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Polyol-combinant saliva stimulants and oral health in Veterans Affairs patients—An exploratory study

An exploratory study investigated the root caries incidence in Department of Veterans Affairs patients with exposed root surfaces. For a period of six to 30 months, the subjects were systematically assigned to groups which used chewable dragées or chewing gums that contained either xylitol or sorbitol as bulk sweeteners. The mean treatment time was 1.8 years (standard deviation = 0.8). The consumption levels of both polyols was up to 8.5 g daily, used typically in five episodes during a 16-hour period. The subjects were examined every six months in connection with their standard scheduled visits at the Veterans Affairs Medical Center. The risk for a root-surface lesion in the xylitol group was only 19% of that for a surface in the sorbitol group (relative risk, 0.19; 95% confidence interval, 0.06-0.62; p ≤0.0065). Simultaneous study in periodontal patients showed that both polyols significantly reduced the gingival index scores, and slightly (but not significantly) reduced the plaque index scores. Collectively, both studies suggest that frequent daily consumption of chewable, saliva-stimulating products containing essentially nonfermentable or slowly fermentable dietary carbohydrate sweeteners (xylitol and sorbitol) may have an oral-health-improving effect in Department of Veterans Affairs Medical Center patients. It is necessary to evaluate if these procedures would be efficacious in larger and expanded patient cohorts.

Resident patients and outpatients of Department of Veterans Affairs Medical Centers constitute a special focus for nursing care from an oral health perspective. Among the most important oral health problems of this cohort are root-surface caries (RSC) and periodontal infections, which consume substantial health care resources and cause suffering, pain, and loss of esthetics. Several researchers have emphasized the increasing impact RSC has on the adult and geriatric population in general, especially since the means to treat and prevent this disease are limited[1-5] and because dental treatment in compromised patients in general must consider complicating issues related to patients' medical problems.[6,7] These efforts will be aggravated if the effectiveness of antimicrobial functions of oral secretions declines.[8] In addition, the same concerns affect the prevention and treatment of periodontal infections in those patients.

Several studies have shown that xylitol, sorbitol, and other dietary polyols, when substituted for sucrose in chewable dietary items, can reduce caries (for reviews[9–13]). However, no studies on sugar alternatives have been carried out in subjects with exposed root surfaces. The purpose of this paper is to report results from an exploratory study of the usage of xylitol- and sorbitol-containing chewable saliva stimulants (chewing gums and dragées) among patients with exposed root surfaces and patients receiving periodontal treatment.

Methods

This exploratory study was carried out at the Veterans Affairs Medical Center (VAMC) in Dayton, Ohio. In accordance with Veterans Affairs regulations, the Dental Service of the VAMC must see all resident patients and outpatients every six months for dental checkups, including treatment of possible RSC and periodontal infections. The clinical examinations of the present study were carried out as part of these pre-scheduled, standard recalls; the performance of this study did not presume extra visits.

(A) RSC program

Subjects

After the approval of the study protocol, the examiner (DP) who performed the RSC examinations introduced the program to potential subjects. Recruiting of subjects continued from the spring of 1989 to February, 1992. The program was introduced to all inpatients with exposed root surfaces, upon the patients' regular visits to the clinic. The subjects were informed about the details of the program, followed by a reading and signing of the standard VAMC consent form; all questions presented by the subjects were answered. Participation was voluntary. All of the VAMC's ambulatory, domiciliary

Table 1. Baseline characteristics of the subjects in the RSC program.

Group	Sample Size[a]	Mean Age (SD) (years)	Mean No. of Active SGRSC Lesions at Baseline (SD)	Mean No. of Root Surfaces at Risk at Baseline (SD)	Mean No. Drugs Used Daily to Treat Medical Conditions (SD)
No intervention	105	59.8 (11.2)	1.29 (2.48)	35.8 (21.9)	2.5 (1.5)
Sorbitol	42	58.6 (10.7)	0.38 (1.03)	35.5 (15.9)	2.8 (1.1)
Xylitol	41	54.8 (10.3)	1.10 (2.54)	35.6 (22.2)	2.9 (1.4)

[a]All non-participating subjects available (105) were included to increase the sample's representativeness.

patients with exposed root surfaces and with putative cooperativity were eligible. Patients who were mentally incapacitated, who did not comprehend the purpose of the program, and who could not sign the consent form were excluded. By February, 1992, when the last subjects were recruited, a total of 220 patients had been interviewed. One hundred and eighty-eight subjects (later called "active subjects") consented to the program, and were systematically assigned to xylitol or sorbitol. The average number of examinations (RSC registrations) after treatment assignment (including baseline) was 4.7 (standard deviation = 1.5). The examinations were carried out as part of the regular, prescheduled six-month recalls of the patients. The maximum number of follow-up examinations (for a few patients) was 7. The subjects were followed for 1.8 years (standard deviation = 0.81) on the average. About 60% of the patients had used the VAMC dental services for more than three years before this study. About 30% had used these services for fewer than three years, while 10% of the patients had visited the Dental Service once or twice before the study (normally presuming a six- to 12-month stay at VAMC). Table 1 gives other baseline characteristics of the samples.

The VAMC patient base is statistically skewed and differs significantly from the outpatient population. This skew results mostly from the use of tobacco, alcohol, and drugs, from poor oral hygiene and diabetes, and from use of prescribed and other medicines. The most common medications used included antidepressants, those for hypertension and heart problems, and insulin. The patients received these medicines in the form of pills. The mean number of drugs used daily is shown in Table 1. In general, these subjects did not respond well to oral hygiene instructions. Flossing and use of other oral hygiene procedures were not common. Several subjects had periodontal infections and exposed roots. The subjects (including non-participating ones; *vide infra*) had, on average, 18 teeth present, of which an average of eight had exposed roots at baseline. Of those subjects who completed the minimum of six months of treatment, 15 had complete dentures (normally in the upper jaw), while 45 had partial dentures. None of the subjects suffered from Sjögren's syndrome or malfunction of the salivary glands because of radiation therapy or surgery.

All active resident subjects had, on average, two VAMC-made meals a day in the dining room. These meals were nutritionally balanced. Some patients consumed a clinical diet. All patients had access to a canteen where most had an average of two or more meals or snacks daily. The canteen food items were not dietetically controlled and represented typical foods that contain salt and sugars. The mean age of the subjects was 56.6 years.

