International Journal of Dental Hygiene

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International Journal of Dental Hygiene

ORIGINAL ARTICLE

Effectiveness of Chewing Gum After Water Rinsing in Removing Remnants of Sticky Cookies From Posterior Teeth—A Prospective Interventional Study

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Received: 7 November 2022 | **Revised:** 14 May 2024 | **Accepted:** 13 October 2024

Funding: The authors received no specific funding for this work.

Keywords: carbohydrates | caries | chewing gum | fermented foods | fissure sealant | prevention | retention of food | water rinsing

ABSTRACT

Objective: To evaluate the effectiveness of chewing sugarless gum (SG) after water-rinsing in removing retained Oreo chocolate cookies (CC) from occlusal surfaces of teeth with and without fissure-sealant (FS).

Methods: A prospective study was performed on healthy children receiving prophylaxis at the paediatric-dentistry department. Immediately afterward, they chewed two CC. The occlusal surfaces of their posterior teeth were photographed 3 times: after 10 min, after 1 min of water-rinsing and after 4 min of chewing SG. An independent dentist screened all photos for the presence (partial or complete) or the absence of retained CC.

Results: Participants included 28 children 7–14-year-old, with 100 primary and 214 permanent molars, of which, 150 teeth had FS. After chewing two CC, 290 (92.4%) teeth had retained CC. Water-swishing removed all, partial or none of the CC in 23%, 72.4% and 4.6% of the teeth, respectively. The effectiveness of chewing SG in completely removing retained CC was significantly higher than water-rinsing ($p < 0.001$), OR = 43.83, Cramer's V value = 0.871, suggesting a very strong correlation.

The presence of FS raised the probability of completely removing retained CC after SG or water-rinsing ($p < 0.001$, OR = 107.7 and 25.9), with Cramer's $V = 0.66$ and 0.57, respectively, means a very strong association, as compared to teeth without (For both $p < 0.001$).

Conclusion: Chewing gum for 4 min was significantly more effective than water-rinsing for 1 min in removing retained CC. Moreover, FS considerably decreased the probability of retained CC on occlusal surfaces and increased the effectiveness of SG in removing it.

1 | Introduction

Two of the multifactorial aetiologies of dental caries include the presence of oral bacteria, especially streptococci mutants and lactobacilli in the dental plaque, and eating sticky fermentable carbohydrates, which adhere to the occlusal surfaces of posterior teeth [1]. Longer retention periods of sticky carbohydrates provide time for oral bacteria to convert the complex carbohydrate molecule into simple carbohydrates (glucose) and initiate/progress dental caries [2, 3]. It should be emphasised, however, that food retention on the occlusal surface of the teeth does not depend only on food stickiness but also on the presence of deep occlusal fissures. Accordingly, an important component of the prevention of occlusal carious lesions includes the application of fissure sealants on occlusal surfaces of newly erupted permanent teeth. A Cochrane Systematic Review found that

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treatment with fissure sealants prevented between 11% and 51% of occlusal caries lesions in children for at least 24 months compared to no sealant [4]. It is accepted that its preventive effect results from blocking food, water and bacteria from getting into these grooves and fissures, and providing smooth surfaces that are easily accessible for saliva and toothbrushing [5].

The most accepted way to remove retained carbohydrates from the occlusal surfaces of teeth is toothbrushing. Nevertheless, children often do not comply with this recommendation, especially when they are out of the house or when eating sticky snacks in the morning on their way to school. However, they may rinse their mouths with water or chew gum to remove the retained food from their teeth. Previous studies have shown that chewing sugarless gum for 20 min after meals significantly decreased caries incidence by 7.9%–45% after 2 years [6–8]. Its anticariogenic properties refer to its effect on saliva, namely increased flow of saliva, elevated saliva pH, increased remineralisation, and decreased demineralisation [6–8]. To our knowledge, no previous study evaluated the effectiveness of chewing gum in removing the remnants of retained sticky carbohydrates from occlusal surfaces of posterior teeth to prevent dental caries.

