Effect of Xylitol Candies on Plaque and Gingival Indices in Physically Disabled School Pupils

Maddi Shyama, BDS, MDS, PhD

National School Oral Health Program
Ministry of Health, Kuwait

Eino Honkala, DDS, DDPH, MSc, PhD **Sisko Honkala, DDS, PhD**

Faculty of Dentistry
Kuwait University, Kuwait

Sabiha A. Al-Mutawa, BDS, MSc, DSc

National School Oral Health Program
Ministry of Health, Kuwait

Abstract

- **Objective:** To evaluate the effectiveness of xylitol candies on plaque and gingival index scores on physically disabled school pupils in Kuwait.
- **Methodology:** Altogether 145 school pupils (105 in the xylitol group and 40 in the control group), with ages ranging from 10 to 27 years (mean age = 14.7 ± 3.1 years), participated in this 18-month intervention program. The school health nurses distributed xylitol candies to the pupils three times during the school day. Plaque was scored according to the Silness and Löe Plaque Index, and gingivitis according to the Löe and Silness Gingival Index.
- **Results:** The mean Plaque Index score decreased from 1.73 to 1.14 ($p < 0.001$), and the mean Gingival Index score from 1.74 to 1.16 ($p < 0.001$) in the study group. Significant differences were found between the xylitol and the control groups in the reduction of Plaque ($p = 0.037$) and Gingival Index scores ($p = 0.008$). There was high correlation between the individual Plaque and Gingival Index scores at baseline ($r = 0.93$) and at the final examinations ($r = 0.95$).
- **Conclusion:** Consuming xylitol candies three times during school days seemed to reduce both the Plaque and Gingival Index scores. This school-based delivery system offered a practical way to distribute and use xylitol candies among these disabled pupils. The regular use of xylitol candies may, therefore, support oral hygiene routines in disabled pupils.

(J Clin Dent 17:17–21, 2006)

Introduction

Individuals with physical disabilities have a reduced ability for self-care and mobility, which affect access to dental services. Physical disabilities are known to compromise hygiene habits, and may affect an individual's ability to manage effective oral hygiene.[1] Further, many physically disabled individuals have problems with manual dexterity, motivation, coordination, and self-help skills, and the ability to comprehend complex tasks. Due to the physical limitations and the inability to master the techniques required for tooth brushing, the achievement and maintenance of oral hygiene and gingival health can be extremely difficult and remain as outstanding challenges to their care. Thus, additional methods to easily improve daily oral hygiene routines could be beneficial in these individuals.

Xylitol is a natural sweetener, which is systematically classified in organic chemistry as a polyol. It has attracted much attention as an alternative sweetener[2] since it has a pleasant, cooling taste, and is not fermentable by most microorganisms. Several studies carried out during the past three decades have suggested that the usage of xylitol can improve the status of oral hygiene.[2,3] It was demonstrated that the amount and adhesiveness of plaque decreases with regular xylitol consumption, and indeed xylitol has been shown to have a decreasing effect on plaque accumulation[2-10] and on gingivitis development.[11,12] Several studies have demonstrated that the amount of plaque decreases with the regular xylitol consumption,[2,3,7,8,12,13] and that the intake of xylitol between meals has been shown to decrease both the adhesiveness and quantity of dental plaque.[14,15]

Previous studies have suggested reduced plaque formation with the use of a xylitol-containing chewing gum.[8,10,12,16] In several short-term studies, a xylitol-containing chewing gum has been more effective in the reduction of dental plaque formation in comparison to the use of a sucrose-sweetened gum.[7,17-19] The chewing of xylitol-flavored gum, even during the simultaneous intake of sucrose, reduces the amount of plaque and causes certain changes in its chemical composition. These claims were based on the results of the Turku sugar studies.[16-19] In a long-term study, habitual xylitol consumers had less plaque than the controls, and it was suggested that the adhesiveness of the plaque was affected by regular xylitol consumption.[8] Use of both xylitol and xylitol-sorbitol chewing gums have shown significant reductions in the amount of plaque,[7,20] and xylitol-containing gums were significantly superior to sorbitol gum in retarding plaque re-growth.[10]