The research protocol approved by the governing bodies involved (*vide infra*) presumed a study of xylitol stimulants, with the corresponding sorbitol products regarded as active controls (placebos), as has been done in some studies. No other placebo-control groups could be formed. However, the VAMC resident patient population included several individuals who did not participate in this program (either declining or being incapacitated to participate). The RSC records of some of those patients were available. The mean age of these non-participating subjects, and their racial and gender distribution, dietary habits (including visits at the canteen), and medical histories were more or less similar to those of the treated groups. These patients were treated at the VAMC exactly as patients receiving xylitol or sorbitol products. However, no saliva samples (*vide infra*) were collected from these patients. The purpose was not to regard the non-participating subjects as a customary control group; their inclusion resulted from the availability of their SGRSC records for comparative purposes.

Study design

The consenting subjects were systematically assigned at baseline to xylitol or sorbitol (every other patient was assigned to the xylitol group, in the order the patients visited the Dental Service). The groups did not differ with regard to oral health dietary habits, number and type of medicines received, gender, race, age, and other relevant characteristcs (such as the number of missing teeth, teeth present, the number of teeth with exposed roots, and the number of

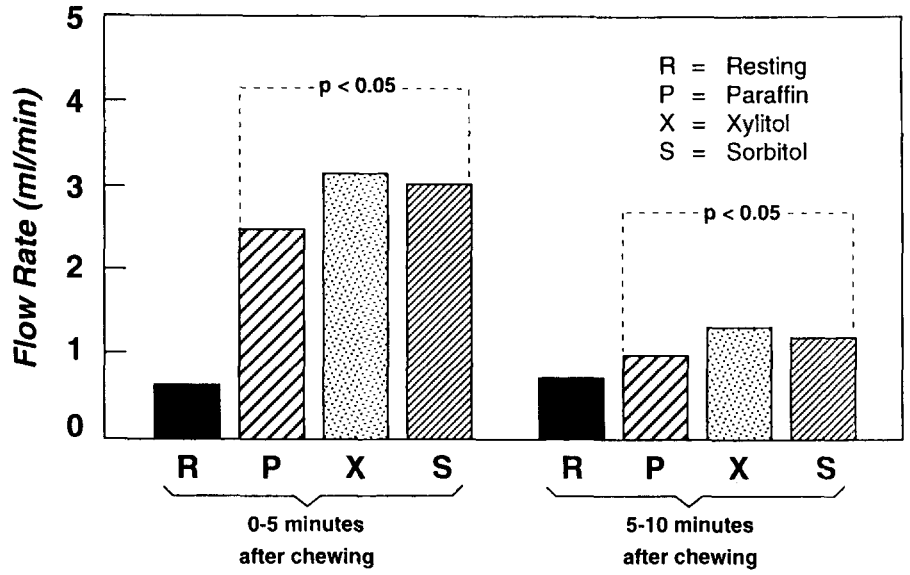

Fig 1. Effects of saliva stimulants on salivary flow rates in RSC patients. Ten subjects with SGRSC lesions were tested on three consecutive days at 09.00 hours. On day 1, two resting saliva samples were collected (after subjects avoided chewing for a period of 30 min), one during 0-5 min, another during 5-10 min. On day 2, the subjects chewed a piece of paraffin for 5 min. Saliva samples were thereafter collected as above, with no stimulus used. On day 3, similar saliva collections were carried out after subjects chewed xylitol gum for 5 min. Application of the *t* test showed the following: Paraffin and the chewing gums differed significantly as shown [xylitol and sorbitol did not differ significantly; resting saliva flow rates differed from stimulated saliva flow rates at the $p < 0.001$ level (0-5 min) or at the $p < 0.05$ or $p < 0.01$ level (5-10 min)]. Gums and paraffin were used in this test rather than dragées because gum base and paraffin caused similar mechanical stimulations. To make the gums isosweet, investigators added aspartame to sorbitol gums.

SGRSC lesions at baseline). A dental assistant who knew the patients personally carried out the delivery of the saliva stimulants. Normally, a sufficient quantity of products was given to each patient for one-month use. The patients were advised to use from three to five dragées (polished, rounded tablets; *vide infra*) or one stick of gum at a time five times a day after main meals and after sugary snacks. Neither the nursing home personnel nor the dental assistant made active attempts to check on the patients' actual usage of the stimulants; volunteerism related to the program was emphasized and maintained. The dental assistant was trained and instructed to keep a compliance diary on each subject. The subjects were not aware of this practice. The study personnel received further information on compliance from the resident attendants. Experience gained by the study personnel suggested that all active subjects who had consented to the program and who had completed the first period (baseline to six months) generally complied well during the rest of the program.

The subjects had the opportunity to choose between gums and dragées, and to change from gum to dragées and *vice versa*. This was done to emphasize volunterism and to increase compliance. The estimated average daily consumption level of xylitol and sorbitol *per* subject was up to 8.5 g (estimated based on the quantity of dragées and gums provided). Normally, a dragée dose was consumed in less than 3 min, while subjects chewing gum were instructed to chew 15 min. Eighty-five percent of the subjects in both experimental groups used predominantly dragées. The dragées were polished, rounded tablets weighing 0.65 g each, and were initially flavored either with peppermint, spearmint, cinnamon, or cherry. These flavors were used evenly in both experimental groups during the initial 3 to 4 weeks of the trial; most subjects prefered peppermint-flavored products during the rest of the study. The dragées were packed in white, tamper-proof, number-coded cardboard boxes wrapped with a plastic foil, containing about 40 pastilles. The contents of one box was normally consumed in about two days. The gums were stick-shaped and weighed 2.8 g each, and were flavored by peppermint. Five individually wrapped sticks were packed in blank, white, number-coded wraps. The dragées and the gums were made by the Leaf Group of Huhtamäki (Helsinki, Finland). The dragées contained about 98% of either sorbitol or xylitol, the rest including flavor, polishing and binding agents, and water. The dragées were relatively brittle and dissolved easily in saliva, stimulating salivation. The gums contained from 60.5 to 61.2% of either sorbitol or xylitol, gum base, glycerol, Lycasin®, lecithin, and flavor.[14] The efficacy of such gum in stimulating salivation in RSC patients is shown in Fig. 1. Even five to ten minutes after subjects chewed polyol gum, the flow rates were significantly higher than those measured after they chewed paraffin. Similar results were obtained when dragées were used as stimulants (not shown). The polyol composition of random samples of all products was monitored throughout the program by means of HPLC. The supplies were stored at the VAMC in a locked, air-conditioned space.

