

Xylitol-containing Chewing Gum for Caries Prevention in Students with Disabilities: A Randomised Trial

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Purpose: This cluster randomised controlled trial evaluated the effectiveness of a school-based xylitol chewing-gum programme on caries prevention among students with visual or hearing impairment.

Materials and Methods: The study compared xylitol gum plus oral health education (intervention group, n = 93) with oral health education alone (control group, n = 81) among students aged 7–18 years in special needs schools in Khon Kaen, Thailand. The primary outcome was caries onset rate measured as the change in caries onset on tooth surfaces. The secondary outcome was plaque index. Between-group differences were determined using generalised estimated equations and a general linear model under the intention-to-treat approach.

Results: After 1 year, there was a significantly lower caries rate in the primary dentition among the intervention group compared to the control group (0.08 vs 0.12 surfaces per surface-year, respectively; adjusted relative risk = 0.64, 95% confidence interval 0.44–0.96; p = 0.03), but there was no significant difference in the caries rates for the permanent dentition. Remineralisation also occurred more in the intervention vs the control group in the primary dentition only. Oral hygiene was significantly improved in the intervention but not in the control group (p = 0.001).

Conclusion: This programme reduced the caries rate and enhanced remineralisation in primary dentition, and improved oral hygiene in students with disabilities.

Key words: chewing gum, dental caries, disabilities, randomised controlled trial, xylitol

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Xylitol has been shown to be effective in reducing plaque formation¹¹ and the level of mutans streptococci,^{8,10,36} as well as preventing dental caries.⁶ It is effective in school-based oral health programmes,^{12,28,30} and is recommended for caries prevention by several organisations,^{2,7,31} although the evidence is still limited.³¹ One study found that the benefits of caries prevention persisted beyond the active intervention period. Children who used xylitol gum for 2 years had a 44%–59% lower rate of dental caries 3 years after the study had ended compared to those who did not use it.¹⁵

Conflicting results on the efficacy of xylitol have been attributed to limitations in study design, heterogeneity in xylitol dose, frequency of use, and outcome measures.³⁹ Even though the cost:benefit ratio of xylitol programmes has been questioned,^{27,39} a Finnish study reported more cost savings accruing in the xylitol group a decade later among participants in a clinical trial.⁴² A Cochrane review of randomised trials concluded that fluoride toothpaste containing xylitol may be more effective than fluoride-only toothpaste for preventing caries in the permanent teeth of children.

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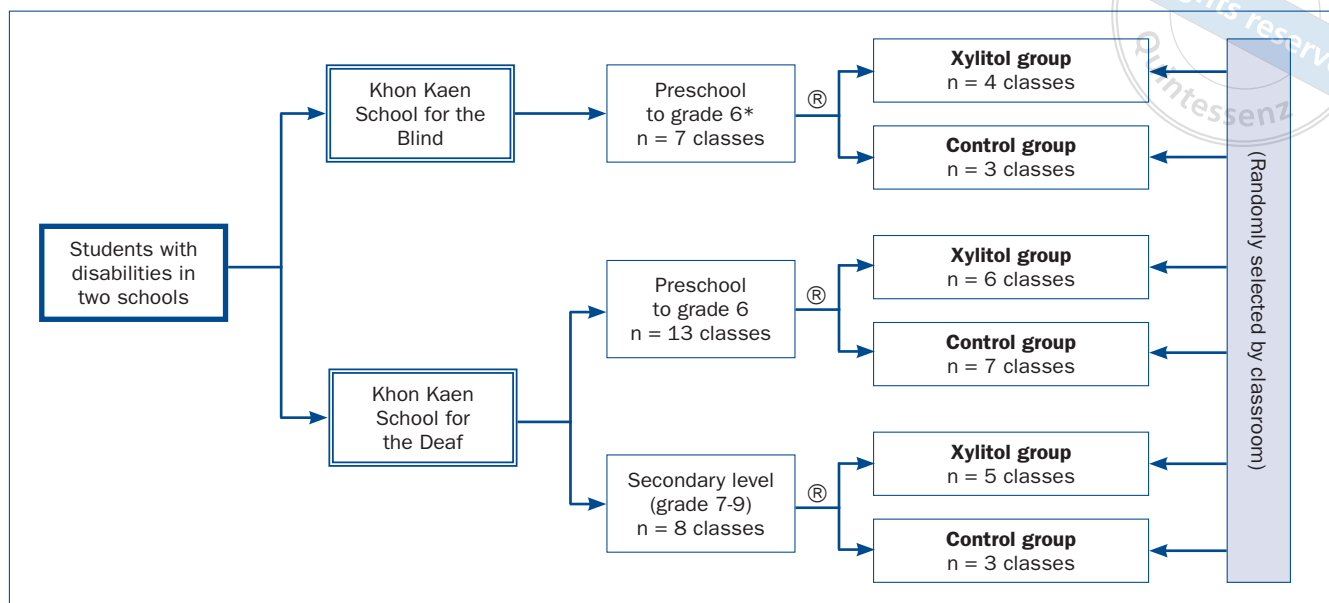