In a study of school children, the ingestion of candy sweetened with a mixture of xylitol and sorbitol reduced the Plaque and Gingival Index scores to below those obtained after consumption of candy sweetened with sucrose.[11] The use of xylitol chewable tablets was associated with a decrease in the Plaque Index and Gingival Index scores in a study of mentally retarded children.[21] Subjects consuming xylitol- or sorbitol-containing candies also

formed less plaque than those consuming sucrose-containing candies when the basic diet was carbohydrate-free.[22] Also, systematic use of xylitol-containing saliva stimulants (pastils) may be more effective in the control of dental plaque than similar use of erythritol-containing products in normal subjects or those with various degrees of mental or physical handicap.[23]

Chewing gum containing antimicrobial agents (chlorhexidine acetate and xylitol) supported oral hygiene routines[24] and significantly improved periodontal health in elderly occupants of residential homes.[25] It was shown that sugarless chewing gum can provide both plaque and gingivitis benefits when used in conjunction with regular tooth brushing.[12] The use of a sugar-free chewing gum containing sorbitol, maltitol, xylitol, and sodium bicarbonate for 20 minutes twice a day, in conjunction with once daily tooth brushing, showed reductions in Plaque and Gingival Index scores.[26]

Physically disabled individuals may have difficulty in chewing gum due to poor dentition and uncoordinated or involuntary movements and mastication. Considering that xylitol candies have a similar preventive effect as chewing gum, they would be a reasonable alternative to xylitol chewing gum in school-based programs, since the candies are slowly dissolved in the mouth and swallowed, whereas chewing gum has to be disposed of after use. This study aimed to test the effectiveness of the regular use of xylitol candies on Plaque and Gingivitis Index scores among physically disabled pupils in two special schools in Kuwait.

Materials and Methods

The individuals in this study were pupils in a school for special needs, who had demonstrated poor oral hygiene and periodontal conditions.[27] The physically disabled included individuals with cerebral palsy, rheumatoid arthritis, congenital deformities, poliomyelitis, spinabifida, progressive muscular dystrophies, osteogenesis imperfecta, meningomyelocele, scoliosis, and traumatic quadriplegia. The pupils were classified according to their principal disability, and no other disabling conditions were recorded. Ethical approval for this study was given by the Ethical Committee of the Faculty of Dentistry, Kuwait University.

The baseline clinical examinations were conducted on 176 pupils. There were 31 dropouts in the study leaving 145 (82.4%) enrolled who remained to the end of the trial (18 months). Subject ages ranged from 10–27 years (mean age = 14.7 ± 3.1 years). Pupils whose parents or guardians signed and returned the informed consent form were assigned to the xylitol group (n = 105); the remainder comprised the control group (n = 40) with no intake of xylitol candies. The pupils were only examined as a part of the regular dental screening by the national school health program, where they had their informed consent for dental examinations and annual treatment. For practical reasons, some pupils who returned the consent form were assigned to the control group when there were several refusals in the same classroom. The xylitol and control group pupils were in different classrooms, and xylitol group pupils never shared candy with the control group. The gender and age distributions of the pupils in the xylitol and control groups are presented in Table I.

Two dental hygienists led the pupils in small groups from the classrooms into the examinations, which were held in a normal classroom where no teaching was going on. The pupils sat in a chair during the examinations. The chair was placed in front of a well-lighted window, but not in direct sunlight, with the pupil facing the window. Those suffering from severe physical handicaps and confined to a wheelchair were examined in their wheelchair. No artificial dental illumination was used. The examinations were carried out with the aid of a plain mouth mirror, and a WHO ball-tip probe.

Table I
Pupils in the Xylitol and the Control Group According to Gender and Age

Age Group (Years)	Male				Female			
	Xylitol		Control		Xylitol		Control	
	n	%	n	%	n	%	n	%
10–12	19	31.1	6	25.0	10	22.7	3	18.8
13–15	25	41.0	11	45.8	15	34.1	4	25.0
16–18	14	23.0	4	16.7	14	31.8	5	31.3
19–27	3	3.0	3	12.5	5	11.4	4	25.0
Total	61	100	24	100	44	100	16	100

Plaque and gingivitis were evaluated from four sites on each tooth, excluding the third molars. No disclosing solution was used. Separate recordings of the Plaque Index (PI) and Gingival Index (GI) were made for the four smooth surfaces of each tooth. Each tooth surface was evaluated and each of the buccal, mesial, lingual, and distal surfaces was given a score of 0–3; whole-mouth scores were calculated from all scorable tooth surfaces. Plaque thickness at the gingival margin was assessed. Plaque was scored according to the Silness & Löe Plaque Index.[28] The criteria for scoring was as follows: 0–No plaque in the gingival area; I–A film of plaque adhering to the free gingival margin and adjacent area of the tooth. The plaque may only be recognized by running a probe across the tooth surface, not visible by the naked eye; 2–Moderate accumulation of soft deposits within the gingival pocket, on the gingival margin and/or adjacent tooth surface, which can be seen by the naked eye; 3–Abundance of soft matter within the gingival pocket and/or on the gingival margin and adjacent tooth surface.