The subjects and the RSC examiner were unaware of the types of gums or dragées used by each individual. Periodic checking of the subjects' and the examiner's awareness of the products' assignments confirmed that the effectiveness of the masking was not affected. One author (KKM) made 18 monitoring site visits at the VAMC during the implementation of the program. The purpose of the visits was to verify the correct delivery of the clinical suppies, to confirm the correct use of the supplies, to meet with several subjects and with the study personnel, and to ensure the

general implementation of the program. An independent monitor (Richard C. Brogle Associates, Upper Montclair, NJ) was used to assess the integrity of the program (4 visits).

RSC registrations and treatment of RSC

The examining experienced dentist (DP) carried out all registrations and had the information on active supragingival root-surface caries (SGRSC) entered by the assistant onto standard VAMC patient sheets, marking the anatomical location and size of the SGRSC lesions on the dentition scheme, using a non-erasable red marker. From these VAMC forms, the SGRSC information was transfered to "statistical" forms for data entry into computer. Only active SGRSC lesions were included. An active RSC lesion was regarded as any root-surface area that was well-defined, *i.e.*, showed a yellowish or light-brownish discoloration, and that was softened or leathery upon examination with a sharp curette applied with moderate pressure. Carious tissue could be removed from an active RSC lesion by curette. Such lesions were frequently covered by visible plaque. Inactive lesions were found to be impenetrable to a sharp caries explorer, but still showed the typical discoloration. The criteria used in diagnosis corresponded to those of Fejerskov *et al.*[15,16] According to VAMC practice, all active SGRSC lesions were restored at the regular six-month recalls (indicating that it was not possible for the remineralization of such lesions to be studied). If the lesion was very small, or if there was doubt about its nature, it was not registered as an active SGRSC lesion, and it was not restored; a red marking was furnished with a "watch" sign for the next examination six months later. Such small lesions were, however, cleaned, followed by application of 0.4% SnF_2. All deeper lesions were also curretted, treated with SnF_2, and restored with amalgam or light-cured glass-ionomer material. The number of subjects who received topical fluoride treatment and fluoride-containing restorative materials was estimated to be similar in all experimental groups. The intraexaminer reproducibility was tested by the examination of a total of 588 exposed root surfaces twice 2 to 3 weeks apart. The examiner had good scoring consistency, with a kappa value of 0.80. The purpose of the study was not to investigate the conversion of active lesions to inactive lesions ("healing effect"). The clinical examiner made note of such conversion (regarding lesions marked with the "watch" sign), but, because of their statistically smaller number, no further calculations on these reactions were made. (Although observations of the remineralization of such lesions could be made, the effects of fluoride application and polyol usage could not be differentiated.)

Statistical treatment of SGRSC data

This study can be regarded as an exploratory controlled randomized trial. At baseline, the subjects were systematically assigned to either sorbitol or xylitol groups. Since systematic assignment and even "true" randomization do not necessarily eliminate all biases, the effects of confounding variables on the treatment efficacy estimates were evaluated in the analyses. In addition to the treatment groups, longitudinal data were collected for subjects who either refused to participate in the trial or were unable to participate. This group was designated as the non-participants' group. Because only about 15% of the subjects used gum, it was not justifiable to break down the data separately for dragées and gums. Furthermore, some subjects used both types of saliva stimulants.

The purpose of the statistical analyses was to study the association between the rate of new SGRSC and type of polyol used.[17,18] During the clinical examination, a call was made at the tooth level whether the tooth had exposed root surfaces (an "exposed root surface" was presumed to be normal with at least about 1 mm recession, depending on the location and size of the tooth). If a tooth was diagnosed as having no exposed root surfaces, no RSC calls were made. If a tooth was coded as having exposed root surfaces, root surfaces could have two possible codes: (1) no SGRSC present, implying that the root surface was sound or had been treated by either planing of the affected surfaces until they were hard and smooth, or by restoration; or (2) SGRSC was present. Occasionally, a tooth was coded as having no recession at one visit, and as having recession and SGRSC at the next visit. Possibly, such RSC scores reflected the discovery of subgingival RSC (a SGRSC lesion could also have been initially subgingival, becoming supragingival after recession, and diagnosed as a new SGRSC lesion).

For each surface, an entry date and an exit date were calculated. The entry date was the date the surface was first at risk for RSC. If a surface was exposed at baseline (degree of exposure defined above), the entry date was the baseline visit date. If a surface was non-exposed at baseline, but became exposed during the study, the entry date was the date corresponding to the midpoint[19] between the date the surface was last called non-exposed and the date the surface was called exposed. The exit date was the date of SGRSC onset, or the date the surface was last examined. Since the exact date of SGRSC onset was not known, the exit date was the date corresponding to the midpoint between the date of the visit the surface was last called non-carious, and the date of the visit the surface was called carious. Consequently, for each surface (lingual, buccal, distal, mesial), three outcome variables were available: (1) the entry date, (2) the exit date, and (3) the RSC call. The explanatory variables investigated for each patient were: treatment (xylitol, sorbitol, or non-participant), gender, subject's age, and subject's SGRSC experience and risk status at baseline (*i.e.*, number of surfaces with active SGRSC at baseline, and number of surfaces with recession at baseline,

and number of SGRSC lesions restored at baseline).

Poisson regression models were used to relate the onsets of active SGRSC to the explanatory variables $\log(y_{ij}) = \log(T_{ij}) + \alpha + \sum(\beta_s X_{ijs})$, where α is the intercept and β_s the slope coefficient associated with the explanatory variable X_{ijs}.[20] Exponentiating β ($e^{\beta s}$) provides an estimate of the rate ratio, and explains on a multiplicative scale how the root-surface caries reference rate varies as a function of the explanatory variable. Generalized estimating equations[21] were used to estimate the model's parameters. Generalized estimating equations are an extension of the multiple regression model to a class of maximum likelihood procedures.[22] The statistical significance of each parameter was assessed by means of the Wald statistics.

