Original Article

Comparing the efficacy of xylitol-containing and conventional chewing gums in reducing salivary counts of *Streptococcus mutans:* An *in vivo* study

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Abstract

Objective: Dental caries is among the most common chronic diseases in humans. *Streptococcus mutans* is generally responsible for most cases of dental caries. The present study sought to compare the effects of xylitol-containing and conventional chewing gums on salivary levels of *S. mutans*. **Materials and Methods:** This study adopted a crossover design. Two type of chewing gums (one containing 70% xylitol and approved by the Iranian Dental Association, and another containing sucrose) were purchased. The participants were 32 individuals aged 18–35 years whose oral hygiene was categorized as moderate or poor based on a caries risk assessment table. Salivary levels of *S. mutans* were measured at baseline, after the first and second phases of chewing gums, and after the washout period. The measurements were performed on blood agar and mitis salivarius-bacitracin agar (MSBA). Pairwise comparisons were then used to analyze the collected data. **Results:** Salivary levels of *S. mutans* in both groups were significantly higher during the two stages of chewing gum than in the washout period or baseline. Moreover, comparisons between the two types of gums suggested that chewing xylitol-containing gums led to greater reductions in *S. mutans* counts. This effect was more apparent in subjects with poor oral hygiene than in those with moderate oral hygiene. **Conclusions:** Xylitol-containing chewing gums are more effective than conventional gums in reducing salivary levels of *S. mutans* in individuals with poor–moderate oral hygiene.

Key words: *Chewing gum, dental caries, oral hygiene, Streptococcus mutans, sucrose, xylitol*

INTRODUCTION

Dental caries is an infectious disease that destroys tooth enamel.[1,2] Dental caries is a multifactorial disease.[3] It is the cumulative result of consecutive cycles of demineralization and remineralization at the interface between the biofilm and the tooth surface.[4] Upon this acid challenge, the hydroxyapatite crystals are dissolved from the subsurface. A number of etiologic factors, e.g., the presence of cariogenic microorganisms, regular consumption of refined carbohydrates, and poor

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oral hygiene, contribute to the development of dental caries.[5-7]

Dental caries occurs as a result of imbalance between the remineralization and demineralization processes as the interface between the enamel surface and dental biofilm.[8-10]

Dental caries should be prevented in children.[11,12] Dental caries is preventable in its early stages.[13] Some favorable properties of sugar (sucrose) are its availability and, most importantly, its cost and public perception, which made it(sucrose) acceptable by the public. Replacing sugar (sucrose) with a suitable substitute to combat dental caries is an option that is wide open. Recent, encouraging studies suggest antimicrobial properties as well as lower cariogenicity of some sugar substitutes such as xylitol. In the beverage field, it is clear that artificial sweeteners formed new products that were additional to the sugar-sweetened products and not competitive with them. Saccharin can substitute for the taste of sugar; lactose or sorbitol for the weight or bulk of sugar; xylitol for both taste and bulk. Similarly, the point remains that the *per capita* consumption of sugar has been stable for decades, in spite of the use of saccharin, cyclamate, and now aspartame.[14] Xylitol is a polyalcohol known to be capable of reducing dental caries by 50%.[15,16] As xylitol is almost nonfermentable by plaque bacteria, it can inhibit the proliferation, growth, and accumulation of oral bacteria and reduce dental plaque adhesion.[17] Long-term consumption of xylitol has been associated with reduced growth and activity of *Streptococcus mutans*[18] and lower numbers of these microorganisms in both dental plaque and saliva.[19] These beneficial effects of xylitol render it a good option for the prevention of dental caries.

Numerous studies have evaluated the effects of xylitol on dental caries.[20-22] However, they have reported contradictory results. While some researchers have confirmed the efficacy of this substance in preventing caries,[23-26] others have rejected such benefits.[19,27] Wennerholm *et al*.,[28] Isotupa *et al*.,[29] and Twetman[30] compared the effects of various xylitol and sorbitol concentrations on *S. mutans* counts in normal individuals, subjects with fixed braces, and 2–4-year-old children, respectively. We compared the effects of xylitol and glucose-containing chewing gums among adults with poor–moderate oral hygiene, and their findings were similar to ours.

Considering the significance of dental caries prevention and the antibacterial effects of xylitol, the present study sought to compare the effects of chewing xylitol-containing gums and conventional gums on *S. mutans* in the saliva of subjects with moderate and poor oral hygiene.

