Changes in buccal white spots during 2-year consumption of dietary sucrose or xylitol

Maarit Rekola
Department of Cariology, Institute of Dentistry, University of Turku, Turku, Finland

Rekola M. Changes in buccal white spots during 2-year consumption of dietary sucrose or xylitol. Acta Odontol Scand 1986;44:285–290. Oslo. ISSN 0001–6357.

The purpose of the present study was to quantitate changes in buccal white-spot lesions during sucrose and xylitol consumption. Standardized color macrophotographs of white-spot lesions were taken 7 months after the beginning and at the end of the 2-year study. The quantification was based on the planimetry of these photographs. The area of white-spot lesions decreased in the xylitol group in absolute values ($p < 0.01$) and in percentages ($p < 0.001$). In the sucrose group the area of white-spot lesions increased in absolute values ($p < 0.05$) and in percentages ($p < 0.01$) during the 17-month observation period. The stereomicroscopic evaluation gave a similar result; the ordinally quantified caries scores (CIS) increased in the sucrose group and decreased in the xylitol group, and the difference between the groups was highly significant ($p < 0.001$). Thus the present findings showed that xylitol consumption caused remineralization of incipient white-spot lesions on buccal surfaces. □ *Enamel caries; planimetry; remineralization; stereomicroscopy; sugar*

Maarit Rekola, Institute of Dentistry, University of Turku, SF-20520 Turku, Finland

The early carious lesion, or white spot, is the precursor of a carious cavity. A carious lesion is formed when calcium phosphate is removed from the surface of the enamel (1). The repair of the lesions by redeposition of minerals in the defect is theorectically possible, since the oral fluid contains all the necessary chemical elements (2). Precipitated calcium phosphate has been found in large carious lesions (3), in incipient subsurface lesions in defects (4), in and on acid-etched surfaces (5), and in mechanically roughened areas on sound surfaces (6). The remineralization process seems to require an interface of apatite and an aqueous medium supersaturated in the ionic composition of the solid. A dynamic equilibrium exists between demineralization and remineralization at the enamel interface. When the pH is 7.0 or higher, hydroxyapatite can precipitate from supersaturated saliva, but after sugar consumption the pH drops and the enamel starts to dissolve (2).

Several methods have previously been used for the quantification of dental caries. Von der Fehr et al. (7) reported on the Caries Index Score (ICS) method of inducing and reversing changes in the enamel surface of teeth in human volunteers, with a dissection microscope. Edgar et al. (8) also used a modification of the CIS method. Instead of recording only the highest-scoring area on each tooth, they assessed the CIS by three methods: by direct microscopic examination, from black and white photographs with a ×5 enlargement, and from projected color slides. The data from the black and white photographs were considered to be invalid, but the mean values obtained by the microscopic method and from the color slides indicated a close and highly significant relationship.

Koulourides et al. (9) developed a caries test model, the Intraoral Cariogenicity Test (ICT), in which a slab of enamel was held in a prosthetic appliance. The hardness of the enamel surface was calculated on the basis of the geometry of the Knoop indentor. Pearce & Gallagher (10) found that the indentor only penetrated 2–3 μm into softened enamel and thus measured the hardness of the outer layer only. The bulk of the probably more highly decalcified enamel subsurface was not assessed. This explains the lack of correlation between the extent of caries evaluated by measurement of the

microhardness and that shown by microradiography. Nevertheless, hardness testing seemed to be a sensitive qualitative method for measuring experimental caries.

The aim of this study was to quantitate planimetrically and stereomicroscopically the progression of incipient carious lesions on buccal smooth surfaces caused by a sucrose diet and to consider the effects of total substitution of sucrose with xylitol on the progression of carious lesions.

Materials and methods

The Turku sugar study

In the 2-year feeding study (11) dietary xylitol was almost completely substituted for sucrose. The subjects were allotted to groups on an individual preference basis. Initially, no significant differences were observed between the experimental groups with regard to age, sex, number of primary and secondary carious tooth surfaces with and without defect, number of filled surfaces and extracted (missed) teeth, and the DMFS index. The sugars were used in about 100 products, including pastry, confectionery, jams, juices, canned products, tomato ketchup, mustard, ice cream, and so forth. The subjects were examined several times during the study. After 2 years the mean increment of decayed, missed, and filled tooth surfaces was 7.2 in the sucrose group and 0.0 in the xylitol group. The cumulative increment, including the secondary caries reversals, was 10.5 in the sucrose group and 0.9 in the xylitol group.