Measurements of saliva

The use of two available test kits to monitor microbiologic changes of whole saliva samples of all active RSC patients using xylitol or sorbitol was studied. For this purpose, all active subjects were tested at the end of each visit for salivary mutans streptococci (which involves one-minute chewing of paraffin; the saliva so formed was swallowed), followed by a separate collection of a five-minute paraffin-stimulated sample of whole saliva. An aliquot of this sample was used for a test of lactobacilli. These tests were carried out by means of the Orion Dentocult® SM and LB test kits, respectively (Orion, Espoo, Finland); literature on these procedures is available upon request. The rest of each saliva sample was stored at -20°C until analyzed within 6 to 8 weeks for IgA (by Kallestad's Low Level IgA Endoplate as instructed by the test kit insert and Kallestad's Technical Bulletin; Sanofi Diagnostics, Chaska, MN), lysozyme (with the Calzyme Laboratories *Micrococcus lysodeicticus* lysed cells used according to the supplier's instructions), peroxidase,[23] amylase,[24] SCN^-,[25] protein,[26] and sucrase (the reducing sugars were determined by the neocuproine [2,9-dimethyl-1,10-phenantroline; Sigma] method[27]), and protease activity with Azocoll as substrate.[28] The rationales of using these tests have been explained earlier.[29]

Questionnaire presentations

Questionnaire forms were presented on one occasion (spring, 1991) to those "treated" patients (75%) who consented to an interview. This questionnaire focused on the patient's use of the VAMC dining hall, the canteen, the types of sweet items used and the frequency of their use, as well as smoking habits and practice of oral hygiene. The groups did not differ with regard to these properties.

(B) Periodontal program

The periodontal portion of the study utilized periodontal outpatients of the VAMC. The staff periodontologist (JC) recruited the subjects to the program and examined and treated them at all subsequent clinical examinations. The examiner was not aware of the grouping of the subjects. By February, 1992, a total of 150 patients had been interviewed. One hundred and twenty-five subjects consented. Of these, 25 discontinued their participation before the end of the first six-month period. Of the 100 remaining subjects, 57 were seen in at least two successive examinations, 52 were seen in at least three examinations, 37 were seen in at least four examinations, while 30 were seen in at least five examinations (corresponding to the 24-month "treatment"). The number of patients who were seen at least six times (corresponding to 30-month usage of saliva stimulants) is also given (n = 15) but was considered too low for further consideration. The distribution of the subjects in the sorbitol and xylitol groups remained similar during the study. These subjects constituted a patient sample that was not as skewed statistically as the domiciliary patients but that still displayed considerable heterogeneity. None of these subjects had Sjögren's syndrome or other malfunction of the salivary glands owing to radiation therapy or surgery. About 50% of these subjects had used the VAMC outpatient periodontal services longer than three years. The subjects were examined every six months at their regularly scheduled visits to the Periodontal Unit.

No sialochemical tests were performed on the periodontal subjects. However, the plaque index and gingival index scores were measured at each visit.[30,31] A microbiologic study on the plaque levels of several suspected periodontopathogens[32] was also conducted by means of a "slot immunoblot" procedure.[33]. A curette was used to collect a subgingival plaque sample of about 2 mg (fresh weight) from the buccal surface of one posterior tooth on the right side and of one posterior tooth from the left side. The samples were taken from a diseased site with the highest pocket depth present, and were obtained from either mandibular or maxillary tooth surfaces which did not show any signs of RSC. The samples were immediately suspended in 0.5 mL of 1.0% formaldehyde in 1.5-mL cryovials. The mixtures were stored well-capped at +4°C until studied for the presence of microorganisms shown in Table 3.

The study design presumed the comparison of saliva stimulants containing either xylitol or sorbitol as the bulk sweetener, with the latter polyol regarded as a placebo. The limited patient base did not allow for the formation of an untreated control group of periodontal subjects. Accordingly, each subject's gingival status during polyol usage was compared with the same subject's baseline values. At the end of the program in 1992, 30 subjects could be recruited for a comparison study of six months' duration, involving the measurement of plaque index and gingival index scores at three-month intervals. These outpatients were similar to "treated" subjects with regard to all relevant measures (age, gender, oral and general health, dietary habits), and they were subjected to the same standard six-month recalls of the VAMC system as

Table 2. Changes from baseline to end point of treatment in the rate of SGRSC and in the relative risk (rate ratio, RR) estimates[a] in the RSC program.

Group	Crude Incidence Rate of SGRSC[b]	Rate Ratio	95% Confidence Interval	Adjusted for the Following Variables: Age	Gender	No. of SGRSC Lesions at Baseline	No. of SGRSC-free Surfaces at Baseline
Sorbitol (n = 42)	13.7 (5.9-31.8)	-	-				
Xylitol (n = 41)	2.6 (1.1-6.1)	0.19	0.06-0.62 (P ≤ 0.0065)				
		0.20	0.06-0.61 (P ≤ 0.0051)	x			
		0.20	0.06-0.61 (P ≤ 0.0051)	x	x		
		0.21	0.07-0.62 (P ≤ 0.0049)	x	x	x	
		0.19	0.06-0.66 (P ≤ 0.0085)	x	x	x	x

[a] Means and RR are presented as crude values and also as values adjusted for age; for age and gender; for age, gender, and the number of SGRSC lesions at baseline; and for age, gender, and number of SGRSC lesions and recession at baseline (the P values were calculated separately for the adjustments indicated). The RR values, because they are smaller than 1, indicate a decreased risk of SGRSC with xylitol *vs.* sorbitol, a beneficial effect. The percent confidence interval expresses the 95% probability that reported intervals include the true relative risk. The RR (percent confidence interval) statistic is used as a measure of treatment efficacy.[17,18]
[b]SGRSC lesion onsets *per* 1000 surfaces *per* year (95% confidence intervals).

the active participants.