Fig 1 Randomisation process. *Khon Kaen School for the Blind does not have a secondary level. ®denotes randomisation.

However, there was insufficient evidence to determine whether any other xylitol-containing products can prevent caries in children or adults.³² A recent systematic review and meta-analysis combining all types of xylitol products concluded that xylitol is effective in preventing caries.²⁰

There have been few published reports on the effect of xylitol-containing products on caries prevention in children with visual or hearing impairment. A collaborative WHO field study in Hungary among institutionalised children reported a significantly lower 3-year DMFS increment in the xylitol group (4.2) than in the systemic fluoride (6.5) and control groups (7.7).³⁴ However, the study had a high dropout rate (30%) with only 10% of the participants having visual or hearing impairment, thus limiting its generalisability to children with disabilities.

Children with disabilities generally have high caries rates and poor oral hygiene.^{19,29} This is possibly due to limited physical ability, ineffective oral self-care, lack of cooperation and limited access to oral care.⁴⁰ Use of xylitol gum to supplement other oral health activities in schools can be useful because it is simple to implement, and does not need health professionals or additional equipment. Therefore, this study aimed to evaluate the efficacy of a school-based xylitol chewing gum programme on dental caries prevention among students with visual or hearing impairment in Thailand.

MATERIAL AND METHODS

Design and Participants

This cluster-randomised, single-blind, parallel-group, controlled trial was conducted in two special needs schools in Khon Kaen, Thailand: 1) School for the Blind, and 2) School

for the Deaf. Students were eligible if they attended the schools in the Academic Year 2008 including the summer semester (June 2008–March 2009), studied in grades pre-school through 9, were 7 to 18 years old, and had a visual or hearing impairment. Exclusion criteria were: difficulty in swallowing or chewing, temporomandibular disorder, history of phenylketonuria, or refusal to participate. Information regarding general health or medication use of the students was obtained from classroom teachers and health teachers. No students habitually used xerogenic medication.

Before the study began, there was no oral health care programme in either school. Students brushed their teeth with 1000-ppm fluoride toothpaste which was provided by the schools twice daily (before breakfast and before going to bed) without close monitoring. Dental floss was not used. Our project encouraged students to brush their teeth regularly and teachers to monitor student toothbrushing sessions. Our programme did not provide dental treatment during the 1-year period, but students were free to receive their usual dental care. Both schools provided the children with meals that typically consisted of rice, meat, eggs and vegetables three times daily. Students also consumed desserts, seasonal fruits, sweetened milk, and snacks between meals. Snacks, sweets and soft drinks were mostly donations to the school. The fluoride content of bottled and piped water in Khon Kaen area is less than 0.3 ppm.³

The study was conducted in accordance with the principles of the Declaration of Helsinki. Parents or guardians of the participants gave written informed consent at the time of enrollment. Students who were determined by the researcher as being capable of giving meaningful assent were also asked to sign the same form. Approval for the study was granted by the Khon Kaen University Ethics Committee for Human Research (HE 510405).