Planimetry

The material of this study consisted of color photographs taken during the 2-year Turku sugar study (11). Three photographs with a ×1.2 magnification were taken of all subjects—33 subjects in the sucrose group and 47 subjects in the xylitol group—7 months after the beginning of the study and at the end of the entire 24-month feeding regimen. The photographs were taken of right and left sides and of the front of maxillary and mandibular teeth with a standardized technique, using a 35-mm camera with focusing bellows and an f = 90 mm 1:4 Leitz Elmar lens (enlargement ×0.6), equipped with two Megablitz 212 flashes. Agfachrome 50 S Professional film was used throughout the study. A few minutes before the photographic session the subjects brushed their teeth thoroughly, and the tooth surfaces were dried with compressed air immediately before photography. The head of the subject was kept in a fixed position by means of an adjustable head- and chin-rest and an additional support immobilizing the camera.

The white-spot lesions of teeth 16–26 and 36–46 were measured. A total of 35 white-spot lesions in 11 subjects of the sucrose group and 60 white-spot lesions in 16 subjects of the xylitol group were found in the photographs and measured after both 7 and 24 months. The other subjects had no white spots on their teeth. A total of 690 photographs, comprising about 5500 tooth sites, were examined.

All planimetric measurements of the white-spot lesions were analyzed twice, and in two different situations. The interval between the duplicate analyses, which were made with the same method and by the same observer, was about 2 months. The author was unaware of the grouping of the subjects or the phase of the study during which the photographs had been taken. The photographs were projected with a projector on a planimetry platen with a digitizing surface with a ×13 linear magnification for measurement of the area of each white-spot lesion. The areas of the lesions were circumscribed with a cursor connected to a digitizer (Model 9864 A Digitizer, Hewlett-Packard, Loveland, Colo., USA), and the digitizer entered the data on a calculator (Model 9821 A, Hewlett-Packard) which gave the area of the lesions in square millimeters (12).

Stereomicroscopy

During the 2-year study the teeth of all subjects were also examined with a stereomicroscope. The surface of teeth 15 to 25 and 45 to 35 were inspected, using a magnification ×16, in accordance with the CIS

described by von der Fehr et al. (7). The scores 0, 0.5, 1, 1.5, 2, 2.5, and 3 were used. The microscope was fixed with the support that had immobilized the camera during the photography session. The stereomicroscopic inspection was performed eight times during the study. The sum of the scores of the teeth was calculated for every subject. Hypoplasias and arrested (discolored) carious lesions were excluded from the evaluation. The difference between the first and last examination value was calculated.

Statistical methods

The following statistical methods were used in this study: the absolute method error: the formula $E = \sqrt{\frac{\Sigma(x_1 - x_2)^2}{2n}}$ (method error statistics), where x_1 and x_2 are the first and third values of the three measurements in the same situation, and n = number of pairs; the systematic method error: the paired t test—the difference between the sums of the lowest and highest values of the three measurements in the same situation; changes in frequencies within the groups: Wilcoxon test; changes in lesion size between the groups: Student's t test; and changes in CIS values: Mann–Whitney U-test.

The following significance levels were used: NS = not significant; $p < 0.10$ = indicative; $p < 0.05$ = almost significant; $p < 0.01$ = significant; and $p < 0.001$ = highly significant.

Results

Method error

The magnitude of the method error calculated by the formula of the method error statistics was E = 0.0914, calculated from all white-spot lesions ($n = 95$). The difference between the sums of the lowest and highest values of the three measurements in the same measuring situation was 8.3%. The systematic method error based on duplicate recordings carried out at an interval of 2 months was not significant.

Planimetry

Planimetric analysis showed a tendency towards an increasing size of white-spot lesions in the sucrose group ($p < 0.10$), whereas a decrease of the lesion area was found in the xylitol group ($p < 0.01$) during the 17-month observation period (Fig. 1). The number of positive and negative changes in the size of the white spot in the sucrose group amounted to 25 and 10, respectively, whereas there were 10 positive and 47 negative changes in the xylitol group. Three lesions did not change in size in the xylitol group during the study. Three white-spot lesions were filled during the study in the xylitol group. In the sucrose group no new fillings were applied to replace the white-spot lesions. The difference between the experimental groups was not significant at 7 months, but at 24 months the mean area of the white-spot lesions in the xylitol group was significantly smaller than in the sucrose group ($p < 0.01$).