Gingivitis was scored according to the Löe & Silness Gingival Index.[29] The GI consists of four grades, which are judged according to inflammation, color change, and bleeding at each tooth surface. The criteria for scoring were: 0–Normal gingiva; 1–Mild inflammation—slight change in color, slight edema, no bleeding on probing; 2–Moderate inflammation—redness, edema and glazing, bleeding on probing; 3–Severe inflammation—marked redness and edema, ulceration, tendency toward spontaneous bleeding. Plaque and Gingival Index scores were recorded prior to the study. The subjects were asked to maintain their normal dietary and oral hygiene habits throughout the intervention period.

Two calibrated examiners (MS, EH) conducted all of the examinations and the intra- and inter-examiner reliability was high. The inter-examiner assessments correlated highly both for plaque (r = .96) and gingivitis scores (r = .94). There was full agreement on 80% of the surfaces for plaque scores and for gingivitis scores. Examiners were kept blind as to which group each pupil was assigned. Xylitol (49%) candies used in this study were

Läkerol Plus® (Leaf Confectionary Company, Turku, Finland). The candy contained sweetening agents (xylitol 49%, maltitol syrup), hardened vegetable oil, different preservatives, and coloring agents. The strawberry-flavored variety, a favorite of children, was chosen.

Two female school health nurses in the girl's school and one male nurse in the boy's school distributed one xylitol candy to the pupils three times every school day (after breakfast at 8:00 a.m., after lunch at 11:00 a.m., and just before the pupils left school at 1:00 p.m.). The daily dose of xylitol was 3.6 g, which equalled three candies. No candies were given during the weekends, during the summer, or on school holidays. The candies were given to the nurses in plastic containers, which were filled once a month by the authors, and were delivered by a plastic spoon to the hand of the pupil. The dental team visited the school once a month, offering encouragement and support to the staff. The nurses advised the pupils to suck the candies as long as possible rather than biting and swallowing them quickly, in order to increase the time in the mouth up to 5–10 minutes. The candies were consumed under the supervision of the nurses and teachers, and the nurses were responsible for keeping the candies in a safe place.

Statistical Methods

The data were analyzed by statistical software SPSS, Windows Version 12.0. The paired-samples t-test was used to assess the differences in the mean plaque and gingival scores at the baseline and final examinations. Analysis of covariance was used to test differences in the mean plaque and gingival scores between the study and control groups. An independent-samples t-test was used to test the differences in gender and nationality. Bivariate correlations were used to measure the relationships between mean plaque and gingival scores for the baseline and final assessments. Pearson's correlation coefficient (r) was used to measure the linear association between the mean Plaque and Gingival Index scores.

Results

The mean PI and GI scores were reduced in both the xylitol and the control groups. The mean PI score decreased from 1.73 ± 0.67 to 1.14 ± 0.71 ($p < 0.001$), and the mean GI score decreased from 1.74 ± 0.70 to 1.16 ± 0.75 ($p < 0.001$) in the xylitol group (Table II). The mean PI score decreased from 1.84 ± 0.67 to 1.50 ± 0.55 ($p = 0.006$), and the GI score decreased from 1.89 ± 0.67 to 1.63 ± 0.61 ($p = 0.007$) in the control group (Table II). There was no difference in the mean PI ($p = 0.354$) and mean GI ($p = 0.238$) at the baseline examination between the xylitol and control group. There was a difference in the mean PI ($p = 0.005$) and GI ($p = 0.001$) at the final examination between the groups. Significant differences were found between the xylitol and the control groups in the reduction of plaque ($p = 0.037$) and on the GI scores ($p = 0.008$; Table II). There were no differences between the xylitol and control groups with respect to gender representation and nationality.