Accordingly, the aims of the present study were to evaluate the effectiveness of rinsing the mouth with water and chewing sugarless gum in removing retained fermentable carbohydrates from occlusal surfaces in the presence or absence of fissure-sealant or restoration.

Our null hypotheses were that the type of posterior teeth (primary or permanent) or types of dentitions (primary mixed or permanent) will affect the degree of retained sticky CC includes cookies; rinsing with water for 1 min will effectively remove CC remnant from occlusal surfaces of teeth; chewing gum for 4 min will not remove the CC remnants retained after rinsing the mouth with water and fissure sealant/occlusal restoration will not affect the effectiveness of rinsing with water or chewing gum in removing food remnants.

2 | Study Population and Methodology

The Moscow Research Ethic Committee (REC reference number 27/2021) approved this study. During the study period, August 2021–January 2022, healthy children who arrived at the paediatric dentistry department of the Peoples' Friendship University of Russia in Moscow for routine dental treatment were candidates for participation in the present study. Their parents were asked to sign an informed consent form and their children were asked to give their assent to participate in the study. Inclusion criteria were healthy children without background illnesses who did not take any medication on a regular basis. Exclusion criteria included children allergic to any of the materials used in the study, incapable of chewing or rinsing their mouth, who had orthodontic braces, edentulous children, uncooperatively for taking photographs or if their parents refused to sign an informed consent.

Before initiation of the study, 10 dentists who had children were asked to give their opinion on which was the stickiest snack they have experienced when brushing their own children's teeth. According to their answers, Oreo chocolate cookies (CC) were chosen as a representative of an adhesive fermentable carbohydrate.

Healthy children visiting the paediatric-dentistry department received prophylaxis and then were given two CC to munch on. 10 min after the children finished munching on the CC, the occlusal surfaces of their posterior teeth were photographed (Figure S1a). Children with retention of CC's remnants on their teeth were then asked to swish water in their mouth for 1 min. Immediately afterward another photograph of the occlusal surfaces of their posterior teeth was taken (Figure S1b). When cookie remnants were still evident on their teeth, the children were asked to chew sugarless chewing gum (Orbit, strawberry flavour, containing xylitol, Moscow, Russia) for 4 min, and immediately afterward, another photograph was taken (Figure S1c). Children in whom CC remnants were still retained on their teeth, received professional prophylaxis. All children received at the end of the study application of topical fluoride.

The photographs were screened for the presence of retained CC in two steps. In the first step, an independent dentist, blinded to the group (F.K., post-graduate dentist in the paediatric dentistry department) reviewed all the photos and determined, in each photo, how many posterior teeth were included, the type of teeth/dentition (primary/permanent/mixed) and which of the teeth contains CC remnants. Only teeth that were clearly seen in the photograph were included in the study. In the second step, the same dentist compared the amount of CC remnants in various stages of the study (after rinsing with water and after chewing gum) and marked whether there was complete or partial removal. To determine the intra-observer reliability of the independent dentist, the dentist re-evaluated the same 15 photos twice, within a two-week interval.

All demographic and dental variables collected, included: patient's age, sex, type and number of posterior teeth in each photograph, type of dentition, the presence or absence of fissure sealant or occlusal restoration, the presence of retained CC after each step of the study and effectiveness of removing the retained CC (partial or complete).

2.1 | Statistical Analysis

Univariate analyses were conducted to detect differences between groups: rinsing the mouth with water and chewing gum. The categorical variables were compared using the Chi-squared test or Fisher's exact test (where the numbers were small). If possible, an Odds ratio statistic was calculated to quantify the strength of the association between variables. Differences in variables measured by an ordinal scale were analysed using the nonparametric Mann–Whitney *U* test. Normally distributed quantitative variables were analysed using Two Independent *t*-tests and abnormally distributed variables were analysed using nonparametric tests. The strength of significant associations was assessed by Cohen's *d* value for quantitative variables. For categorical variables, the strength of the associations was assessed by either Cramer's *V* value or Cohen's *d* for binary variables.

