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RS Keukenmeester
DE Slot
NAM Rosema
C Van Loveren
GA Van der Weijden

Effects of sugar-free chewing gum sweetened with xylitol or maltitol on the development of gingivitis and plaque: *a randomized clinical trial*

Authors' affiliations:
RS Keukenmeester, DE Slot, NAM Rosema and GA Van der Weijden, Department of Periodontology, Academic Centre for Dentistry Amsterdam (ACTA), University of Amsterdam and VU University, Amsterdam, the Netherlands
C Van Loveren, Department of Preventive Dentistry, Academic Centre for Dentistry Amsterdam (ACTA), University of Amsterdam and VU University, Amsterdam, the Netherlands

Correspondence to:
Dagmar E. Slot
Department of Periodontology Academic Centre for Dentistry Amsterdam (ACTA)
University of Amsterdam and VU University Amsterdam
Gustav Mahlerlaan 3004
1081 LA Amsterdam the Netherlands
Tel.: +31205980179/307
E-mail: d.slot@acta.nl

Abstract: *Objective:* The objective of this study was to test the effect of sugar-free chewing gum sweetened with xylitol or maltitol compared to the use of a gum base or no gum on gingivitis and plaque scores under both brushing and non-brushing circumstances. *Methods:* The design of the study was a four-group, double-blinded, randomized controlled study with a 3-week duration. In each group, the participants did not brush the teeth in the lower jaw designated to develop experimental gingivitis, while maintaining normal oral hygiene procedures in the upper jaw. After professional dental prophylaxis, the participants were allocated into one of four groups (xylitol, maltitol, gum base or no gum). Chewing gum was used five times a day for 10 min. *Results:* 220 participants completed the study and provided evaluable data. The increase in bleeding on marginal probing (BOMP) and plaque scores (PS) in the non-brushed (lower) jaw with experimental gingivitis was significant in all groups ($P < 0.001$). As compared to the gum base, the increase in BOMP in the xylitol and maltitol group was significantly lower. In the brushed upper jaw, no significant changes for BOMP were observed from the baseline to the end point of the study, and there were no significant differences in BOMP and PS between the groups. *Conclusion:* In circumstances where regular brushing is performed, no effect of chewing gum was observed on bleeding and plaque scores. In the absence of brushing, chewing xylitol or maltitol gum provided a significant inhibitory effect on gingivitis scores compared to chewing gum base. The difference when compared to the group not using gum was not significant.

Key words: chewing gum; gingivitis; maltitol; plaque; randomized clinical trial; xylitol

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Introduction

Chewing gum consists of a gum base, sweetener, flavouring and an aromatic agent. By the 1900s, chewing gum was manufactured in many different shapes and sizes (long pencil-shaped sticks, ball form, flat sticks and blocks) and flavours (peppermint, fruit and spearmint) (1).

Historically, commercially available chewing gum was sweetened with sugar (sucrose), and its use could contribute to dental caries (2). Sugarless or sugar-free gums first entered the market in the early 1950s. Today, synthetic materials have replaced natural gum ingredients to provide a chewing gum with better quality, texture and taste. According to the International Chewing Gum Association, chewing gum is now one of the

most popular forms of confectionery worldwide. Currently, most chewing gums sold in Western countries are sweetened with sugar substitutes (3). The most common polyols in sugar-free chewing gum are xylitol, sorbitol, mannitol and maltitol. Evidence suggests that sugar-free chewing gum used immediately after meals has a caries-reducing effect (4), and there is consistent evidence to support the use of sugar-free chewing gum as part of normal oral hygiene to prevent dental caries (5). The observed caries reduction can be ascribed to salivary stimulation throughout the chewing process, the lack of sucrose and the inability of bacteria to metabolize polyols into acids (4).