Results

(A) RSC Program—Baseline characteristics

The total sample size was 188 patients, with 105 subjects in the non-participating group, and about 40 in each treatment group (Table 1). The distributions of the following variables were compared at baseline: age, gender, average number of root surfaces with a SGRSC lesion at baseline, and average number of root surfaces with recession *per* patient. There were no significant differences between the xylitol group and the sorbitol group at baseline, although the number of active SGRSC lesions at baseline was smaller in the sorbitol group than in other groups. Subjects in the sorbitol group were, on average, five years younger than those in the non-participants' group (95% CI, 0.19 to 0.83). The difference in age between these two groups was responsible for a significant heterogeneity in age distribution across the compared groups (one-way analysis of variance, p ≤ 0.045). Patients in the treatment groups also had more SGRSC lesions than those in the non-participants' group (95% CI, 0.10 to 1.73). This difference in the number of SGRSC lesions between the two groups was not sufficient to cause a significant overall heterogeneity in SGRSC distribution across the compared groups. The number of exposed root surfaces was approximately 36 for all groups. About 10% of the sample consisted of female subjects, and there were no significant differences in the proportion of females among the compared groups (chi-square with two degrees of freedom, p ≤ 0.443).

RSC Program—Effectiveness of SGRSC treatments

In the sorbitol group, there were 36 SGRSC surfaces and a total root-surface time at risk of 2632 years, leading to a SGRSC rate of 13.7 onsets *per* 1000 surfaces *per* year (95% confidence intervals: 5.9 to 31.8; Table 2). In the xylitol group, there were six SGRSC onsets and a total root-surface time at risk of 2349 years, leading to a SGRSC rate of 2.6 onsets *per* 1000 surfaces *per* year. A ratio of the caries rates in the two groups leads to an estimate of the relative risk of 0.19 (95% confidence intervals: 0.06 to 0.62; p ≤ 0.0065). Adjustment of the relative risk estimate for potential confounding factors did not appreciably change these conclusions (Table 2). Only the comparison between sorbitol and xylitol is shown, since a comparison with the non-participating group was not considered justified. The crude SGRSC rate calculated for this group (n = 105) was 33.6 *per* 1000 surfaces *per* year (95% confidence intervals: 26.7 to 42.3).

RSC Program—Ancillary studies

The whole-saliva samples obtained from RSC patients did not differ significantly between polyol-using groups with regard to the levels of protein, SCN^-, amylase, sucrase, protease, peroxidase, lysozyme, and IgA. The salivary flow rates did not differ. When the baseline values were compared with values determined during "treatments" in each group, no consistent and significant differences were observed. No chemical or biologic studies were conducted on non-participating patients.

The Orion Diagnostica test kit for salivary mutans streptococci evalu-

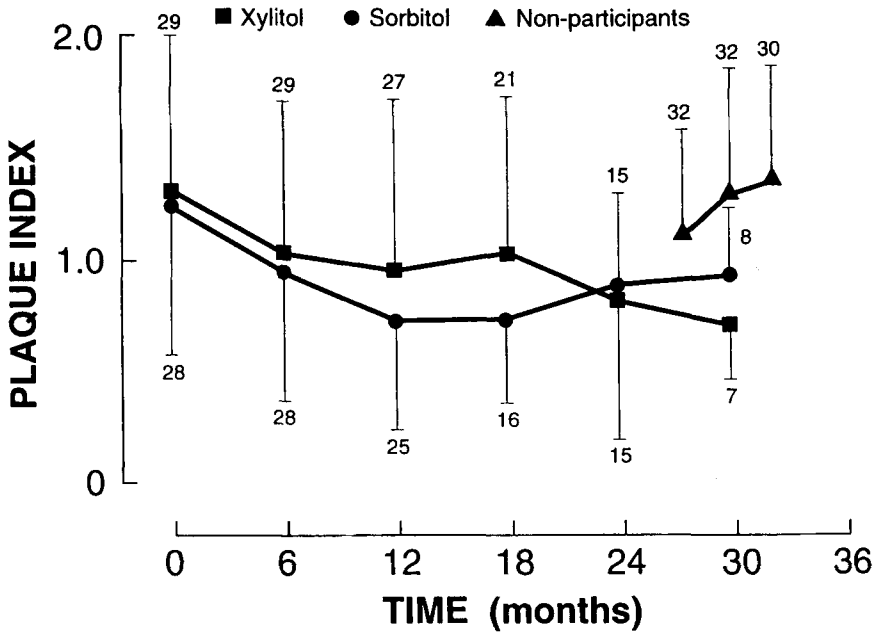

Fig 2. Mean plaque index scores (± SD; number of patients studied at each examination is indicated) of the VAMC periodontal outpatients who received xylitol- or sorbitol-containing saliva stimulants for periods of six to 30 months. Similar plaque index measurements were carried out at 27-33 months in non-participating subjects who did not receive the above saliva stimulants. The 24-month values in both polyol groups differed significantly ($p < 0.05$; ANOVA) from the two last (30- and 33-month) non-participants' values.

ates the presence of these organisms by means of a score system (zero, 1, 2, and 3). The mean scores at baseline were 1.32 ± 0.90 for the sorbitol group and 1.16 ± 0.91 for the xylitol group, respectively (not shown). These means did not differ significantly. After 24 months, the mean score had been reduced by 30% in the sorbitol group and by 57% in the xylitol group. At 24 months, 74% of the sorbitol group subjects and 94% of the xylitol-using subjects had a low score (*i.e.*, zero or one). The number of subjects with low scores was significantly ($p < 0.05$) higher in the xylitol group, but not in the sorbitol group. These trends were visible also at the six-, 12-, and 18-month examinations, but not as clearly as at 24 months. The number of whole-saliva samples was not sufficient for these tests at 30 months. The mean $\log_{10}$ counts of salivary lactobacilli at baseline were 3.75 in the sorbitol group and 3.21 in the xylitol group. The $\log_{10}$ counts remained essentially unchanged in the sorbitol group during 24 months, while in the xylitol group the 18- and 24-month mean $\log_{10}$ counts were 2.44 and 2.64, respectively, the 18-month counts differing significantly between sorbitol and xylitol ($p < 0.001$), the difference in the 24-month counts approaching significance ($p = 0.07$) (not shown). These bacteriologic results (obtained with commercial test kits) did not change if alternative procedures (such as calculating the percentage of low and high scores) were used, instead of the mean scores calculated.