All statistical analyses were performed by a statistician, using SPSS software, version 27. In all tests performed, $p < 0.05$ was

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considered statistically significant. Cohen's *d* values were calculated using G*Power software (1996).

2.2 | Sample Size Determination

Regarding the sample size, the 314 teeth in the study were based on a minimum power of 90%, while in most tests the power was > 99%. Given the sample of 28 participants and including 314 teeth in the study, we detected an odd ratio of 43.8 between treatment and tooth cleaning efficiency. Calculating using the WinPepi programme shows that detecting an odds ratio of 43 using a sample size of 314 teeth promises a 97.5% level of confidence and power > 99%.

3 | Results

Twenty-eight children (14 boys) aged 10.4 ± 3.5 years (median 11.0 years, range 6–17 years) were included in the present study. The children had 100 primary molars (31.8%) and 214 permanent molars (68.2%). 12.7% of these posterior teeth were in primary dentition, 40.8% in mixed dentition and 46.8% in permanent dentition. 47.1% of the posterior teeth were with sealants or with occlusal restorations. Following 10 min of munching on the CC includes cookies, 92.4% of the teeth had retained CC on their occlusal surfaces.

Missing data included 138 teeth that were unclear/missing on imaging and an additional 24 teeth were not evaluated for the effectiveness of water rinsing as they were primarily free of retained CC (Figure 1). Sixty teeth were not evaluated for the effectiveness of chewing gum following water rinsing as it completely removed the retained CC. The intra-reliability rate of the photo's assessment related to the degree of removal of CC remnants from teeth was 100%; for the presence of fissure sealants or composite restoration on teeth, the intra-reliability rate was 94.6%.

3.1 | Retained Adhesive Carbohydrates

CC were retained on 290 (92.4%) teeth; the presence of fissure sealants did not significantly influence CC retention, as 89.3% versus 95.1% of teeth with or without sealant had retained adhesive carbohydrates. Similarly, neither type of teeth (primary or permanent) nor the type of dentition (primary, mixed dentition or permanent dentitions) influenced CC retention on the occlusal surfaces, $\chi^2(1) = 1.45$, $p = 0.33$ and $\chi^2(2) = 0.23$, $p = 0.63$, respectively (data not shown) (Figure S1a).

3.2 | Effectiveness of Water Rinsing in Removing Retained CC

One hundred and fifty-two teeth were available for evaluating the effectiveness of water rinsing in removing retained CC. Swishing the mouth with water for 1 min removed completely, partially or did not remove the retained CC in 23%, 72.4% and 4.6% of the teeth, respectively. The effectiveness of water-rinsing in clearing the CC from the teeth was not affected by the type of tooth, primary or mixed dentitions, as compared to permanent dentition ($\chi^2(1) = 1.04$, $p = 0.4$) (Data not shown) (Figure S1b).

3.3 | Effectiveness of Chewing Gum in Removing Remaining Retained CC (After Water Rinsing)

The effectiveness of chewing gum in removing the retained CC after water rinsing was almost 44-fold higher than that of rinsing with water only: $\chi^2(1) = 209.264$, $p < 0.001$ OR = 43.83, 95% CI for OR: [23.8, 80.67], Cohen's $d = 2.09$, which is considered a very large effect. In addition, a Cramer's V value calculated to assess the strength of the correlation between chewing a gum and removing the remained CC yielded a $V = 0.871$, suggesting the strength of the correlation is very strong (Figure S1c).

The superiority of removing CC remnants from teeth by chewing gum (96.46% of teeth) as compared to water (59.21% of teeth) was confirmed also by conducting a *t*-test. Statistical t (404) = 19.9, $p < 0.001$, suggesting chewing gum had yielded a higher success rate for removing CC remnants compared to rinsing with water. The effect size of removing CC remnants from teeth by chewing gum was estimated by Cohen's $d = 17.22$, which suggests a very strong correlation between chewing a gum and the percent of teeth which had no CC remnants.