Randomisation

Students were allocated to treatment groups based on three stratified randomisation levels: 1) school, 2) education (primary level or lower vs secondary level), and 3) classroom. Simple randomisation by drawing with replacement was performed at the classroom level, not the individual level, to facilitate management and prevent group contamination. Randomisation was performed by an investigator (S.W.) prior to baseline oral examination (Fig 1).

Intervention

This study compared xylitol chewing gum plus oral health education (intervention group) with oral health education alone (control group). The chewing gum used in the study contained 55% xylitol by weight of total sweeteners or 0.96 g xylitol per pellet (gum base 16.85%, maltitol 34.06%, sorbitol 1.30%, aspartame 0.02%, blueberry flavoured). Students in the intervention group were instructed to chew two gum pellets for five min after meals three times daily, yielding a total dose of 5.76 g of xylitol per day. The intervention was conducted for nine months during the academic year. Students in both groups received oral health education from their classroom teachers in 6 sessions spread over the year about components of oral cavity, caries, toothbrushing method, and healthy food for oral health.

Before the intervention, all teachers received oral health education training from health professionals. Teachers in intervention group received additional training on the use of xylitol chewing gum, its benefits for caries prevention and possible side effects.

Measurements

The primary outcome of this study was the development of caries on a previously sound or unerupted tooth surface. The secondary outcome was oral hygiene measured by the Silness and Loe plaque index (PI).³⁷ We carried out oral health examinations at baseline, 9 months (end of academic year), and 12 months. Students were examined at their schools on a mobile dental chair in a supine position and under artificial light. A dentist (A.P.) evaluated the oral hygiene on six Ramfjord teeth, including teeth number 16, 21, 24, 36, 41 and 44 on both buccal and lingual surfaces of the teeth. Basic fuchsin was applied as disclosing agent on tooth surfaces to clarify visualisation. All teeth were professionally cleaned before the caries examination.

A second dentist (N.C.) with formal training in the International Caries Detection and Assessment System (ICDAS II) examined the participants for caries using a plane mouth mirror and a periodontal probe with the aid of compressed air. Caries was scored as follows: 0 = sound, 1 = first visual change in enamel, 2 = distinct visual change in enamel, 3 = localised enamel breakdown without clinical visual sign of dentin involvement, 4 = noncavitated surface with underlying dark shadow from dentin, 5 = distinct cavity with visible dentin, and 6 = extensive distinct cavity with visible dentin cavity.¹⁶ Scores 1 to 6 were grouped into carious lesions and compared with no caries (score 0). The

same criteria were applied for both permanent and primary teeth using numbers for permanent teeth and letters for primary dentition. Approximately five percent of the subjects were re-examined to test for consistency. Intra-examiner reliability for caries assessment was high, with kappa values as follows: 0.76 at baseline, 0.75 at second examination phase, and 0.75 at last visit. The kappa values were similar when considering carious surfaces only (0.68, 0.73 and 0.65, respectively, for each visit). Oral examiners were blinded to the group allocation.

Compliance

The teachers distributed xylitol gum to participants in the intervention group and supervised the 5-min chewing session at a fixed time. After chewing, each child's chewed gum was collected in a transparent plastic bottle which was recovered monthly to check for compliance. Teachers maintained records of xylitol gum use and its side effects. The students were not forced to chew the gum pellets if they did not wish to do so. The programme was monitored weekly during the first four weeks and monthly thereafter.

Power Calculation

Of the 228 students enrolled in the two schools, 174 were eligible for the study. The students were clustered within classroom, which was the unit of randomisation. Power calculation was estimated using a sample size calculator for cluster-randomised trials (<http://www.abdn.ac.uk/hsru/samplesize/ssc.exe>).⁴ Estimates of caries incidence for power calculation were obtained from a 24-month cohort study.²⁵ Using an intra-cluster correlation coefficient of 0.21 and a significance level of 5%, there was 90% power to observe 3-fold differences in caries incidence between the comparison groups.