(B) Periodontal program

The Silness-Löe plaque index scores showed a reducing but not significant trend during the study in both experimental groups (Fig. 2). The mean scores determined for the non-participating group patients were similar to those measured at baseline for the polyol-using subjects. The mean gingival index scores reduced significantly during "treatment" in both polyol groups (Fig. 3). The scores measured for the non-participating subjects were not significantly different from those determined at baseline for the polyol-using patients.

The polyol-receiving subjects provided plaque samples which were studied for the presence of the following organisms: *Streptococcus mutans, S. sanguis, Prevotella intermedia, Porphyromonas gingivalis, Actinobacillus, Treponema denticola, Actinomyces viscosus, Fusobacterium nucleatum, Bacillus forsythus*, and *Selenomona sputigena* (Table 3). The results suggest that the usage of both saliva stimulants was associated with some shifts in the mean index scores of these organisms compared with baseline. The plaque levels of *S. mutans* showed some period effects for up to 24 months when the number of diseased sites sampled was still relatively high. More consistent shifts were observed, however, in the plaque levels of *Actinobacillus* and *T. denticola*, which increased toward the end of the program. The levels of *S. sputigena* showed, in turn, decreasing scores at 24 and 30 months. The preliminary nature of these findings must be emphasized. The values shown for the 6th visit (at 30 months) should be viewed against the lower number of diseased sampling sites available at this examination, *i.e.*, 25 sites in the sorbitol group and 21 sites in the xylitol group (Table 3).

Discussion

The results suggest that habitual consumption of xylitol-containing saliva stimulants can be associated with a significantly decreased root caries risk when compared with sorbitol usage. There are several viewpoints, however, that should be considered in evaluation of the effects of xylitol and sorbitol on the prevention of SGRSC in this study. The number of subjects available for the study was relatively small. The "treatment" time was relatively short in several patients. The study design had to acknowledge the right of the subjects to choose between chewing gums and dragées; the subjects could switch from gums to dragées and *vice versa*. Although this did not happen frequently, this study did not demonstrate which form—the gum or the dragée—is most effective. The study

lacked a true control group. It is possible that the recruiting process persuaded only the most alert and health-conscious patients to consent to the program, excluding several RSC-prone individuals who were perhaps typically included in the non-participating group. It would have been useful to determine the degree of gingival recession in all RSC patients, and, conversely, the gingival recession data of the periodontal subjects should have been compared with the incidence of RSC in these subjects (the RSC and the periodontal programs utilized different patient samples, and were separate because of administrative and practical reasons). RSC indices, diagnostic criteria, and clinical signs of RSC have been discussed.[16,34,35] The measurement of RSC indices could not be performed, whereas the diagnostic criteria used can be regarded as comparable with those used by other researchers. It can also be argued that the allocation of patients to the polyol groups was not truly random and that some subjects showed improvement in periodontal health owing to the semi-annual recalls rather than the usage of saliva stimulants. The semi-annual recalls of the VAMC were routine, however, and the present subjects and the participating periodontist were accustomed to this procedure.

It would be helpful to compare the present SGRSC rates with those calculated for pre-baseline years. Records collections at the VA system allowed for this calculation for a number of subjects for periods of six to 24 months prior to baseline. These SGRSC rates were as follows: non-participating group, 40.33 (95% confidence interval, 26.56-61.25; n = 84); sorbitol group, 18.36 (10.40-32.40; n = 20); and xylitol group, 14.07 (5.90-33.52; n = 22). Although these pre-baseline data were incomplete, they suggest that the non-participating group was more susceptible ($p < 0.05$) to SGRSC than the polyol groups. It is thus likely that more compliant, cooperative, and health-conscious patients volunteered in the program.

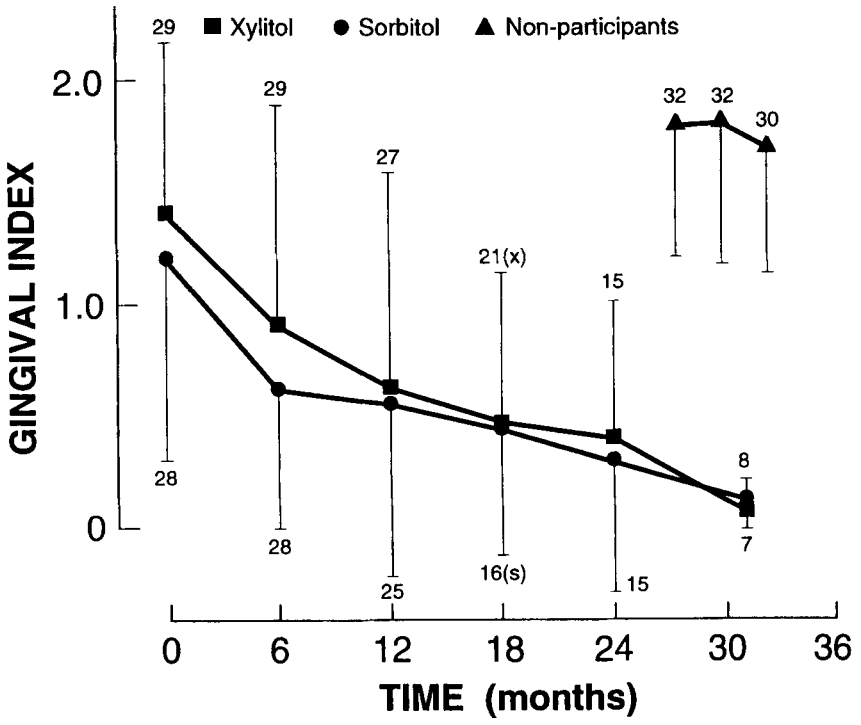

Fig 3. Mean gingival index scores (± SD; number of patients studied at each examination is indicated) of the VAMC periodontal outpatients who received xylitol- or sorbitol-containing saliva stimulants for periods of six to 30 months. Similar gingival index measurements were carried out at 27-33 months in non-participating subjects who did not receive the above saliva stimulants. The 18- and 24-month values, in both polyol groups, differed significantly ($p < 0.05$; ANOVA) from the baseline and non-participants' values.