Table II
Mean (SD) Plaque Index and Gingival Index Scores at Baseline and in Follow-up

	Xylitol	Control	p-value
Plaque Index			
Baseline PI	1.73 (0.67)	1.84 (0.67)	0.354
Follow-up PI	1.14 (0.71)	1.50 (0.55)	0.005
Mean Difference	0.59 (0.62)	0.34 (0.56)	0.037
Gingival Index			
Baseline GI	1.74 (0.70)	1.89 (0.67)	0.238
Follow-up GI	1.16 (0.75)	1.63 (0.61)	0.001
Mean Difference	0.58 (0.64)	0.26 (0.57)	0.008

The mean PI reduction was 33.5% in the xylitol group compared to 17.9% in the control group over the duration of the 18-month study (Figure 1). The mean GI reduction was 33.3% in the xylitol group compared to 13.8% in the control group over the same time period.

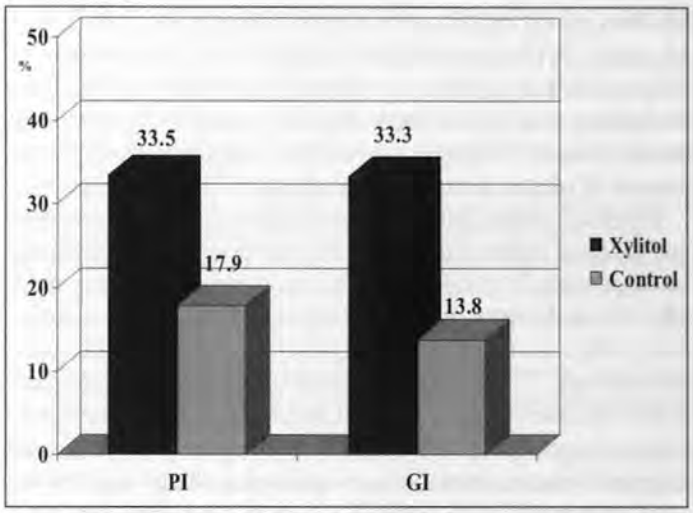

Figure 1. *The mean plaque and gingivitis percentage reduction in the xylitol and control groups.*

A high positive correlation was seen between the PI and GI. There was a high correlation between the individual PI and the GI scores at the baseline ($r = 0.93$) and final examinations ($r = 0.95$). The correlation between the reduction in plaque and the reduction in gingivitis was 0.86. The correlation between the baseline plaque and the final plaque score was 0.60, and 0.60 as well between the baseline and the final gingivitis score.

Discussion

This field study was undertaken to test the effect of xylitol candies on plaque and gingivitis in pupils with physical impairments and an increased risk for periodontal disease, and discusses the possible benefits of adding xylitol candies to their daily oral hygiene routine. The results of this clinical trial demonstrate that disabled individuals using xylitol candies for a period of 18 months had significantly lower levels of plaque and gingivitis when compared to individuals who did not use the candies. This study showed also that the subjects who consumed xylitol candies demonstrated improved oral hygiene compared with subjects who did not use xylitol. The use of xylitol candies was associated with about a 33.5% reduction in plaque levels and 33.3% reduction in gingivitis levels compared to 17.9% and 13.8% for the children of the control group over the same period.

One of the major problems encountered with the physically disabled is the maintenance of adequate oral hygiene due to physical limitations, and the inability to master the techniques

required for effective tooth brushing.[1] The PI could be higher in the physically disabled due to exogenous factors, which can be divided into primary local factors, such as lack of oral hygiene or calculus, and secondary local factors, such as tongue thrusting, malocclusion, and the lack of lip seal. Poor oral hygiene and periodontal disease have been reported in a sample of paraplegics.[30,31]

The findings of the present investigation were in agreement with earlier studies, and showed that the use of xylitol candies improved the state of oral hygiene. Our results confirm the other studies, and suggest that the regular use of xylitol candies may be useful to control dental plaque formation[2-10] and decrease gingival inflammation.[11,12] The plaque-reducing capability of xylitol has been shown earlier, and established that of all the natural sugars tested, xylitol consumption resulted in the least amount of plaque, and that a partial substitution of sucrose by xylitol in the diet during four to five days similarly reduced the amount of dental plaque.[4-6] Several studies have demonstrated that the amount of plaque decreases with regular xylitol consumption.[2,3]