MATERIALS AND METHODS

In this experimental research, 32 individuals (16 dental students and 16 patients visiting dental clinics) who were aged 18–35 years were recruited. The number of participants was selected based on recent studies.[31-33] The participants' oral hygiene was categorized as moderate or poor based on the caries risk assessment table.[12] Individuals were not included if they had any systemic diseases, history of head and neck radiography, or sensitivity to xylitol. Persons receiving any type of antibiotics were not included either. The study protocol was approved by the Ethics Committee of Shahed University, and the participants signed informed consent forms.

Xylitol chewing gums (Orion Food Vina Co. Ltd, Lai Thieu Townlet, Thuan An District, Vietnam) containing 70% xylitol, isomalt, gum arabic, and calcium lactate were purchased from a gum wholesaler in Tehran, Iran [Figure 1]. The gums were 1.5 g each and were approved by the Iranian Dental Association. PK® gums (1.6 g, Wrigley, Vadapalani, Chennai, India) containing sucrose, glucose, gum, mint extract, pigments, and titanium dioxide were also purchased. The chewing gums were packed in similar 30-gum packages and distributed among the participants. All subjects were instructed to take three gums a day after main meals (breakfast, lunch, and dinner) and chew each gum for 15 min.

A crossover design was used in the current research. The two groups with moderate and poor oral hygiene

Figure 1: Xylitol chewing gums (Orion Food Vina Co. Ltd, Lai Thieu Townlet, Thuan An District , Vietnam Vietnam)

(N = 16) were each divided into two groups of eight to receive either PK® gums or xylitol gums during the first 10-day period. After a 10-day washout period, each group received the other type of gum for another 10 days. Saliva samples were collected and tested before and after each stage. It should be noted that 2 participants were excluded from the study due to the administration of antibiotics during the second stage.

The samples were cultured using blood agar powders (Ceneda Co., Germany). At each stage, the culture medium was prepared by mixing 40 gr blood agar powder with 1 L distilled water. The mixture was then boiled and the resultant clear solution was autoclaved at a temperature of 121°C and a pressure of 15 atm for 15 min. After cooling the sterilized solution down to 45–50°C, 50 mL defibrinated sheep blood was added to the medium. The result was a blood agar culture medium containing 5% defibrinated sheep blood. The culture medium was finally transferred to 8-cm plates (Farazbin Co., Tehran , Iran) and the plates were maintained at 4°C until use.

Mitis Salivarius-Bacitracin Agar (MSBA), (Ceneda Co., Germany) was applied to differentiate between colonies suspected to be *S. mutans* and other colonies formed on blood agar plates. In order to prepare MSBA plates, a mixture of 25 medium powder and 250 mL sterile distilled water was boiled to obtain a clear solution. At the same time, 0.25 g potassium tellurite (measured by a sensitive laboratory scale) was mixed with 25 mL sterile distilled water and the mixture was autoclaved (at 121°C and 15 atm) with the medium solution for 15 min. After sterilization, the containers holding the medium and potassium tellurite were cooled down to 45–50°C. The potassium tellurite solution and 0.25 g bacitracin were then added to the medium solution to produce MSBA. The resultant medium was finally moved to 8-cm plates (Farazbin Co., Iran) and kept at 4°C until required for the experiments.

Sampling and microbial culturing were performed at baseline, after the first and second 10-day periods of gum consumption, and after the washout period. At the time of sampling, the participants were asked rinse their mouths with water immediately after getting up in the morning (before eating breakfast or brushing their teeth). Afterward, 0.5 mL samples of unstimulated saliva were collected in sterile capped tubes (Greiner Bio-One, Frickenhausen, Germany) and immediately transferred to the microbiology laboratory of Imam Ali Clinic (Tehran, Iran).

In the laboratory, an inoculating loop was flamed and sterilized. Then, saliva samples were transferred to the blood agar medium using the loop [dilution factor: 10^2 colony-forming units (cfu)/mL]. After placing the plates in a candle jar (containing 5% carbon dioxide), the media were incubated at 37°C. After 24 h, colonies suspected to be *S. mutans* were placed on Petri dishes and Gram staining was performed to confirm the presence of *S. mutans*. A sterile loop was used to move the grown colonies of *Streptococcus* from the blood agar medium to the MSBA. This process was performed near a flame. The MSBA was then placed in a candle jar and incubated at 37°C for 24 h. Colonies of *S. mutans* (dark blue colonies 2–3 mm in size) were then observed on the culture medium. When the presence of *S. mutans* was confirmed, the number of *S. mutans* colonies formed on the blood agar medium was counted. The number of CFUs was identified by morphology, counted in a stereomicroscope, and expressed as CFU mL^{-1}. Ultimately, the collected data were analyzed with paired *t*-tests. All statistical analyses were conducted using SPSS for Windows (SPSS Inc., Chicago, IL, USA).

