The effect of saliva on dental caries

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ABSTRACT

JADA CE CONTINUING EDUCATION ARTICLE 1

Background. The multiple functions of saliva play a significant role in the prevention of dental caries.

Methods. Chewing gum is known to stimulate salivary flow, and the results of studies of the role of stimulated saliva in the oral clearance of food particles, neutralization of dental plaque acids and reduction of the incidence of dental caries have been reported. The author reviews the results of these clinical caries trials.

Results. Seven clinical trials have evaluated the impact of chewing gum on caries incidence. These studies have shown that chewing sugar-free gum after meals results in a significant decrease in the incidence of dental caries and that the benefit is due to stimulating salivary flow rather than any chewing gum ingredient.

Conclusions. Stimulating salivary flow through the chewing of sugar-free gum after meals has been shown to reduce the incidence of dental caries.

Clinical Implications. Practical measures for stimulating salivary flow after meals or snacks should be considered in caries prevention programs.

Key Words. Caries; caries prevention products; chewing gum; saliva; salivary flow.
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The properties and functions of saliva, as well as the role of saliva in oral health, have been discussed extensively in articles, textbooks and a 2004 review.[1] The functions of saliva include lubricating the oral tissues, protecting the oral soft tissues from abrasion during mastication, facilitating the digestion of carbohydrates, antibacterial activity against foreign microorganisms, flushing the oral cavity to clear and remove food particles and debris from the tissues, and chemically maintaining an environment rich in calcium, phosphate and acid-buffering agents. The latter function has been recognized as having the ability to reduce the incidence of dental caries. In this article, I describe some of the data used to evaluate the effect of saliva on dental caries.

THE CARIOGENIC CHALLENGE

Although the etiology of dental caries is reasonably well-established, the chemical-physical

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process that results in the demineralization of enamel and dentin often is less appreciated. Nearly everyone's normal oral flora contains microorganisms that are capable of metabolizing fermentable carbohydrates, leading to the production of a variety of acidic by-products. Furthermore, people need to ingest foods containing fermentable carbohydrates to meet their nutrient and energy requirements. Thus, the stage is set for the oral flora to metabolize the ingested carbohydrates, leading to the production of acids that are capable of demineralizing enamel and dentin.

The production of acids by microorganisms within the dental plaque continues until the carbohydrate substrate is metabolized.[2] It also is known that the plaque's pH goes from acidic to normal (or the resting level) within a few minutes and depends on the presence of saliva.[3] This is due primarily to the carbonate and phosphate pH buffering agents in saliva. Thus, one can think of this process as being an equilibrium (Figure 1). In essence, an equilibrium exists within the dental plaque whereby the pH of the plaque decreases each time the host ingests a snack or meal that contains fermentable carbohydrates; afterwards, the pH returns to the resting level because of saliva.

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Stephan[2] and Englander and colleagues[3] reported plaque pH responses after plaque exposure to foods and beverages that contain sucrose or other fermentable carbohydrates. Within three to five minutes after such exposures, the pH of the plaque decreases below the so-called critical pH values of 5.5 and 6.0 for enamel and dentin, respectively, and demineralization of the underlying enamel or dentin is initiated. The duration of the demineralization depends on the time required for the pH of the plaque to increase above this lowered pH and is controlled primarily by the amount and composition of saliva. When the plaque's exposure to saliva is restricted, the decrease in plaque pH is greater and the recovery period is longer than when normal exposure is allowed. Other study results indicate that the stimulation of salivary flow markedly enhances the recovery rate of the plaque pH and its return to the resting level.[4-7] Moreover, the importance of chewing sorbitol-containing (so-called sugar-free) gum to stimulate salivary flow to restore the pH of the dental plaque to its resting levels has been reported.[8-11]

In addition to neutralizing the acids produced within the dental plaque, saliva also serves as the host's defense mechanism by repairing the demineralization that occurs when the plaque pH is below 5.5 to 6.0. Saliva's ability to remineralize enamel has been known for more than 40 years and has been the focus of investigations during the past 25 years. Perhaps the first clinical evidence of the ability of saliva and the oral environment to remineralize enamel was reported by Backer Dirks[12] in 1966. Backer Dirks recruited 90 children who were 7 years of age and carefully examined them for demineralized areas annually for eight years. The results he observed on the buccal surfaces of maxillary first molars are of particular interest. He identified a total of 72 white-spot lesions in the children at age 8 years and followed these same white spots until the children were 15 years of age. Of these 72 white-spot lesions, 26 (36 percent) had been arrested and remained essentially unchanged, whereas 37 (51 percent) had been remineralized and no longer were clinically detectable (Figure 2).