Previous studies have suggested reduced plaque formation and gingival inflammation with the use of a xylitol-containing chewing gum.[10,12] Xylitol-containing chewing gum was more effective in the reduction of dental plaque formation in comparison to the use of a corresponding sucrose gum in several short-term studies.[7,17-19] In the Turku sugar study, 4.5 to 10.5 g xylitol daily from chewing gum reduced plaque formation compared to a sucrose control.[16] In the longitudinal study by Kandelman and Gagnon,[13] plaque formation was reduced in the group chewing gums sweetened with either 1.1 g or 0.3 g xylitol per piece 3 times daily, compared with the no-chewing-gum control group. An antiplaque preparation containing xylitol with chlorhexidine diacetate and sodium fluoride was found significantly more effective in reducing gingivitis than conventional brushing of the teeth among military academy cadets during their two-week winter camp.[32]

The mechanism by which xylitol inhibits plaque is unclear, although several hypotheses have been proposed. It has been suggested that a decrease in the production of adhesive plaque macromolecules would be responsible for plaque reduction. The total substitution of dietary sucrose by non-metabolizable xylitol could explain the reduction in the amount of plaque in the oral cavity.[3] Most studies reporting an effect of xylitol on plaque quantity utilize plaque index measurements with comparisons of the mean values.[13,16,19] Discrepancies may be caused mainly by the differences in the experimental methodology and in the interpretation of the results.

There are always limitations in field studies. In this study, the group consuming no candies was a control group. In comparison to the study group, salivary stimulation by sucking was lacking. However, it was difficult to find an inert compound from which the control candies could have been made. Furthermore, it would have been very difficult to get informed consent for use of any other artificially sweetened candies; informed consent is compulsory in human studies. Although complete randomization is essential to eliminate selection bias and allow for comparability, it was not possible in this study and this is a limitation on the confidence of results. A randomized clinical trial would be necessary to confirm this "unexpected" strong positive effect on plaque and gingivitis. However, randomatizion in this field study would have been extremely difficult and demanded too much extra work by the school health nurses. For ethical reasons the control group was not chosen, as the baseline assessment showed a high need for improvement in oral hygiene among all the subjects in these two physically disabled schools; hence only pupils whose parents or guardians signed and returned the informed consent form were assigned to the xylitol group and the rest to the control group. Another study limitation was that the subject treatments were nested within classrooms, and the effect of this cluster-sampling could not have been evaluated in the analysis. Distributing xylitol candies to certain children in every classroom was not possible for practical reasons, and it was necessary to prevent xylitol exposure to those children outside the study group who were the controls. In this school-based delivery system, taking into consideration the length of the intervention program, the delivery of xylitol candies was confined within the classrooms to facilitate easy access and distribution to the pupils by the school health nurses.

In this study, the Silness & Löe Plaque Index[28] and Löe & Silness Gingival Index[29] were used for scoring. While all the indices published prior to 1963 were based on the single tooth as a unit, these newer indices evaluate every tooth surface. The Plaque Index is a reliable measure for evaluating mechanical antiplaque procedures. The Gingival Index has also gained wide acceptance as a simple, accurate, and reproducible method for evaluating gingival health or disease in epidemiological and clinical research.There seemed to be a very strong correlation between the plaque and gingivitis scores, both at baseline and in the final examinations. Although there was a consistent reduction in plaque and gingivitis scores in both the xylitol and control groups, this correlation remained. This is a general finding confirming that plaque is the main determinant of gingivitis.

The candies were easily soluble, and we therefore preferred candies instead of chewing gum. In a previous study, xylitol candies were effective in caries prevention.[33] The implementation of this xylitol-based candy prevention program has been beneficial and did not demand great effort nor expensive equipment. Also there was good cooperation with the school authorities and the staff. The nurses were enthusiastic, always available during the school hours, and regularly distributed the xylitol candies to the pupils. The xylitol candies were well-received by the pupils and significantly improved problems with taste and chewing. The majority of the pupils were cooperative and willing to participate in the program.

One-hundred and forty-five (82.4%) of the 176 subjects enrolled remained at the end of the trial. There were 31 dropouts in the study, of which some left the school, some died due to medical ailments, and some refused to take the candies. The reasons for excluding some of the xylitol-consuming subjects from the final calculations were as follows: 1) interruption of continuous consumption of xylitol because of illnesses, or lack of cooperation; 2) failure to determine the plaque or gingival index scores at either one or two examinations due to limited cooperation of the subject; 3) the general difficulties involved when dealing with young, physically disabled subjects in a long-term trial.