This study was the first ever to investigate the effect of the usage of polyol-containing saliva stimulants in Veterans Affairs patients. The practical implementation of this type of a program on a VAMC campus is genuinely affected by the nature of the subjects and by local circumstances. Several patients showed little or no interest in oral health. Maintaining the program even with the present number of subjects was considered a substantial achievement. The best-cooperating subjects were often dismissed from the hospital during the program owing to their improved health status. Such incidents weakened the subject base of the study and contributed to the higher dropout rate. Superimposed on this study was an attempt to modify health behavior. Changing health behavior can be difficult when a change-resistant study group is involved. The experience gathered in this study showed that any attempt to alter Veterans Affairs patients' oral health by means of this type of program will confront formidable difficulties and presumes special motivation of the health care personnel involved. On the other hand, even minor achievements may be considered valuable and should prompt more full-scale studies. It is possible, of course, that the present attempts to modify health behavior may have affected the observed RSC outcome. Such effects should be carefully considered in future full-scale studies of RSC in VAMC patients. However, both the sorbitol (placebo) and the xylitol group subjects were treated similarly in this study, and the same basic treatment (including the use of fluoride-containing materials), prophylaxis, and instructions were given to all subjects, including the non-participating patients. The subjects and the resident attendants did not report any adverse effects from the usage of the present polyol products.

Table 3. Mean index scores of ten microorganisms present in the subgingival dental plaque of the VAMC periodontal outpatients who received sorbitol- or xylitol-containing saliva stimulants over a period of six to 30 months. The plaque was collected from periodontally diseased sites without RSC.

	Time in Months					
Organism	Baseline	6	12	18	24	30
Number of Diseased Sites Sampled						
S	72	55	47	39	30	25
X	67	55	53	45	41	21
S. mutans						
S	0.96 ± 0.94	1.22 ± 0.94[a]	1.43 ± 1.16[b]	1.20 ± 0.98	1.33 ± 0.99[b]	1.19 ± 1.29
X	0.97 ± 0.97	1.09 ± 1.02[a]	1.07 ± 1.05	1.18 ± 1.05[b]	1.19 ± 1.14[b]	1.00 ± 1.15
S. sanguis						
S	1.71± 1.00	1.94 ± 1.03	1.81 ± 1.12	1.79 ± 0.98	1.73 ± 1.11	1.32 ± 1.14[a]
X	1.64 ± 1.05	1.80 ± 1.13[a]	1.62 ± 1.02	1.51 ± 1.08	1.56 ± 1.05	1.33 ± 1.11
P. intermedia						
S	1.62 ± 0.97	1.74 ± 0.93	1.64 ± 1.03	1.77 ± 1.13	1.73 ± 1.01	1.28 ± 1.06
X	1.58 ± 0.96	1.73 ± 0.99[a]	1.75 ± 1.05[a]	1.71 ± 1.10[a]	1.63 ± 1.02	1.62 ± 1.16
Actinobacillus						
S	1.06 ± 0.87	1.47 ± 0.92[b]	1.49 ± 1.08[b]	1.38 ± 0.99[b]	1.40 ± 1.10[a]	1.16 ± 1.07
X	1.10 ± 0.99	1.38 ± 1.01[b]	1.38 ± 1.04[b]	1.49 ± 0.97[b]	1.49 ± 1.00[b]	1.67 ± 1.06[b]
T. denticola						
S	1.19 ± 0.91	1.36 ± 0.97	1.60 ± 1.10[b]	1.61 ± 0.96[b]	1.87 ± 1.01[b]	1.52 ± 1.16[a]
X	0.97 ± 0.98	1.14 ± 1.03	1.26 ± 1.11	1.49 ± 0.99[b]	1.61 ± 1.00[b]	1.67 ± 1.06[b]
P. gingivalis						
S	1.40 ± 1.00	1.44 ± 0.92	1.47 ± 1.12	1.49 ± 1.07	1.17 ± 0.91	1.24 ± 1.16
X	1.28 ± 1.06	1.34 ± 1.00	1.21 ± 1.03	1.40 ± 1.07	1.17 ± 1.12	1.24 ± 1.22
A. viscosus						
S	2.17 ± 0.98	2.25 ± 0.86	2.15 ± 1.00	1.97 ± 1.06	2.17 ± 0.95	1.92 ± 1.11
X	1.98 ± 1.02	2.05 ± 0.95	1.92 ± 0.97	2.04 ± 0.91	2.02 ± 0.91	2.14 ± 0.85
F. nucleatum						
S	1.32 ± 0.86	1.34 ± 0.93	1.40 ± 1.11	1.54 ± 1.00	1.77 ± 0.90[b]	1.40 ± 1.04
X	1.31 ± 1.00	1.27 ± 0.99	1.26 ± 0.96	1.40 ± 1.01	1.49 ± 1.03	1.57 ± 1.12
B. forsythus						
S	1.57 ± 1.08	1.67 ± 0.98	1.55 ± 1.16	1.72 ± 1.00[a]	1.43 ± 0.86	1.44 ± 1.08
X	1.39 ± 1.11	1.44 ± 1.19	1.49 ± 1.19	1.53 ± 0.94[b]	1.49 ± 1.03	1.43 ± 1.16
S. sputigena						
S	1.53 ± 1.10	1.82 ± 1.02	1.66 ± 1.18	1.61 ± 1.02	1.03 ± 1.13[a]	0.80 ± 1.04[a]
X	1.52 ± 1.09	1.58 ± 1.07	1.34 ± 1.13	1.31 ± 1.10	0.98 ± 1.08[a]	1.19 ± 1.17

Two plaque samples were obtained from most patients, one sample from the buccal surface of one posterior tooth on the right side, the other from the left side. In this procedure,[33] scores of 0, 1, 2, or 3 are given to samples depending on the amount of organisms present in the sample (only those samples were included which contained a sufficiently high level of carbohydrates, as described elsewhere[33]).

[a] The difference from baseline approached significance (*i.e.*, $0.05 < p < 0.10$).

[b] The difference from baseline was significant ($p < 0.05$).