Statistical Analysis

The baseline characteristics of the study groups were compared using the chi-squared test for categorical data and t-test for continuous data. The caries rate over one year was defined as the number of new-onset carious tooth surfaces divided by the total surface-year at risk as described by Hujoel et al.¹⁴ Briefly, if the surface did not develop caries during two examinations, the amount of time contributed by that surface equalled the time between the two examinations. If the surface developed caries, we assumed that the caries onset occurred in the middle of the two examinations. If the surface developed caries at 9 months, it was no longer considered as 'at risk' and did not contribute the time to the analysis at the 1-year visit.

The two groups were compared using a Poisson regression model within the framework of generalised estimated equations (GEE) to adjust for correlated responses within classrooms and within the same subjects. Between-group differences in the number of tooth surfaces with decay reversal and secondary outcomes were determined using a general linear model (GLM). Variables which were considered as potential confounders included age, gender, caries experience at baseline, and type of disability. The data were

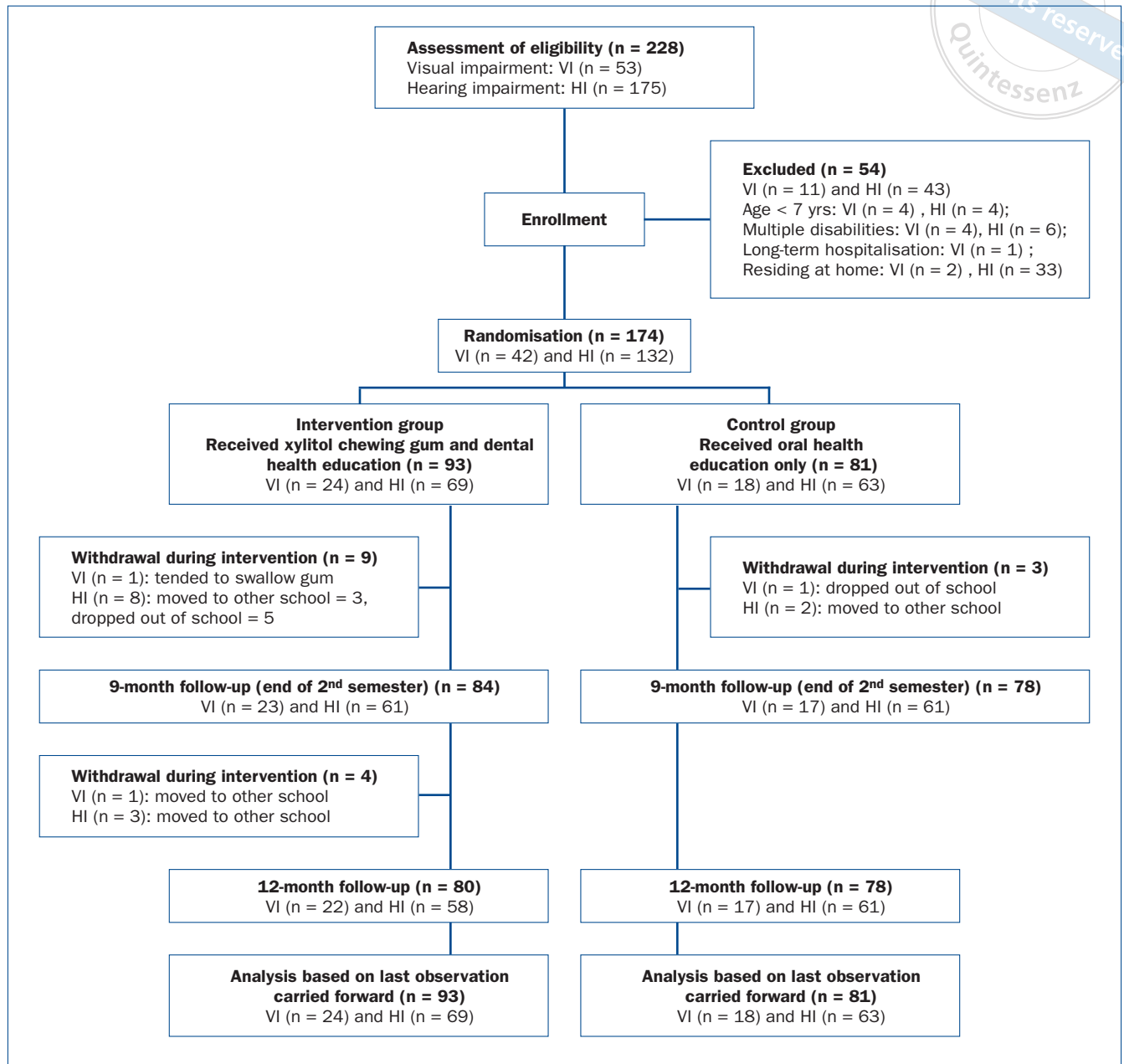


Fig 2 Flow diagram of the participants at each stage of the study. VI denotes visual impairment and HI hearing impairment.

analysed using the intention-to-treat (ITT)/last-observation-carried-forward method. The analyses were also performed using the per-protocol method, and the results did not substantially change. Thus, only the results of the ITT were shown. All analyses except GEE were performed with SPSS (version 17.0, SPSS/IBM; Chicago, IL, USA). GEE analysis was conducted using STATA (version 10.0, Stata; College Station, Texas, USA). All statistical tests were two-sided. To illustrate the magnitude of the intervention effect, number needed to treat (NNT) and prevented fractions (PF) were calculated for the outcomes which showed statistical significance. The NNT was calculated based on the method for