CARIOGENICITY OF FOODS

Numerous studies have been conducted to determine the relative cariogenicity of foods we typically eat. In an attempt to review methodologies and develop a consensus regarding these methodologies in the scientific community, the American Dental Association Health Foundation established the Foods, Nutrition and Dental Health Program and convened annual national conferences from 1977 through 1983.[13-17] The conclusions drawn from these conferences were that no test is capable of determining the cariogenic potential of foods because of factors (such as composition, mineral content, consistency and oral retention) that affect caries potential and that the most practical tests involved intraoral assessments of plaque pH changes and the formation of dental caries in rats.

Using the rat caries model, several investigators have reported that the most important factor influencing the cariogenicity of a food is the frequency at which it is eaten.[18,19] In these investigations, the frequency at which the animals were allowed to ingest a sucrose-containing diet or a sugar-containing food each day (in other words, the number of meals per day) was controlled by using a mechanical feeder, and the results indicated that a greater number of meals each day consistently resulted in an increase in the number of carious lesions that developed in the animals. Such study results supported the results of clinical investigations in which the frequency of ingestion of sugar-containing foods[20] or between-meal snacks[21] was related directly to the development of dental caries in both adults and preschool-aged children. Burt and colleagues[22] more recently confirmed the increase in caries associated with the increased ingestion of sugars and between-meal snacks. A recent systematic review of the literature, however, concluded that the relationship between sugar and caries is much weaker in the modern age of fluoride exposure than it used to be.[23] Bowen[24] also noted that there is no clear relationship between the concentration of sugar in food and its ability to induce dental caries. Recently, a study showed that the high daily consumption of sugar-containing soft drinks has resulted in an increased prevalence of caries.[25]

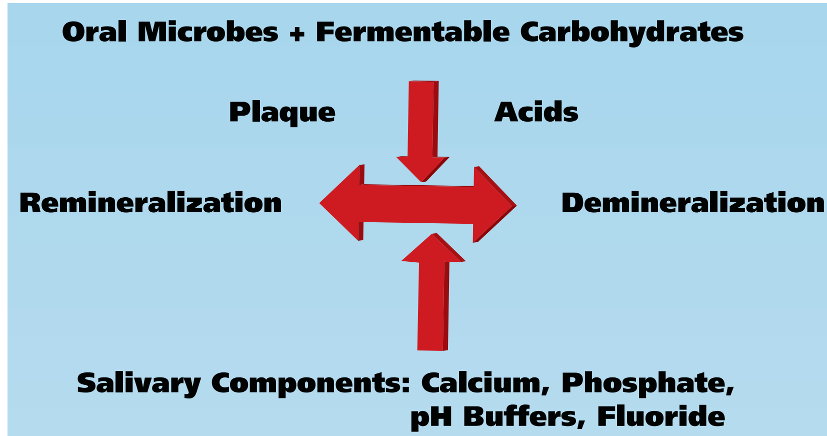

Figure 1. Example of the demineralization-remineralization process in the oral plaque.

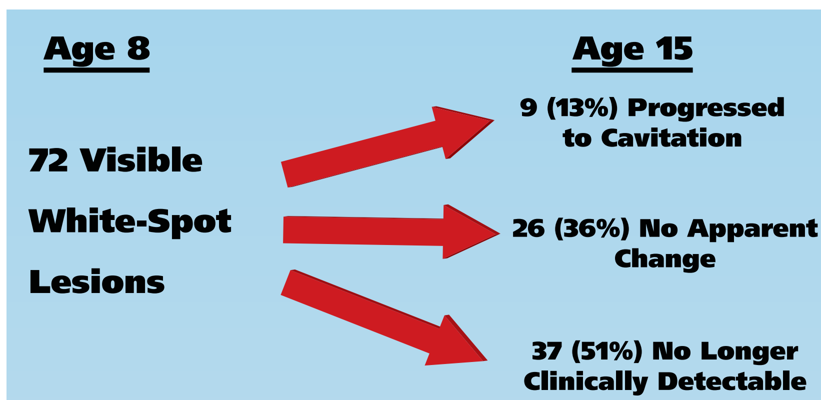

Figure 2. Progression of white-spot lesions over a seven-year period.

CHEMICAL BENEFITS OF SALIVA STIMULATION

Stimulating the flow of saliva alters its composition. Dawes[26] noted that increasing the rate of salivary flow increases the concentration of protein, sodium, chloride and bicarbonate and decreases the concentration of magnesium and phosphorus. Perhaps of greatest importance is the increase in the concentration of bicarbonate, which increases progressively with the duration of stimulation. The increased concentration of bicarbonate diffuses into the plaque, neutralizes plaque acids, increases the pH of the plaque and favors the remineralization of damaged enamel and dentin.