In spite of the shortcomings and difficulties indicated above, the study results were in overall agreement with previous findings regarding the relationship between xylitol consumption and caries prevention, plaque growth, presence of mutans streptococci in whole saliva, and suggestions about the indirect, "inflammation-dampening effect" (reviewed[36]) of xylitol usage. In the present study, most of these effects were also achieved by means of the usage of sorbitol-containing saliva stimulants. Although no previous study has investigated the relationship between consumption of polyol-containing saliva stimulants and SGRSC, there is information on the relationship between polyol usage and coronal caries in adults and juve-

nile subjects. According to this information (reviewed[9–13]), the consumption of xylitol has been more effective than that of sorbitol as a caries-reducing agent. Although RSC and coronal caries, and caries that affects the primary dentition, may be regarded as partly separate diseases, the present results and previous literature suggest that it may also be possible to affect RSC—and perhaps dental caries in its entirety—by means of programs involving systematic usage of essentially nonfermentable saliva stimulants.

The conversion of active RSC lesions into inactive ones by improved oral hygiene has been reported.[15] It was also shown, in a randomized cross-over study, that demineralization of RSC lesions was increased by 83.5% in the "baseline group", compared with only 0.9% in the group that used sugarless gum.[37] In that study, artificial caries lesions were created in root sections which were placed into proximal preparations in molar teeth. Subjects were then given sugar candy for three weeks, after which the root sections were examined.[37,38] Although the present study did not expressly investigate the conversion of active lesions into inactive ones, these findings nevertheless support the above results and suggest that polyol-containing saliva stimulants may actually prevent the formation of new SGRSC lesions. Although old age may not significantly affect an individual's ability to secrete IgA into saliva, or the salivary flow rate and the protein concentration of saliva,[39] it has been reported that the opsonic activity (important in microbicidal activity) of saliva can be adversely affected with age.[8] The use of an essentially nonfermentable saliva stimulant (xylitol) may therefore be of additional value in the planning of preventive strategies for VAMC patients. An unexpected and favorable outcome was several smoking patients' reduced craving for cigarettes as a result of habitual usage of the present saliva stimulants (not shown). This is clearly an area where more research should be conducted.

Previous literature has shown that xylitol usage reduces the growth of dental plaque more effectively than sorbitol usage (reviewed[36]), and that xylitol reduces the growth of mutans streptococci, while sorbitol normally supports their growth. Whether this metabolic feature explains the reported effectiveness of xylitol as a caries-reducing agent, compared with sorbitol, remains outside the scope of this discussion, but it is a defensible explanation. However, usage of sorbitol-containing saliva stimulants did have a SGRSC-limiting effect. Therefore, it is possible that the effects of both stimulants on SGRSC also involve salivary effects. The mere lower fermentation rate of sorbitol and the virtually nonfermentative nature of xylitol in most dental plaque material, compared with sucrose, also contribute to the net effect.

Previous studies suggest that there is a positive correlation between the presence of active RSC and increased plaque levels of mutans streptococci and lactobacilli.[40-42] Plaque and saliva levels of mutans streptococci do not always respond to treatments in the same way. The occasional increases in the plaque levels of mutans streptococci observed in periodontal patients (Table 3) do not, therefore, necessarily contradict the decrease observed in salivary levels of mutans streptococci in RSC patients; in studies involving xylitol usage, it is the salivary levels that are more significantly and consistently reduced. Furthermore, the plaque samples for the periodontal study were not obtained from RSC lesions. Organisms other than mutans streptococci and lactobacilli, however, are also important to dental health.

Several reports have suggested that the usage of xylitol is associated with effects that can lead to less inflamed gingivae ("inflammation-dampening effect"; review[36]). It is possible that xylitol and sorbitol do not differ in their effects on gingival and periodontal health, although there are less-than-adequate data from long-term trials. Short-term gingivitis studies have yielded similar results with these polyols.[43] No known periodontopathogen uses xylitol as a preferred substrate (shifts in the relative amounts of periodontal bacteria may still occur, as shown in Table 3). Xylitol inhibited several periodontopathogens[36] and reduced the adhesiveness of dental plaque (microbial adhesiveness may contribute to periodontal disease).[44]

Studies in experimental animals showed that xylitol plaque obtained from xylitol-consuming human subjects was less inflammatory than samples of sucrose or fructose plaque.[45] Bone culture studies[46,47] support this concept; xylitol plaque was less irritating to macrophages and bones than sucrose plaque. Xylitol mouthrinses were periodontally less harmful than sucrose rinses.[48,49] Gingival bleeding was reduced in juvenile subjects who consumed xylitol saliva-stimulants.[50,51] It is possible that the strongly improved gingival health of the periodontal patients was associated with such phenomena.

This study showed that the slot-immunoblot procedure[33] can be used in this type of long-term clinical program to monitor the presence of periodontal-disease-associated organisms (risk markers) in subgingival dental plaque. The results indicate that while most of the organisms tested showed few or no consistent changes, the plaque levels of two organisms (*Actinobacillus, T. denticola* and possibly *S. sputigena*) tended to change more consistently and significantly in "treated" subjects, with both polyols exhibiting a similar effect. This observation may be related to that of Rateitschak-Plüss and Guggenheim,[52] who found a statistically significant increase in the proportions of anaerobic sorbitol- and xylitol-fermenting bacteria in the dental plaque of sorbitol- and xylitol-consuming subjects during a four-day test period. The present immunoblot procedure does not, however, differentiate between virulent and nonvirulent strains. It is possible that the shifts in the levels of these organisms concerned only nonvirulent strains, although this matter

must be investigated separately. The importance of various bacterial species found in subgingival plaque of periodontitis patients is still subject to debate. Habitual polyol usage may affect the ratios of periodontal organisms in the same way as it affects the levels of mutans streptococci and lactobacilli in some studies.

Conclusions

(1) The oral health status appeared to be favorably affected by the usage of polyol-containing saliva stimulants.

(2) The xylitol-containing saliva stimulants was more effective in preventing active SGRSC than were sorbitol-containing stimulants.

(3) Both polyols appeared to have a similar effect on periodontal health. The microbial shifts that may occur during habitual polyol consumption (in terms of elevated levels of *Actinobacillus* and *T. denticola* in subgingival plaque) should be evaluated in more detailed studies.

(4) The patient population of the VAMC offered considerable challenges. Considering the difficulties generally encountered in instructing VAMC patients with regard to better health habits, any favorable changes in health behavior in such patients—even those changes reported above—should be considered encouraging and should prompt further research.

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