person-time data.³⁸ The PF was the difference in the caries rates between the control and the intervention group divided by the caries rate in the control group.

RESULTS

Of 228 students assessed for eligibility, 54 students were excluded; 93 were randomised to the intervention group and 81 to the control group. After 12 months of follow-up, 80 students (86.0%) remained in the intervention group and 78 (96.3%) in the control group (Fig 2). At baseline, the two

Table 1 Demographic and clinical characteristics of the participants according to study group at baseline

	Control group (n = 81)	Intervention group (n = 93)	Mean difference (95% confidence interval)	p-value
Age (year)				
Mean $\pm$ SD	10.94 $\pm$ 2.44	11.56 $\pm$ 2.98	0.63 (-0.19, 1.44)	NS
Range	7-17	7-18		
Male, n (%)	36 (44.4)	50 (53.8)	1.19 (0.90, 1.57)*	NS
DMFS	19.14 $\pm$ 12.02	17.08 $\pm$ 9.29	-2.06 (-5.31, 1.19)	NS
dmfs	16.78 $\pm$ 16.62	16.29 $\pm$ 15.01	-0.49 (-7.26, 6.28)	NS
Mean number of sound surfaces				
Primary dentition	21.84 $\pm$ 19.01	28.60 $\pm$ 20.83	6.75 (-1.74, 15.24)	NS
Permanent dentition	71.16 $\pm$ 27.13	76.03 $\pm$ 30.63	4.87 (-3.84, 13.59)	NS
Plaque index score	1.35 $\pm$ 0.42	1.28 $\pm$ 0.39	-0.07 (-0.19, 0.05)	NS
Type of disability				
- Hearing impairment	63 (77.8)	69 (74.2)	0.91 (0.67, 1.25)*	NS
- Visual impairment	18 (22.2)	24 (25.8)		

* Relative risk (95% confidence interval) using the control group as reference. NS indicates not statistically significant ($p \geq 0.05$)

Table 2 Caries onsets, surface year at risk, caries rates from baseline to 1 year and relative risk (RR) estimates by study group