RESULTS

A total of 32 individuals aged 18–35 years were allocated to two groups of 16 based on their oral hygiene status (poor or moderate). The study consisted of two stages. Saliva samples were collected and tested before and after each stage. In the group with moderate oral hygiene, the colony count at baseline ranged between 4×10^2 CFU/mL and 9×10^2 CFU/mL. These values were reduced to 2–6 $\times$ 10^2 CFU/mL after the first stage of the study. Further reductions in the mean number of colonies were observed after the second stage (7×10^2 CFU/mL at baseline versus 4×10^2 CFU/mL after the second stage).

In the group with poor oral hygiene, colony counts at baseline (22–50 $\times$ 10^2 CFU/mL) were reduced after the first stage of the study (12–38 $\times$ 10^2 CFU/mL). The mean value measured after the second stage was also lower than the baseline value (19×10^2 CFU/mL vs 27×10^2 CFU/mL).

Overall, 16 subjects with poor and moderate oral hygiene used xylitol gums. The mean baseline colony count in this group (19×10^2 CFU/mL) declined after xylitol chewing gums three times a day for 10 days (11×10^2 CFU/mL). The mean number of colonies was also considerably lower after the second 10 days of xylitol chewing gums than after the washout period (10×10^2 CFU/mL vs 17×10^2 CFU/mL).

The other 16 people with poor and moderate oral hygiene used PK® gums. The mean colony count in this group was 18 × 10^2 CFU/mL, which was lowered to 15 × 10^2 CFU/mL following 10 days of chewing PK® gums three times a day. The value after the washout period (16 × 10^2 CFU/mL) was also reduced to 13 × 10^2 CFU/mL after another 10 days of PK® chewing gums. As the mean reduction was higher in the xylitol group than in the PK® group (7.5 × 10^2 CFU/mL vs 3 × 10^2 CFU/mL), the xylitol-containing gum was more effective.

In the group with moderate oral hygiene, paired *t*-test revealed a significant difference in the mean count of *S. mutans* colonies before and after xylitol gum consumption ($P = 0.000002$). The same test also suggested a significant difference between the numbers of *S. mutans* colonies after the 10-day washout period and after the second 10 days of chewing gums ($P < 0.05$).

In the group with poor oral hygiene, significant differences were detected between the mean *S. mutans* colony counts before and after 10 days of xylitol chewing gums ($P < 0.01$) and before and after the second stage of chewing gums ($P < 0.05$).

Similarly, significant differences in the mean colony counts before and after the first stage of PK® gum consumption were confirmed in subjects with both poor and moderate oral hygiene ($P < 0.01$). Likewise, the mean colony counts before and after the first stage of PK® gum consumption were significantly different in participants with both poor and moderate oral hygiene ($P < 0.05$) [Table 1].

Table 1: *Streptococcus mutans* colony counts in different groups and at different time intervals

Stage	Oral hygiene status	Chewing gum	Before (CFU/mL)	After (CFU/mL)	Difference in means
First stage	Poor	Xylitol	30×10^2	19×10^2	11×10^2
		PK®	31×10^2	25×10^2	6×10^2
	Moderate	Xylitol	7×10^2	3×10^2	4×10^2
		PK®	6×10^2	4×10^2	2×10^2
Second stage	Poor	Xylitol	28×10^2	16×10^2	12×10^2
		PK®	29×10^2	23×10^2	6×10^2
	Moderate	Xylitol	7×10^2	3×10^2	4×10^2
		PK®	7×10^2	5×10^2	2×10^2

CFU=Colony-forming units

DISCUSSION

Xylitol, a nonfermentable polyol, is a natural sweetener that does not promote tooth decay.[34,35] It increases salivary flow, which in turn stimulates the remineralization process and inhibits bacterial growth and metabolism in dental plaques.[36,37] Despite these properties, the efficacy of xylitol as an anticaries agent is still under debate.[20,38]

The present study compared the effects of xylitol-containing and conventional chewing gums on salivary levels of *S. mutans*. Our results indicated the effectiveness of xylitol in inhibiting *S. mutans* growth among people with poor–moderate oral hygiene.