3.4 | The Impact of Fissure Sealants or Occlusal Restorations on CC Adhesion to the Occlusal Surface

The presence of sealant decreased the probability of CC adhesion to the occlusal surface by 57%. This almost reached statistical significance: $\chi^2(1) = 3.719$, $V = 0.12$, $p = 0.054$, OR = 0.43 and Cohen's $d = 0.46$. However, in contrast to our expectations, sealant/restoration decreased the effectiveness of water-rinsing partially or completely removing the retained CC by 94%. $\chi^2(1) = 7.147$, $V = 0.16$, $p = 0.014$, OR = 0.06 and Cohen's $d = 1.55$, as compared to teeth without sealants.

Nevertheless, the presence of sealant or occlusal restoration significantly increased the effectiveness of the chewing gum to partially or completely remove the remnant of retained CC (Table 1). The probability of chewing gum to completely remove the remnant of sticky CC on teeth with sealant/restoration was 107-fold higher as compared to teeth without sealant/restoration; $\chi^2(1) = 119.7$, $p < 0.001$, OR = 107.7, 95%, CI for OR: [34.5, 336.4], with a very strong association of $V = 0.66$ and a very large effect, assessed by Cohen's $d = 2.58$.

In teeth without sealant/restoration, the probability of chewing gum to completely remove the retained CC was only 25-fold higher than that of water; $\chi^2(1) = 91.02$, $p < 0.001$, OR = 25.9, 95% CI for OR: [12.12, 55.33], a very large effect assessed by Cohen's $d = 1.81$ and a very strong association as well, $V = 0.57$.

4 | Discussion

There is widespread agreement that stagnation of retained fermentable carbohydrates on teeth can increase caries morbidity,

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FIGURE 1 | Flowchart of the study.

by increasing the duration of oral bacteria-producing acid [2]. The present study aimed to evaluate the effectiveness of water-rinsing or chewing gum in removing the remnants of retained CC from the occlusal surfaces of posterior teeth in the presence or absence of sealant/occlusal restoration. We demonstrated that chewing sugarless gum for 4 min was significantly more effective than water-rinsing for 1 min in removing retained CC.

Several mechanisms of action were offered to explain the effectiveness of sugarless chewing gum in removing retained food. It is well established that chewing gum, due to its flavouring, acidity and mechanical chewing action increases salivation. Moreover, the xylitol, a polyol sweetener included in sugarless chewing gum composition, elicits a gustatory reflex, and further stimulates salivation, which in turn, facilitates the removal of food debris from the oral cavity [9]. Another optional mechanism of action points to several forces and factors that are involved in the stickiness of foods, adhesive and cohesive forces, as well as viscosity and viscoelasticity [10]. This mechanism of action, therefore, can explain the stickiness/cohesive force of sugarless chewing gum on the retained adhesive CC, demonstrating maintenance of both greater cohesion and exhibiting greater adhesive force to the tooth's occlusal surface, than that of the sticky CC remnants. These were evident in the results showing that following just 4 min of chewing sugarless gum the clearance was significantly more effective than that of rinsing with water only ($p < 0.001$), and indeed the sugarless chewing gum was full of the retained CC. This finding supports the importance of the stickiness/adhesive force of chewing gum in this process. To our knowledge, this is the first study to evaluate this effect and determine the effectiveness of the sugarless chewing gum in maintaining greater stickiness/cohesion and adhesive force to the retained carbohydrates, as compared to the tooth's occlusal surface, therefore removing remnants of retained adhesive carbohydrates.

Several previous studies have demonstrated that chewing sugarless gum containing xylitol after meals promotes a caries-preventive effect [5–7, 11], by several mechanisms of action such as increased salivation, elevation of saliva-pH, decreasing mutans streptococci levels in plaque and saliva [9, 12–14] and decreasing the transmission of mutans streptococci from mother to her child [15].

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TABLE 1 | Effectiveness of water rinsing or chewing gum in removing retained chocolate cookies from the occlusal surfaces of posterior teeth according to the presence/absence of sealants/occlusal restorations.