Group	N	Caries onset per person (mean $\pm$ SD)	Surface year at risk per person (mean $\pm$ SD)	Crude caries rate (95% CI)	Crude RR (95% CI)	p-value	Adjusted RR* (95% CI)	p-value
Primary dentition								
Control	45	3.62 $\pm$ 4.09	30.32 $\pm$ 11.27	0.12 (0.10, 0.14)				
Inter- vention	42	2.83 $\pm$ 2.87	35.05 $\pm$ 12.57	0.08 (0.07, 0.10)	0.68 (0.53, 0.86)	0.001	0.64 (0.44, 0.96)	0.03
Permanent dentition								
Control	81	16.31 $\pm$ 7.97	67.91 $\pm$ 22.93	0.24 (0.23, 0.25)				
Inter- vention	93	15.25 $\pm$ 10.10	73.01 $\pm$ 24.32	0.21 (0.20, 0.22)	0.87 (0.81, 0.94)	0.001	0.95 (0.80, 1.13)	NS

Crude caries rate = caries onsets per surface-year (surfaces per year). CI denotes confidence interval; NS indicates not statistically significant ($p \geq 0.05$).

*Adjusted for age, gender, caries at baseline and type of disabilities.

groups were similar in age, gender, type of disabilities, caries and oral hygiene status (Table 1).

After 1 year, mean numbers of caries onsets per person in primary and permanent dentition were lower in the intervention than in the control group (Table 2). The intervention group had a significantly lower caries rate than did the control group in both dentitions. In the primary dentition, the risk for development of caries on a tooth surface in the xylitol

gum group was 68% of that in the control group (RR = 0.68, 95% CI 0.53–0.86). Adjustment for age, gender, caries at baseline and type of disabilities did not change the results materially (RR = 0.64, 95% CI 0.44–0.96). The NNT was 27.6 tooth surfaces, and PF was 33%, comparing the effect of the intervention to the control. In the permanent dentition, caries risk was also lower in the xylitol gum group than in the control group, but no signifi-

Table 3 Mean $\pm$ standard deviation of number of tooth surfaces with decay reversal in primary dentition by study group after 1 year

Change in surface	Control group (n = 45)	Intervention group (n = 42)	Crude		Adjusted *	
			Mean difference (95% CI)	p-value	Mean difference (95% CI)	p-value
Reversal code B to A	0.73 $\pm$ 1.42	2.60 $\pm$ 4.20	1.86 (0.54, 3.18)	0.01	1.28 (0.40, 2.51)	0.04
Reversal code C to A	1.18 $\pm$ 1.61	1.45 $\pm$ 1.95	0.28 (-0.49, 1.04)	NS	-0.13 (-0.81, 0.55)	NS
Reversal code C to B	0.02 $\pm$ 0.15	0.36 $\pm$ 0.88	0.34 (0.07, 0.60)	0.01	0.33 (0.07, 0.60)	0.02
Total reversal	1.93 $\pm$ 2.84	4.40 $\pm$ 5.49	2.47 (0.63, 4.32)	0.01	1.48 (-0.14, 3.10)	NS
Code A, sound surface; Code B, first visual change in enamel; Code C, distinct visual change in enamel; CI denotes confidence interval; NS indicates not statistically significant ($p \geq 0.05$). *Adjusted for age, gender, and type of disabilities.						

Table 4 Mean $\pm$ standard deviation of number of tooth surfaces with decay reversal in permanent dentition by study group after 1 year

Change in surface	Control group (n = 81)	Intervention group (n = 93)	Crude		Adjusted *	
			Mean difference (95% CI)	p-value	Mean difference (95% CI)	p-value
Reversal code 1 to 0	8.99 $\pm$ 7.04	9.40 $\pm$ 6.17	0.41 (-1.57, 2.39)	NS	-0.22 (-2.16, 1.73)	NS
Reversal code 2 to 0	2.96 $\pm$ 3.45	3.96 $\pm$ 4.12	0.99 (-0.15, 2.14)	NS	0.75 (-0.40, 1.90)	NS
Reversal code 2 to 1	3.28 $\pm$ 4.06	2.95 $\pm$ 2.88	-0.34 (-1.38, 0.71)	NS	-0.57 (-1.64, 0.47)	NS
Total reversal	15.23 $\pm$ 11.57	16.30 $\pm$ 9.98	1.07 (-2.16, 4.29)	NS	-0.03 (-3.16, 3.10)	NS
Code 0, sound surface; Code 1, first visual change in enamel; Code 2, distinct visual change in enamel. CI denotes confidence interval; NS indicates not statistically significant ($p \geq 0.05$). *Adjusted for age, gender, and type of disability.						

cant difference was observed between groups after adjusting for confounding.