In a recent systematic review regarding the efficacy of sugar-free chewing gum for plaque and gingivitis (6), it was concluded that the use of sugar-free chewing gum as an adjunct to tooth brushing provides a small but significant reduction in plaque scores. Based on the collective evidence, no significant effect on gingivitis scores could be established. In the absence of brushing, no scientific evidence for a beneficial effect of sugar-free chewing gum was demonstrated. However, the outcome of the systematic review and quality assessment indicated that properly designed studies with adequate numbers of subjects (sample size) and power are needed to thoroughly determine the effects on both plaque and gingivitis scores. The experimental gingivitis model (7) has been suggested as a suitable short-term model for evaluating the effect of antigingivitis interventions (8). Using this design as a half mouth model provides the opportunity to assess the effect of the intervention during a brushing and non-brushing period at the same time. The objective of this study was to test the effect of chewing gum sweetened with xylitol or maltitol compared to the use of gum base only or no gum as a negative control on the development of plaque and gingivitis scores. This 21-day study had a split mouth brushing and non-brushing design and used adequately powered group sizes.

Material and methods

Ethics approval

The study was conducted in accordance with ethical principles that have their origin in the Declaration of Helsinki and approximate Good Clinical Practice guidelines. Medical ethics approval was obtained prior to the start of the study (MEC NL35214.029.11). The study took place at the Department of Periodontology of the Academic Center for Dentistry Amsterdam (ACTA), The Netherlands, from February 2011–June 2011. Participants were informed about the study in a recruitment letter. After the participants were selected, the purpose, procedures and duration of the study were explained. Participants eligible and willing to participate in this study signed an informed consent form.

Study population

For this study, 303 non-dental students were recruited through e-mails and flyers advertising the study. The participants were screened based on the following eligibility criteria:

Inclusion criteria

1 ≥18 years old, non-smokers
2 Systemically healthy as assessed by a medical questionnaire
3 No use of antibiotics or participation in a clinical study in the previous 30 days.
4 No allergy to any of the ingredients of the study products (xylitol or maltitol).
5 At least five evaluable teeth in each quadrant, without overt caries.
6 No orthodontic banding or removable prosthesis.
7 Moderate gingivitis [30–60% bleeding on marginal probing (BOMP)] (9–11), no current periodontitis (no sites of probing pocket depth ≥ 5 mm or attachment loss of ≥ 2 mm, apart from gingival recession).

Participants were excluded if they had serious medical problems or if they were using medication that could interfere with the outcome of the study variables. In addition, those participants who were already consuming more than three pieces of sugar-free chewing gum a day were excluded. Participants were asked to abstain from visiting a dental professional during the 21-day study period. The elected participants agreed not to consume any other chewing gums than those supplied for the study.

Sample size

Sample size calculations were performed using the PS Power and Sample Size Program (12). A study was planned with independent control and experimental subjects. In previous studies, the response within each subject group was normally distributed with a pooled standard deviation of 0.22 for BOMP (13, 14). If the true difference in the experimental and control means was set 'a priori' at 0.1, this study needed 51 subjects in each group. This number of subjects allows the rejection of the null hypothesis with a probability of 0.8 (power) that the population means of the experimental and control groups are equal. The type I error probability associated with this test of this null hypothesis was set at 0.05. To ensure proper power regardless of circumstance and compensate for potential drop-outs, the authors decided to include 55 participants in each of the four groups.

Design and procedures

The experimental design was a four-group, double-blinded, parallel randomized controlled clinical trial (RCT).

After screening 2 weeks prior to the start of the experiment, the participants were asked to refrain from using chewing gum until their next visit. At the baseline visit, the clinical variables were measured. All clinical assessments were performed at six sites per tooth under the same conditions and were performed by the same examiners (SCS and GVA), with each responsible for a index. As the primary outcome variable, the development of gingivitis was scored (scale 0–2) using BOMP by SCS. Plaque was scored (scale 0–5) by GVA as a

secondary outcome using the method recommended by Turesky *et al*. (15) with the modification of the Quigley and Hein (16) plaque index as described in detail by Paraskevas *et al*. (17). To start the experiment with equally clean teeth, after scoring, professional prophylaxis was performed by a dental hygienist as described in detail by Slot *et al*. (18). At the end of the baseline visit, the participants were allocated into four groups (Table 1). They were instructed in how to use the chewing gum, and they started using their first assigned piece of gum immediately after this visit. Participants were instructed to use their assigned gums five times daily for the duration of 10 min. The participants received a timer to register their chewing time. To check compliance, the participants kept a diary to record the time at which they chewed the gums.