School-based use of xylitol candies may offer a possible preventive system for areas with a shortage of health care resources in dentistry, but with a well-functioning school system. A school-based delivery system can control the regular use of recommended amounts in a reliable way. However, because every pupil would like to get free candies, targeting of xylitol only to high-risk subjects is not possible in a school-based delivery system.

In summary, the present results suggest that it may be possible to favorably affect the status of oral hygiene through systematic and supervised use of xylitol candies. The results seem to suggest that xylitol candies may be an effective way to prevent plaque accumulation and gingival inflammation in pupils with special needs. Chewing the candies was acceptable, and therefore the long-term use of xylitol candies may support oral hygiene routines in the disabled.

Conclusions

The results of this study indicate that the inclusion of xylitol in a candy form may provide an effective measure in the control of dental plaque formation and gingival inflammation. Xylitol candies used three times during school days seemed to reduce both plaque and gingival scores among these disabled pupils. Therefore, for disabled individuals with increased susceptibility to gingival and periodontal disease, the regular use of xylitol candy may be a useful supplement to other oral hygiene measures.

Acknowledgments: Our warmest thanks to all the pupils who participated in this study. We are grateful to the nurses for the careful and regular delivery of candies to the pupils. We thank the dental hygienists, school principals, and the teachers. We express special thanks to the Leaf Confectionary Company for manufacturing and donating the xylitol candies for the study. This study was supported by the Kuwait University Grant No: DI 02/01.

For further correspondence with the author(s) of this paper, contact Dr. Maddi Shyama—mshyama@yahoo.com.