Table 3 shows that remineralisation occurred more in the intervention than in the control group in the primary dentition at the end of one year. Mean number of tooth surfaces with decay reversal was 4.40 $\pm$ 5.49 in the intervention group vs 1.93 $\pm$ 2.84 in the control group ($p < 0.05$). The results became marginally significant after adjustment for age, gender, and type of disabilities ($p = 0.07$). There was no difference between study groups regarding caries reversal in the permanent dentition (Table 4).

At baseline, the oral hygiene of the comparison groups was similar (Table 1), and it improved over time in the intervention group but not in the control group. The intervention group had significantly lower PI scores than the control group both at 9 months (1.32 $\pm$ 0.42 vs 1.74 $\pm$ 0.32) and after one year (1.04 $\pm$ 0.36 vs 1.37 $\pm$ 0.40). The results were similar in adjusted analysis.

One student with visual impairment tended to swallow the gum. For the safety of the participant, the research team and teachers agreed to withdraw the student from the intervention. No other side effects were reported.

DISCUSSION

This randomised controlled trial compared the effectiveness of xylitol chewing gum plus oral health education vs oral health education alone among students with visual or hearing impairment. The study found that daily use of xylitol chewing gum reduced the rate of caries, increased remineralisation in the primary dentition, and improved oral hygiene of individuals with disabilities. The NNT of 27.6 indicates that 27.6 primary tooth surfaces would need to receive xylitol chewing gum to prevent one additional carious lesion over a one-year period. The PF suggests that 33% of primary tooth surfaces with caries can be prevented if exposed to xylitol gum. Although this study was conducted among students with disabilities, the findings may be generalizable to other groups of children with high caries risk.

Only a few studies have investigated the effects of xylitol chewing gum on caries prevention in primary dentition. Xylitol gum use was associated with 65% reduced risk of caries in the primary dentition among 6-year-old schoolchildren over 24 months in a cohort study in Belize.²⁵ The magnitude of reduction seen in the Belize study was greater than that observed (36%) here; this was possibly due to a higher

xylitol dose (100% xylitol), more chewing frequency (5x/d), and longer exposure to xylitol in the Belize study.

In the present study, the caries rates in the permanent dentition were not statistically different in the intervention and control groups, even though the point estimate for caries incidence in the xylitol group was lower. This may be because most of the participants were in the mixed dentition stage and some teeth erupted during follow-up, which meant that permanent teeth were exposed to xylitol for a shorter time than deciduous teeth. In additional analyses excluding teeth erupted during the follow-up period, the adjusted RR decreased from 0.95 (95% CI 0.80–1.13; $p = 0.57$ in the main analysis) to 0.73 (95% CI 0.49–1.09; $p = 0.13$). Although the results were not significant, the direction of the association supported the hypothesis. Moreover, the progression of caries rate in permanent teeth is slower than that in primary teeth,⁴¹ making the effect of xylitol less pronounced in the permanent dentition.

The present results in permanent dentition were inconsistent with previous studies of school-based xylitol gum programmes for healthy children^{18,21,24,33} which found a significant caries reduction in the xylitol group. The discrepancies may be due to the lower xylitol dose used in our study. The duration of xylitol use in our trial was also shorter compared with several studies^{18,21,24} (9 months vs 24 to 40 months). The inconsistency between the present findings and those of other studies over a 1-year period^{21,33} may also result from the differences in the school contexts and nature of subjects. In a Canadian study, the schools had an ongoing preventive dental programme including three sessions of oral hygiene instruction with periodic brushing control, a weekly 0.2% NaF mouthrinse, screening, and referral to a dental clinic for restorative treatment.²¹ In another study, the subjects were predominantly dental and medical students (mean age 22.2 years) with moderate sucrose consumption and a satisfactory level of oral hygiene.³³

The present study is, nevertheless, consistent with a study of 9- to 14-year-old schoolchildren in Lithuania²³ which showed no difference in adjusted caries increment in the permanent dentition between 100% xylitol gum and no-gum groups during the first 2 years of follow-up. However, the beneficial effect of xylitol gum became apparent after 3 years.^{9,23} Xylitol has been shown to be more effective in preventing caries during the second year of the habitual chewing programme than during the first year.^{1,18} Further investigations with longer follow-up periods are therefore needed to confirm the findings in students with disabilities.