Retention in different groups	Occlusal surface condition	Complete removal, *N* (%)	Partial or no-removal, *N* (%)	Chi-squared statistical, OR, 95% CI for OR	
				p	
Following water rinsing	Teeth with sealant $N=77$	16 (20.8%) a	61 (79.2%)	$\chi^2(1)=7.147$ OR = 0.26 95% CI = [0.11, 0.61] a < b $p<0.001$	$\chi^2(1)=209.2$ OR = 43.8 95% CI = [23.8, 80.7] f > c $p<0.001$
	Teeth without sealant $N=75$	19 (25.3%) b	56 (74.6%)		
Total		35 (23%) c	117 (77%)		
Following chewing gum	Teeth with sealant $N=117$	113 (96.6%) e	4 (3.4%)	$\chi^2(1)=4.432$ OR = 3.21 95% CI = [1.03, 10.1] e > d $p<0.05$	
	Teeth without sealant $N=137$	123 (89.8%) d	14 (10.2%)		
Total		236 (93%) f	18 (7%)		

The clinical implication of these findings is that instead of recommending children rinse their mouths with water after meals or snacks, which was proven to not be as effective or always available, a preferred recommendation is that children chew sugarless gum containing xylitol for 4 min, especially when they are outside of their home. This recommendation can also be applied to children eating snacks on their way to school. More studies are recommended to evaluate the effectiveness of different types of sugarless chewing gum in removing retained sticky carbohydrates.

One of the means of caries prevention is the application of pit and fissure sealants on the occlusal surfaces of posterior teeth. Fissure sealants provide a physical barrier that inhibits microorganisms, water and food particles from penetrating the fissures and thus preventing caries initiation and arresting caries progression [4]. According to our study, we propose another optional mechanism of action of fissure sealants which is in addition to decreasing the probability of retained carbohydrates on the entire occlusal surfaces, the sealants increase the effectiveness of the sugarless chewing gum in removing retained food. Accordingly, further clinical studies are warranted to evaluate the effectiveness of sugarless chewing gum after meals in decreasing caries incidence in children with and without fissure sealants on their posterior teeth.

Surprisingly, the presence of sealants decreased the effectiveness of swishing the mouth with water in removing retained CC. This unexpected finding may be related to the surface's roughness of the fissure sealants, surface energy, the hydrophobicity of the fissure sealant material, as compared to the tooth surface or to the fact that the water surface tension strengthens the adhesiveness of the CC to the sealant/composite materials. The effects of these variables in inhibiting biofilm formation on tooth surfaces are well established [2, 16–18]. Additional studies are warranted to evaluate the effect of these variables on the adhesion of refined sticky carbohydrates to tooth surfaces.

In the present study, we evaluated the effectiveness of sugarless chewing gum in removing the retained CC after rinsing the mouth with water. The aim of this plan was to evaluate the superiority of chewing gum on rinsing with water. More studies are warranted to evaluate the effectiveness of sugarless chewing gum in removing the retained carbohydrates 10 min after consuming food.

The limitation of the present study was the missing photos of 138 teeth after rinsing with water, mostly due to the lack of cooperation of the children. Nevertheless, there was still enough data to enable us to reach reliable results.

5 | Conclusions

1. Chewing gum for 4 min was significantly more effective than water-rinsing in removing the remnant of retained adhesive cookies from the occlusal surfaces of primary and permanent teeth.
2. The presence of fissure sealant increased significantly the effectiveness of sugarless chewing gum in removing the remnant of retained cookies from the occlusal surfaces of primary and permanent teeth.

6 | Clinical Relevance

6.1 | Scientific Rationale for the Study

Retention of fermentable carbohydrates on the occlusal surfaces of posterior teeth after meals increases the risk of caries development by providing a longer period for the oral bacteria to convert them into acid.

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6.2 | Principal Findings

Chewing gum was superior to water-rinsing in eliminating sticky fermentable carbohydrates. Additionally, fissure sealants reduce the likelihood of these carbohydrates adhering to occlusal surfaces and improve their clearance from teeth by chewing gum.

6.3 | Practical Implications

Chewing gum for 4 min is a viable option for removing remnants of sticky, fermentable carbohydrates thus decreasing the risk of dental caries.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available in the Supporting Information of this article.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

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