Development in the individual subject between month 7 and month 24 was studied with regard to increases or decreases in lesion areas and the number of subjects affected by these changes (Table 1). The sucrose group included an almost significantly larger number of subjects with increased lesion areas than subjects with

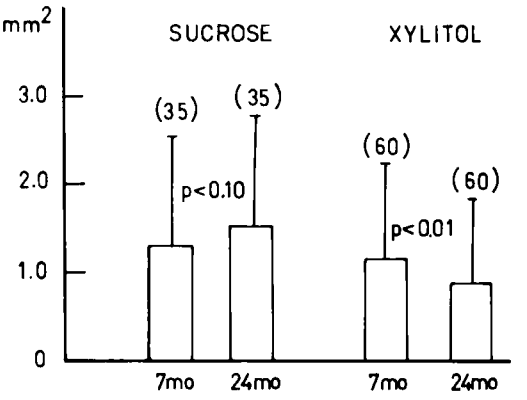

Fig. 1. Mean area of white-spot carious lesions in sucrose and xylitol groups at 7 and 24 months of the 2-year study. The values shown are the mean ± SD; the number of lesions measured was 35 in the sucrose and 60 in the xylitol group (Student's t test).

Table 1. Changes in lesion size between 7 and 24 months in the experimental groups. The values refer to numbers of subjects (Wilcoxon test)

	Sucrose	Xylitol
Subjects with a greater number of increased lesion areas	9	1
Subjects with a greater number of decreased lesion areas	1	15
Total	10	16
p	<0.05	<0.01

decreased lesion areas, whereas in the xylitol group the number of subjects with decreased lesion areas was significantly higher than that of subjects with increased lesion areas.

The relative mean change in white-spot lesion areas in percentages decreased in the xylitol-consuming subjects by 19.8% ($p < 0.001$), whereas in the sucrose group the lesion sizes increased by 15.0% ($p < 0.01$). The difference in the changes in percentages was highly significant between the groups ($p < 0.001$) (Fig. 1). The difference between the sucrose and xylitol groups was also highly significant for changes in lesion size calculated per subject ($p < 0.001$) (Fig. 2).

Stereomicroscopy

The sum of CIS values of teeth 15 to 25 and 45 to 35 increased in the sucrose group and decreased in the xylitol group (Table 2). The difference between the sucrose and xylitol groups was highly significant ($p < 0.001$). The sum of the CIS values was also calculated separately for the upper and lower teeth by grouping left and right premolars, canines, and incisors into three subgroups. No difference was seen in the xylitol group between the upper and lower jaw or between the tooth groups. In the sucrose group, however, the increment of the CIS values was higher in canines than in premolars or incisors in both jaws ($p < 0.01$). No difference was seen between premolars and incisors in either jaw. The difference between the canines of the upper and lower jaw was almost significant in the sucrose group ($p < 0.05$). The difference between the sucrose and xylitol groups was highly significant in every tooth group and both jaws ($p < 0.001$).

Discussion

Planimetric analyses

The first photographs taken in the 2-year study were black and white. The photographs were not useful because the borders of the lesions were not distinct. The first color macrophotographs were taken at the 7-month stage of the 2-year study. Therefore, the situation at the beginning of the trial could not be recorded planimetrically.

In the photographic method the direction and angle of the light and the angle of the camera influenced the appearance of the white-spot lesion. Dehydration of the tooth surface strongly influenced the discernibleness of the white-spot lesion. The longer the drying, the chalkier and more visible the lesion became. In this study the teeth were dried with compressed air immediately before photography, with the aim of standardizing the procedure to a short burst of

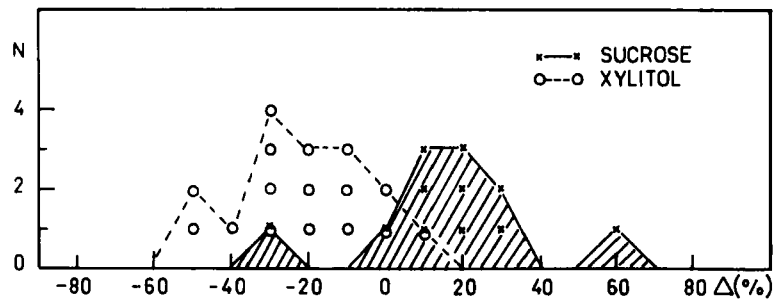

Fig. 2. Changes in the size of white-spot lesions in percentage during the 2-year study. Δ = mean change in size in percentage rounded off to the nearest tenth; N = number of subjects.