Test gum pieces had a weight of 1.4 g each and gum base pieces had a weight of 1.0 g. As test gum pieces consist of a coating and a blended core containing gum base, subjects had to take two pieces of test gum containing approximately 0.5 g of gum base in order to end up with approximately 1.0 g of pure gum base after chewing, similar to the weight of a gum base piece as used by the control group.

From the baseline visit on, the participants were instructed not to brush the lower jaw for 3 weeks (experimental gingivitis) while maintaining their normal oral hygiene procedures in the upper jaw. They were provided a tube of toothpaste without any particular antiplaque or antigingivitis agents (Prodent Classic, Sara Lee International, Utrecht, the Netherlands). During the study period, the participants were not allowed to use any mouth rinses or other dental cleaning devices. The evening before the visits was the last time they brushed. The participants were not allowed to chew, eat or drink within 2 h before the visits, except for plain water. The last piece of gum was used the evening before the evaluation visit, after 21 days. At this appointment, the endpoint clinical assessments were conducted. Subsequently, the participants restarted their normal oral hygiene measures.

Randomization, blinding and treatment allocation

The participants were randomly assigned using a computerized block randomization table and were not informed about the group allocation. The examiners were blinded with respect to treatment allocation. Allocation concealment was performed by the study coordinator Nienke Hennequin-Hoenderdos (NHH). The participants were asked not to discuss matters related to product use with the examiners. The codes were disclosed after statistical analysis of the data was concluded. The products, which were prepared by Roquette Freres with components that are normally used in chewing gum, were identically packed in sufficient portions needed by single participants for the 21-day study duration. The gum base was unsweetened, but with a light mint flavour similar to the intervention gums. Though, it were uncoated blocks (similar as the commercially available flat stick gums).

Data analyses

Data means (SD) were calculated first by participant and subsequently by group and then analysed. The statistical analysis (intention to treat) was performed by NAMR who was blinded to the group allocation. The overall treatment effect on bleeding scores was analysed using a generalized linear model, with 'base' as the covariate and 'end' as the dependent variable.

Analyses comparing differences between the intervention and control groups per session, being baseline and end, were performed using the (nonparametric) Kruskal–Wallis test. When significant, the search for the origin of this significance was further performed using Mann–Whitney tests. Within-group changes between sessions were tested using Wilcoxon tests. Values of $P < 0.05$ were defined as statistically significant.

Results

In total, 303 participants were assessed for eligibility, of which 223 participants were found to be suitable and were subsequently assigned to one of the four groups (Fig. 1).

Table 1. **Description of the intervention groups (n = 2) and control groups (n = 2) and their regimen. No brushing in the lower jaw was allowed, but the subjects maintained normal oral hygiene in the upper jaw**

Group	Product and brand	Regimen
Intervention 1 (xylitol)	Chewing gum containing xylitol Xylisorb ®, ROQUETTE, Lestrem, France	Chew two pieces of chewing gum five times a day for 10 min after breakfast, lunch, snack in the afternoon or in the middle of the afternoon, after dinner and before sleeping.*
Intervention 2 (maltitol)	Chewing gum containing maltitol SweetPearl®, ROQUETTE, Lestrem, France	Chew two pieces of chewing gum five times a day for 10 min after breakfast, lunch, snack in the afternoon or in the middle of the afternoon, after dinner and before sleeping.*
Positive control (gum base)	Gum base (combination of food-grade polymers, waxes and softeners that gives the 'chew' texture)	Chew one piece of chewing gum five times a day for 10 min after breakfast, lunch, snack in the afternoon or in the middle of the afternoon, after dinner and before sleeping.
Negative control (no gum)	No gum	No gum use.

*The amount of gum base obtained after chewing two pieces of sugar-free gum is comparable to the amount in one piece in the gum base group.