S. mutans is the most important microorganism involved in dental caries. The acid produced following the fermentation of sugar and sugar alcohols by *S. mutans* can destroy tooth enamel and result in dental caries. It, however, cannot ferment xylitol, which contains five carbon atoms. Furthermore, xylitol can inhibit the growth of *S. mutans* by creating an alkaline environment in the mouth. Xylitol is also able to form a complex with calcium. The formation of such complexes in the mouth will promote the remineralization of tooth enamels that have previously lost their minerals.[39,40]

Although Makinen *et al*. reported similar results,[41] our results are more reliable due to the use of a crossover design. Wennerholm *et al*.,[28] Isotupa *et al*.,[29] and Twetman and Stecksen-Blick[30] compared the effects of various xylitol and sorbitol concentrations on *S. mutans* counts in normal individuals, subjects with fixed braces, and 2–4-year-old children, respectively. While we compared the effects of xylitol and glucose-containing chewing gums among adults with poor–moderate oral hygiene, their findings were similar to ours.

In a randomized clinical trial, Ritter evaluated 21–80-year-old individuals in terms of occlusal and smooth surface caries over a 33-month period. The results confirmed the beneficial role of xylitol in preventing root caries in adults with active decay. We, however, adopted a crossover approach and recorded bacterial counts in two different stages. Despite differences in methodology, our study and that of Ritter's yielded similar results. Nevertheless, our findings might be more accurate because we calculated colony counts after the chewing of both types of gums.

In contrast to our findings, Duane followed preschool children for 9 months and 21 months and reported lozenges, xylitol/maltitol, and erythritol/maltitol to be ineffective in reducing dental caries.[42] This difference can be attributed to the type of intervention

and the age group of the participants (18–35 years in the present research). In addition, we used a crossover design to determine microbial counts after the chewing of gums.

The frequency of chewing gums, rather than the exact concentration of xylitol, seems to be the important determinant of reduction in salivary levels of *S. mutans* and tooth decay prevention. In fact, chewing gums should be used at least three times a day to reduce dental caries by 40–50%.[43] We followed the same procedure and observed reductions in salivary levels of *S. mutans*. Long-term application of xylitol is believed to inhibit the growth and activity of *S. mutans* and prevent dental caries.

In the current study, chewing gums (either xylitol or PK®) could more effectively decrease salivary levels of *S. mutans* in subjects with poor oral hygiene (without usual hygienic measures) than in those with moderate oral hygiene (with usual hygienic measures). In the absence of all usual hygienic measures in the group with poor oral hygiene, chewing gums could dramatically reduce *S. mutans* counts in their saliva. It is also noteworthy that in both groups, xylitol (which did not contain sucrose) was more effective than PK® (containing sucrose). This finding can be justified by the intrinsic capabilities of sugar substitutes to decrease salivary levels of *S. mutans* and control the acidity of saliva.

The present study adopted a crossover design. As all subjects were both cases and controls, our results regarding the effects of the intervention (xylitol or PK®) were more reliable than other, similar studies. To the best of our knowledge, no previous research has ever used this design. Moreover, previous research has generally used higher frequencies of chewing gums or longer periods of follow-up. Considering the significance of lowering salivary levels of *S. mutans* in individuals with poor oral hygiene, we compared the effects of xylitol-containing and conventional chewing gums in people with poor and moderate oral hygiene. We observed both types of gums, especially xylitol, to effectively reduce salivary levels of *S. mutans* in the two groups. This beneficial effect was more noticeable in participants with poor oral hygiene.

The major limitation of the present study was the lack of exact supervision in the appropriate use of chewing gums.

Considering the effects of xylitol in decreasing dental plaques, further studies are recommended to assess the effects of this polyol on periodontal diseases. Researchers are also suggested to evaluate the effects of xylitol-containing mouthwashes, toothpastes, and candies on oral bacteria and periodontal diseases.

CONCLUSION

Dental caries is a multifactorial, diet-associated infectious disease. Based on the results of this study, sucrose-free (xylitol) chewing gums when chewed 3 times a day for 15 min over a period of 10 days were more effective than sucrose-containing chewing gums in reducing salivary levels of *S. mutans*, especially in subjects with poor oral hygiene. Using these chewing gums can thus be recommended as an effective substitute for mechanical methods in individuals with poor oral hygiene or mental and/or physical disabilities.

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Conflicts of interest

There are no conflicts of interest.

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