Table 2. Stereomicroscopic study in accordance with von der Fehr et al. (7) of teeth 15 to 25 and 45 to 35. n = number of subjects (Mann–Whitney U-test)

	Sucrose (n = 33)				Xylitol (n = 47)		
	Beg.	End	Δ		Beg.	End	Δ
Sum of CIS values of teeth 15–25, 45–35	530	613	+83		780	509	−271
p				<0.001			

air making only the relevant tooth surfaces free of saliva.

The planimetric analysis indicated that the mean area of white-spot lesions in the xylitol group was slightly smaller than in the sucrose group at the first evaluation 7 months after the beginning of the trial (Fig. 1). It should be noted, however, that the first photographs were thus obtained at a stage when the first intermediate clinical and radiographic data indicated a virtually complete arrest of new caries in the xylitol group (11). If the trend observed in the changes of the areas of the white-spot lesions had been consistent during the first 7-month period (that is, decreasing areas of white-spot lesions in the xylitol group and increasing ones in the sucrose group), the initial difference between the xylitol and sucrose groups in lesion size would have been even smaller at the beginning of the 2-year clinical trial.

Stereomicroscopic analyses

The changes in white-spot lesions recorded stereomicroscopically were evaluated by the CIS method in the Turku sugar study (11), but the results of this evaluation were not analyzed, mainly because the use of this unconventional method would have invalidated comparison with other studies.

The CIS system has some weaknesses, in particular the crudeness of the method, as indicated by von der Fehr et al. (7) and Edgar et al. (8). In spite of these reservations the CIS findings agreed with the results of the planimetric evaluation.

CIS values were determined for teeth 15 to 25 and 35 to 45; planimetric evaluation, however, also involved first molars. Furthermore, planimetric evaluation only involved the visible white-spot lesions, which represent a value of 3.0 in the CIS scores. It should also be noted that the planimetric quantification takes place on a continuous numerical scale, whereas the stereomicroscopic analysis involved an ordinal assessment.

As a whole, both types of determinations, which show that long-term xylitol consumption has the effect of decreasing the size of white-spot caries lesions and decreasing the caries scores in the stereomicroscopic evaluation, are in accordance with the substantial reduction in caries incidence previously observed in conventional clinical and radiographic recordings (11).

References

1. Featherstone JDB, Dungan JF, Cutress TW. A mechanism for dental caries based on chemical processes and diffusion phenomena during *in vitro* caries simulation on human tooth enamel. Arch Oral Biol 1979;24:101–8.
2. Ten Cate JM. Remineralization of enamel lesions. A study of the physico-chemical mechanism. [Academic dissertation]. University of Groningen, The Netherlands, 1979.
3. Frank RM. The ultrastructure of the tooth from the point of view of mineralization, demineralization, and remineralization. Int Dent J 1967;17:668–83.
4. Silverstone LM. Remineralization phenomena. Caries Res 1977;11(suppl 1):59–84.
5. Gonzalez M, Feagin F. Electron microscopy of the enamel surface after reactions of apatite accretion. J Oral Pathol 1973;2:142–9.
6. Feagin FF, Phantumavanit P. Remineralization in enamel. J Dent Assoc Thai 1976;26:77–83.
7. Von der Fehr FR, Löe H, Theliade E. Experimental caries in man. Caries Res 1970;4:131–48.
8. Edgar WM, Rugg-Gunn AJ, Jenkins GN, Geddes DAM. Photographic and direct visual recording of experimental caries-like changes in human dental enamel. Arch Oral Biol 1978;23:667–73.

9. Koulourides, T, Bodden R, Keller S, Manson-Hing L, Lastra J, Housch T. Cariogenicity of nine sugars tested with an intra-oral device in man. Caries Res 1976;10:427–41.
10. Pearce EIF, Gallagher IHC. The behaviour of sucrose and xylitol in an intra-oral caries test. NZ Dent J 1979;75:8–14.
11. Scheinin A, Mäkinen KK. Turku sugar studies, I-XXI. Acta Odontol Scand 1975;33(suppl 70):1–351.
12. Rekola M, Scheinin A. Quantification of dental plaque through planimetric analysis. Scand J Dent Res 1977;85:51–5.

Received for publication 20 February 1986