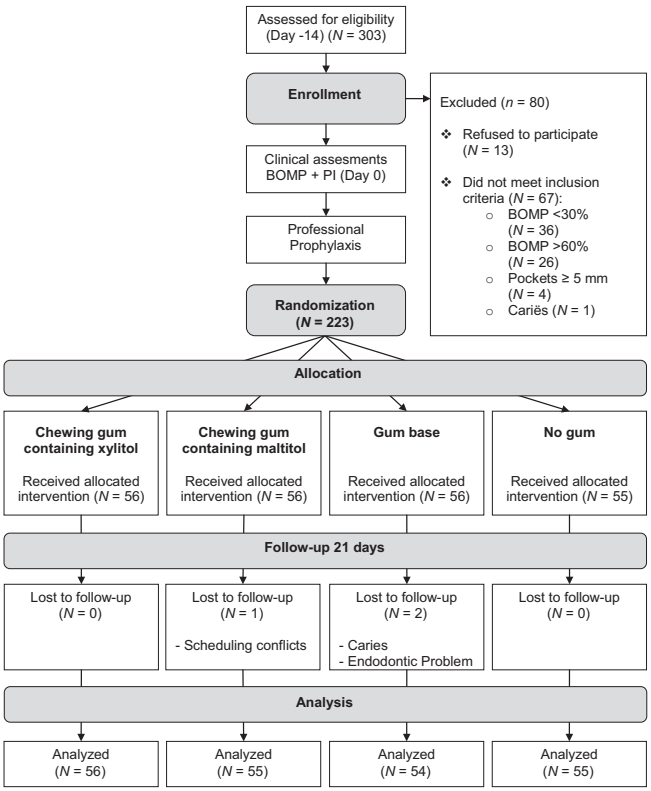

Fig. 1. Flow chart of participant enrollment.

At the end of the study, 220 participants completed the protocol and provided evaluable data. The groups were comparable in age (± 21.9 years of age) and gender ratio (Table 2). No adverse events were reported by any of the participants during this study. In addition, the weight of the used chewing gum per group is presented in Table 2. In the xylitol and maltitol groups, on average 281 g was used by each participant. Each xylitol and maltitol stick of gum weighed 1.4 g, which implies that on average each participant used 201 pieces in 3 weeks. This deviated only slightly from the requested use of 210 pieces over the 3 weeks. In the gum base group, each participant used on average 102 g of gum base during the study period. Each gum base piece weighed 1.0 g, which also minimally deviated from the requested 105 pieces over the 3 weeks of use.

At the screening appointment (day-14), the mean bleeding scores between the groups did not significantly differ, with an overall mean (SD) BOMP of 0.82 (0.21) (n = 220).

The baseline and end scores for BOMP are presented in Table 3. In the brushed (upper) jaw, the mean BOMP at baseline and end assessments did not significantly differ between the four groups. For the non-brushed (lower) jaw with experimental gingivitis, no significant difference (P = 0.068) was found between the groups at baseline. The increase in BOMP in the (lower) jaw with experimental gingivitis was significant in all groups when comparing the baseline to 21 days (P < 0.001). The increase in BOMP in both sugar-free chewing gum groups was 0.26, which was significantly less than the increment in the gum base group with an increase of 0.48 (P < 0.005). However, the increase in the no gum group being 0.36 was not significantly different from the xylitol and maltitol groups.

The plaque scores (PS) results are also presented in Table 3. At baseline, the plaque scores in the brushed (upper) and experimental gingivitis (lower) jaw were not significantly different between the groups. At the baseline assessment, all visible plaque was removed following professional prophylaxis. After 21 days, there was no significant difference in PS observed between the groups, and the PS had increased in the non-brushed lower jaw and decreased in the brushed upper jaw.

Discussion

Model

The experimental design of the present study was a four-group, double-blinded, parallel randomized controlled clinical trial. The parallel-arm design is the simplest type of randomized trial. When the treatment assignment for each patient is performed independently of the assignment of all other patients as in this study, this design is sometimes called the completely randomized design to denote that there are no constraints on the random assignments and that one patient's assignment does not influence the assignment of another patient (19).

The experimental gingivitis study design is a frequently used clinical model for the evaluation of the effects of antimicrobial agents on the development of plaque and gingivitis (8). An advantage of this model is that the effect of an intervention on gingivitis is measurable in a relatively short time. Recognizing the observation reported by Löe *et al.* (7) that the gingivitis

Table 2. **Participant demographics and chewing gum amount used, presented by group**

	Xylitol	Maltitol	Gum base	No gum
N	56	55	54	55
♀ Female	41	40	39	38
♂ Male	15	15	15	17
Mean (SD) age in years	21.6 (2.7)	21.8 (2.8)	21.9 (2.3)	22.2 (2.8)
Range in years	18–29	18–30	18–29	18–30
Used gum mean (SD) grams	281 (28)*	281 (20)	102 (11)*	NA
Range in grams	158–332	238–320	71–124	NA

*Based on individuals who returned their gum: group 1, N = 54, group 3, N = 52.