References

1. British Society for Disability and Oral Health: *Guidelines for Oral Health Care for People with a Physical Disability*. London, pp. 1–9, 2000.
2. Mäkinen KK, Isokangas P: Relationship between carbohydrate sweeteners and oral diseases. *Prog Food Nutr Sci* 12:73–109, 1988.
3. Trahan L: Xylitol: A review of its action on mutans streptococci and dental plaque—Its clinical significance. *Int Dent J* 45:77–92, 1995.
4. Scheinin A, Mäkinen KK: The effect of various sugars on the formation and chemical composition of dental plaque. *Int Dent J* 21:302–321, 1971.
5. Scheinin A, Mäkinen KK: Effect of sugars and sugar mixtures on dental plaque. *Acta Odontol Scand* 30:235–257, 1972.
6. Scheinin A, Mäkinen KK: Turku sugar studies I-XXI. *Acta Odontol Scand* 33(Suppl):5–348, 1975.
7. Söderling E, Mäkinen KK, Chen C-Y, Pape HR Jr, Loesche W, Mäkinen P-L: Effect of sorbitol, xylitol, and xylitol/sorbitol gums on dental plaque. *Caries Res* 23:378–384, 1989.
8. Söderling E, Isokangas P, Tenovuo J, Mustakallio S, Mäkinen KK: Long-term xylitol consumption and mutans streptococci in plaque and saliva. *Caries Res* 25:153–157, 1991.
9. Söderling E, Trahan L, Tammiala-Salonen T, Hakkinen L: Effects of xylitol, xylitol-sorbitol, and placebo chewing gums on the plaque of habitual xylitol consumers. *Eur J Oral Sci* 105:170–177, 1997.
10. Cronin M, Gordon J, Reardon R, Balbo F: Three clinical trials comparing xylitol-and sorbitol-containing chewing gums for their effect on supragingival plaque accumulation. *J Clin Dent* 5:106–109, 1994.
11. Harjola U, Leismaa H: Effects of polyol and sucrose candies on plaque, gingivitis and lactobacillus index scores. *Acta Odontol Scand* 36:237–242, 1978.
12. Steinberg LM, Odusola F, Mandel ID: Remineralizing potential antiplaque and antigingivitis effects of xylitol and sorbitol sweetened chewing gum. *Clin Prev Dent* 14:31–34, 1992.
13. Kandelman D, Gagnon G: A 24-month clinical study of the incidence and progression of dental caries in relation to consumption of chewing gum containing xylitol in school preventive programs. *J Dent Res* 69:1771–1775, 1990.
14. Grenby TH, Bashaaret AH, Gey KF: A clinical trial to compare the effects of xylitol and sucrose chewing-gums on dental plaque growth. *Br Dent J* 152:339–343, 1982.
15. Birkhed D, Edwardsson S, Wikesjö U, Ahlden M-L, Ainamo J: Effect of 4 days consumption of chewing gum containing sorbitol or a mixture of sorbitol and xylitol on dental plaque and saliva. *Caries Res* 17:76–88, 1983.
16. Larmas M, Scheinin A, Gehring F, Mäkinen KK: Turku sugar studies XX. Microbiological findings and plaque index values in relation to 1-year use of xylitol chewing gum. *Acta Odontol Scand* 34:381–396, 1976.
17. Mouton C, Scheinin A, Mäkinen KK: Effect on plaque of a xylitol containing chewing-gum. A pilot study. *Acta Odontol Scand* 33:27–31, 1975.
18. Mouton C, Scheinin A, Mäkinen KK: Effect on plaque of a xylitol-containing chewing-gum. A chemical and biochemical study. *Acta Odontol Scand* 33:33–40, 1975a.
19. Mouton C, Scheinin A, Mäkinen KK: Effect of a xylitol chewing gum on plaque quantity and quality. *Acta Odontol Scand* 33:251–257, 1975c.
20. Topitsoglou V, Birkhed D, Larsson L-A, Frostell G: Effect of chewing gums containing xylitol, sorbitol or a mixture of xylitol and sorbitol on plaque formation, pH changes and acid production in human dental plaque. *Caries Res* 17:369–378, 1983.
21. Pakkala U, Liesmaa H, Mäkinen KK: The use of xylitol in the control of oral hygiene in mentally retarded children. A clinical and biochemical study. *Proc Finn Dent Soc* 77:271–277, 1981.
22. Rateitschak-Plüss EM, Guggenheim B: Effects of a carbohydrate-free diet and sugar substitutes on dental plaque accumulation. *J Clin Periodontol* 9:239–251, 1982.
23. Mäkinen KK, Isotupa KP, Kivilompolo T, Mäkinen PL, Toivanen J, Söderling E: Comparison of erythritol and xylitol saliva stimulants in the control of dental plaque and mutans streptococci. *Caries Res* 35:129–135, 2001.
24. Simons D, Beighton D, Kidd EAM, Collier FI: The effect of xylitol and chlorhexidine acetate/xylitol chewing gums on plaque accumulation and gingival inflammation. *J Clin Periodontol* 26:388–391, 1999.
25. Simons D, Brailsford S, Kidd EAM, Beighton D: The effect of chlorhexidine acetate/xylitol chewing gum on the plaque and gingival indices of elderly occupants in residential homes. *J Clin Periodontol* 28:1010–1015, 2001.
26. Sharma NC, Galustians JH, Qaqish JG: An evaluation of a commercial chewing gum in combination with normal tooth brushing for reducing dental plaque and gingivitis. *Compend Cont Educ Dent* 22:13–17, 2001.
27. Shyama M, Al-Mutawa SA, Honkala S, Sugathan T, Honkala E: Oral hygiene and periodontal conditions in special needs children and young adults in Kuwait. *J Disabil Oral Health* 1:13–19, 2000.
28. Silness J, Löe H: Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condition. *Acta Odontol Scand* 22:121–135, 1964.
29. Löe H, Silness J: Periodontal disease in pregnancy I. Prevalence and severity. *Acta Odontol Scand* 21:533–551, 1963.
30. Stiefel DJ, Truelove EL, Persson RS, Chin MM, Mandel LS: A comparison of oral health in spinal cord injury and other disability groups. *Spec Care Dent* 13:229–235, 1993.
31. Lanchasire P, Janzen J, Zach GA, Addy M: The oral hygiene and gingival health of paraplegic inpatients—A cross-sectional survey. *J Clin Periodontol* 24:198–200, 1997.
32. Nuuja MC, Meurman JH, Murtomaa H, Pesonen T: Effects of chewable antiplaque preparation on plaque and gingival index scores in military academy cadets during their two-week winter camp. *Mil Med* 158:438–440, 1993.
33. Alanen P, Isokangas P, Gutmann K: Xylitol candies in caries prevention: Results of a field study in Estonian children. *Community Dent Oral Epidemiol* 28:218–224, 2000.