. *Caries Res* 1993; 27: 495-8.

Kohler B, Bratthall D. Practical method to facilitate estimation of *Streptococcus mutans* levels in saliva. *J Clin Microbiol* 1979; 9: 584-8.

Loesche WJ. Role of *Streptococcus mutans* in human

dental decay. *Microbiol Rev* 1986; 50: 353-80.

Loesche WJ, Grossman NS, Earnest R, Corpron R. The effect of chewing xylitol gum on the plaque and saliva levels of *Streptrococcus mutans*. *J Am Dent Assoc* 1984; 108: 587-92.

Makinen KK. Sweeteners and prevention of dental caries with special reference to xylitol. *Oral Hrealth* 1988; 78: 57-66.

Makinen KK. Dietary prevention of dental caries by xylitol-clinical effectiveness and safety. *J Am Nutr* 1992; 44: 16-28.

Makinen KK, Bennett CA, Hujoel PP, *et al*. Xylitol chewing gums and caries rate: a 40-month cohort study. *J Dent Res* 1995; 74: 1904-13.

Makinen KK, Soderling E, Isokangas P, Tenvuo J, Tieekso J. Oral biochemical status and depression of *Streptrococcus mutans* in children during 24-to-30-month use of xylitol chewing gum. *Caries Res* 1989; 23: 261-7.

Masalin K. Caries-risk-reducing effects of xylitol containing chewing gum and tablets in confectionary workers in Finland. *Comm Dent Health* 1992; 9: 3-10.

Ministry of Public Health, Thailand. National oral health survey 2000-2001. Fact Sheet-Dental Health 2002: 7.

Senti R. Health aspects of sugar alcohols and lactose. Bethesda, MD: US Department of Heath and Human Sciences, Life Sciences Research Office, FASEB, 1986. Food and Drug Administration. Report prepared for Food and Safety and Applied Nutrition. Contract No. FDA 223-83-3020. 1986.

Soderling E, Isokangas P. Tenovuo J, *et al*. Long-term xylitol consumption and mutans streptococci in plaque. *Caries Res* 1991; 25: 153-7.

Tanzer JM, Freedman ML, Fitzgerald RJ. Virulence of mutants defective in glucosyltransferase, dextran-mediated aggregation, or dextran activity. In: Magenhagen S, Rosan B, eds. Molecular basis of oral microbial adhesion. Washington, DC: American Society for Microbiology, 1984: 204-11.

Trahan L, Soderling E, Drean MF, *et al*. Effect of xylitol consumption on the plaque-saliva distribution of mutans streptococci and the occurrence and long-term survival of xylitol-resistant strains. *J Dent Res* 1992; 71: 1785-91.

Wennerholm K, Emilson CG, Birkhed D. Sweeteners and dental health In: Marie S, Piggott J, eds. Handbook of sweeteners. Sweden: Glasp Blackie and Son 1991: 205-24.

Wennerholm K, Arends J, Birkhed D, *et al*. Effect of xylitol and sorbitol in chewing gums on mutans streptococci , plaque pH and mineral loss of enamel. *Caries Res* 1994; 28: 48-54.

Wennerholm K, Emilson CG. Effect of sorbitol-and-xylitol containing chewing gum on salivary microflora, saliva, and sugar clearance. *Scand J Dent Res* 1989; 97: 257-62.