Table 3. **Mean (SD) plaque scores according to the Quigley and Hein plaque index (17) and bleeding on marginal probing (BOMP) scores (9–11) for all groups at both assessments**

		BOMP scores				Plaque scores		
	Group (N = 220)	Baseline (Day 0)	End (Day 21)	Difference	P-value†	Baseline (Day 0)	Baseline after prophylaxis (Day 0)	End (Day 21)
Brushed upper jaw	Xylitol (N = 56)	0.84 (0.35)	0.70 (0.31)	−0.14 (0.38)	0.380	2.09 (0.36)	0**	1.93 (0.43)‡
	Maltitol (N = 55)	0.77 (0.26)	0.73 (0.26)	−0.04 (0.26)		2.18 (0.37)		1.95 (0.38)‡
	Gum base (N = 54)	0.77 (0.30)	0.73 (0.32)	−0.04 (0.26)		2.15 (0.40)		2.01 (0.43)§
	No gum (N = 55)	0.81 (0.27)	0.69 (0.28)	−0.12 (0.27)		2.05 (0.41)		1.97 (0.48)
	P-value*	0.626	0.543	0.121		0.354		0.761
Non-brushed experimental gingivitis lower jaw	Xylitol (N = 56)	1.15 (0.38)	1.41 (0.36)‡	+0.26 (0.35)	0.072	2.13 (0.34)	0**	2.70 (0.32)‡
	Maltitol (N = 55)	1.08 (0.38)	1.34 (0.33)‡	+0.26 (0.35)		2.15 (0.35)		2.65 (0.39)‡
	Gum base (N = 54)	0.97 (0.34)	1.45 (0.35)‡	+0.48 (0.38)¶		2.15 (0.33)		2.80 (0.33)‡
	No gum (N = 55)	1.02 (0.27)	1.38 (0.30)‡	+0.36 (0.41)		2.10 (0.38)		2.75 (0.33)‡
	P-value*	0.068	0.288	0.008		0.893		0.131

*Kruskal–Wallis, statistical evaluation of differences among groups.
†Generalized linear model, using 'base' as covariable and 'end' as dependent variable.
‡Significantly different compared to baseline, $P < 0.001$ *(Wilcoxon).*
§Significantly different compared to baseline, $P < 0.010$ *(Wilcoxon).*
¶Significantly different compared to groups 1 and 2, $P \leq 0.005$ *(Mann–Whitney).*
**After the baseline assessment, professional prophylaxis was performed to remove all visible plaque to start the study with subjects having equally clean teeth.

induction period varied considerably among the participants in their original study (9–21 days), it was suggested that the period of no mechanical tooth cleaning should be extended to 14–21 days (8). In the present study, the longest advised duration of 21 days was chosen to monitor changes in plaque and bleeding scores. Because the experimental gingivitis model serves as a screening tool (8), the need for a long-term study remains, in accordance with the American Dental Association (ADA) guideline for adjunctive dental therapies for the reduction of plaque and gingivitis (20).

Bleeding scores

The present study tested the effect of chewing gum sweetened with xylitol or maltitol compared to the use of gum base or no use of gum on gingivitis and plaque scores in a 21-day parallel study design. The results of this study add to the existing data on sugar-free chewing gum regarding the parameters of gingival inflammation and plaque (6). The results demonstrated no differences in plaque scores when using chewing gum compared to not chewing gum.

Both sugar-free gums (xylitol and maltitol) produced a positive significant effect compared to the gum base in terms of the BOMP scores in the (lower) jaw with experimental gingivitis. The reduced increase in bleeding on probing in the xylitol and maltitol group could not be linked to plaque removal because in both jaws, no significant effect on plaque was found. These results are comparable to the data presented in a systematic review by Keukenmeester *et al.* (6), where it was observed that the use of sugar-free chewing gum in the absence of brushing provided no beneficial effect on plaque scores. An experimental gingivitis study design was not included in the systematic review. Therefore, inferences with regard to BOMP data could not be made. The plaque data for the brushed jaw conflict with observations in the previous systematic review. The reason for this discrepancy cannot be explained from the present results. The number of included subjects in the present study is assumed to have provided sufficient power.