In this study, we observed a reversal of demineralisation in the primary dentition. The beneficial effect of xylitol on remineralisation was also reported in earlier studies.^{13,21,22} Failure to observe reversal of demineralisation in the permanent dentition was likely because the study participants were mostly in the mixed dentition stage, meaning that the permanent teeth were exposed to caries risk for a shorter time than were the primary teeth.

Our finding that PI scores decreased only in the xylitol group is consistent with previous studies conducted in

healthy children.²⁶ PI scores might also have decreased because the students were familiar with oral self-care and received motivation and encouragement from their teachers and research team,³⁵ although this was not the case for the control group.

The caries-preventive effect of xylitol gum may be a result of xylitol itself or salivary stimulation and mechanical plaque removal. Our study did not use placebo gum and therefore could not distinguish these mechanisms of action. We chose to study xylitol gum, as it is simple to use and independent of professional health intervention. Additionally, students enjoyed the flavour of xylitol gum, which resulted in acceptance of and good cooperation with the programme. The use of placebo gum might not be suitable in schools for the disabled, as it has no flavour and thus may contribute to noncompliance.

The advantages of this study were: first, the study directly compared the intervention and control groups using a randomised controlled design; second, the study was conducted among a high caries-risk group; third, it was conducted in a real-life setting with simultaneous assessment of feasibility, making its results generalisable; third, we used the ICDAS method, which is effective in assessing the early stages of carious lesions.¹⁷ Lastly, we estimated the incidence rates of caries onsets by incorporating the time at risk and surface-specific information. This method is particularly appropriate for the analysis of mixed dentition, as it takes into account the changes in number of tooth surfaces at risk over time due to eruptions or exfoliations. We also employed the GEE statistical method to account for correlated data, leading to increased efficiency of statistical analysis.

This study had some limitations. First, the participants were not blinded to the intervention. As a result, students receiving chewing gum may have been more motivated to maintain better oral hygiene than those who did not, and that may have contributed to better oral health outcomes in the intervention group. The potential for this limitation affecting the results could have been minimised either by using a placebo in the control group, or motivating all the participants to maintain good oral hygiene. We did not use a placebo but had oral health education sessions for participants in both the intervention and control groups. Second, the intervention period included school vacations (3 months in total), during which time the participants went home, and did not receive any intervention. This aspect of the design would make the intervention less effective. As the vacation period was the same for the intervention and control groups, its effect would likely be to attenuate the study effects. Third, the relatively short follow-up duration of 1 year may not have been sufficient to observe an effect in caries reduction, even though it is considered adequate for detecting caries demineralisation and remineralisation.⁵ Fourth, there could be misclassification of the outcome because of examiner error; however, its effect on the study results was likely minimal because intra- and inter-examiner reliability of the measurements was good ($\kappa = 0.75$ to 0.76), and the examiners were blinded to the intervention

status of the participants. At the 12-month follow-up, there was a higher attrition rate in the intervention group than in the control group. But since the reasons for attrition (moved to other school or dropped out of school) were not related to the study intervention, the selective attrition was unlikely to introduce bias.

CONCLUSION

Within the limitations of this study, the results suggest that a school-based xylitol chewing gum programme reduces the development of caries and promotes remineralisation in primary dentition, as well as improves the oral hygiene in children with disabilities who are at high risk for developing caries. Further studies with longer follow-up periods and larger sample sizes are warranted to determine the long-term effects of xylitol gum on caries prevention in similar populations.

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