Power

The estimation of the required sample size is essential for the planning of an RCT. Trials that are too small to observe clinically important differences may be scientifically useless and hence unethical in their use of subjects and other resources (21). Selecting the sample size for a study inevitably requires a compromise that balances the needs for power, economy and time lines (22). The intent of the present investigation was to design a study that would provide sufficient power through the number of panellists involved. Based on the 'a priori' power analysis, 51 subjects needed to be included. At the end of the study, there were at least 54 participants in each group. As analysed, no difference was found at any point between the maltitol and xylitol chewing gum groups. The increase in BOMP in the gum base group in the lower jaw with experimental gingivitis was statistically significantly different from the increases in the two sugar-free chewing gum groups, whereas there was no significant difference with respect to the no gum group. This finding may be related to the numerical difference (although non-significant) in BOMP that was already present at baseline. Lower scores at baseline allow a numerically greater increase after 21 days, which could have contributed to the statistical significance.

Regimen

The results of this study indicate that the use of two pieces of chewing gum sweetened with xylitol or maltitol has an inhibitory effect on gingivitis development. In a previous systematic review, Keukenmeester *et al.* (6) found that chewing of sugar-free gum five times daily for 10 min also reduced the plaque score as an adjunct to tooth brushing as compared to the non-use of gum. More studies are needed to determine the optimal chewing regimen.

The intervention regimen of the present study was to chew one or two pieces of chewing gum for 10 min with a frequency of five times daily. The compliance with these instructions was good. The participants in the xylitol and maltitol group used an average of 201 pieces of gum during the 21-day study period rather than the 210 requested by study regimen. The participants in the gum base group used 102 pieces of chewing gum in 3 weeks. The requested chewing regimen was 105 pieces. Compliance therefore only slightly deviated from the required and requested use regimen.

One could argue whether the outcome differences between the gum base group and the two test groups might have been affected by the initial differences in gum mass taken per chewing moment as the gum base group had to take approximately half the weight of gum.

Rosenhek *et al.* (23) showed that gum chewing resulted in rapid loss of weight for the sweetened gum group. Yet after 5 min of chewing, approximately only one-third of the initial gum weight remained. Comparing this finding to the present study, it seems plausible that all gum chewing groups had approximately a similar amount of gum base to chew after 5 min. As the test gum pellets contained one-third of gum base, it is unlikely that the observed differences are related to the differences in weight. Differences in gum weight may have affected salivary flow rate. Rosenhek *et al.* (23), however, also showed that between five groups chewing different gum masses varying from one gram to nine grams, the difference in flow rate did not significantly differ. Moreover, no significant differences were observed between flow rates comparing gum base to sweetened gum.

Limitations

- The two types of intervention gums were identical in form, appearance, size and taste. The gum base was uncoated. This may have influenced the blinding of the participants.
- As an inclusion criterion, 30–60% BOMP was used. The effect on gingivally healthy patients cannot be established with this study.

Conclusion

In circumstances where regular brushing is performed, no effect of chewing gum was observed on plaque and bleeding scores. In the absence of brushing, chewing xylitol or maltitol gum provided a significant inhibitory effect on gingivitis scores compared to chewing gum base. The difference when compared to the group not using gum was not significant.

Clinical relevance

Scientific rationale for the study

The conclusion of the systematic review on sugar-free chewing gum Keukenmeester *et al.* (6) and quality assessment indicated that properly designed studies with adequate numbers of subjects (sample size) and power are needed to thoroughly determine the effects on both gingivitis and plaque scores.

Principal findings

In circumstances where regular brushing is performed no effect of chewing gum was observed on bleeding and plaque scores. In absence of brushing, the groups chewing xylitol or maltitol gum provided a significant inhibitory effect on gingivitis scores compared to the gum base group, no significant effect was found when compared to the group using no gum.

Practical implications

The effect in subjects with a healthy gingiva could not be established with this study. This study indicated that there may be some effect of sugar-free gum in case of experimentally induced gingivitis.

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Conflict of interest

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