CHEWING GUM REDUCES CARIES INCIDENCE

The results of seven clinical caries investigations[27-33] further attest to the merits of stimulating salivary flow. The first clinical trial to determine the cariostatic effect of using a sorbitol-containing chewing gum after meals was conducted in Denmark.[27] Children 8 to 12 years of age from two schools participated in the study; students in one school were assigned to chew one piece of chewing gum after each meal throughout the two-year study, and the children in the other school served as the no-gum control group. During the school year, the chewing sessions, which took place after breakfast and lunch, were conducted in the schools. The children received visual-tactile dental caries examinations supplemented with bitewing radiographs at baseline and after one and two years.

At the conclusion of the two-year study, the 151 students in the no-gum control group had an average caries increment of 6.2 surfaces, and the 161 students in the sorbitol-containing chewing gum group had an average caries increment of 5.6 surfaces. The difference of 9.7 percent in caries incidence was statistically significant. The investigators reported that the number of caries reversals was perceptibly greater in the group of children who were assigned to use chewing gum.

Glass[28] also reported the results of a two-year clinical trial of a sorbitol-containing chewing gum. The participants were children 7 to 11 years of age at baseline, and they were assigned randomly to either a no-gum control group or a chewing gum group. Students in the chewing gum group were given two sticks of chewing gum daily throughout the study period and their use was supervised once daily during school days. Apparently, no overt attempt was made to associate the chewing experience with the ingestion of a meal. Visual-tactile dental caries examinations supplemented with bitewing radiographs were performed at baseline and after one and two years. The results after two years indicated that the dental caries increments were 4.70 and 4.63 decayed or filled surfaces in the control and test groups, respectively. This difference was not statistically significant, and the investigator concluded that the sorbitol-containing chewing gum was noncariogenic.

Increasing the rate of salivary flow increases the concentration of protein, sodium, chloride and bicarbonate and decreases the concentration of magnesium and phosphorus in saliva.

Mäkinen and colleagues[29] reported the results of a 40-month clinical investigation involving schoolchildren in Belize City, Belize. The children recruited for the study were in the fourth grade (age range, approximately 9-11 years; average age, 10.2 years) and were divided by schools into nine parallel groups of 136 to 157 subjects. At the end of the study, there were 80 to 120 subjects in each of the nine groups. One group of children received no chewing gum and served as the control group. The children in the other groups received chewing gum containing sucrose, sorbitol or xylitol in stick or pellet form. The children in the sucrose- and sorbitol-containing chewing gum groups were instructed to use the chewing gum five times per day, and those in six xylitol-containing groups used sticks or pellets of chewing gum either three or five times per day. On 200 school days each year, teachers supervised five-minute periods of chewing gum use at intervals spaced throughout the day, and parents supervised chewing gum use on other days. The children were examined for dental caries at baseline and after 16, 28 and 40 months.

The results observed at the end of the 40-month study indicated that the children who chewed the sucrose-containing chewing gum experienced a modest increase in the incidence of dental caries when compared with the children who received no chewing gum; however, that difference was not statistically significant ($P = .11$). In contrast, the children who chewed the sorbitol-containing chewing gum experienced a statistically significant decrease in dental caries of 20.8 percent when compared with the children in the no-gum control group. Even greater reductions in caries incidence were observed in all of the groups given xylitol-containing chewing gums; when compared with the caries incidence in the no-gum control group, these reductions ranged from 43 to 71 percent.

In a study conducted in Puerto Rico,[30] 2,601 children in grades five through seven were recruited, and 1,403 children completed the three-year study. The children were examined by an experienced examiner for dental caries at baseline and annually by means of the conventional visual-tactile procedure supplemented with bitewing radiographs. The children were assigned randomly by classroom into either a control group (no chewing gum) or a chewing gum group. Those in the chewing gum group were asked to chew sorbitol-containing gum for 20 minutes after each of three meals daily. The gum-chewing periods were supervised in the schools during the morning and after lunch on school days; all other chewing periods were unsupervised. The supervised gum-chewing sessions were about one-third of the total number of prescribed sessions.

Table 1 summarizes the two- and three-year results for all of the subjects who were available at the conclusion of the study, as well as those who were considered to be at greater caries risk (that is, the subjects who had a baseline caries score greater than zero) when the study was initiated. After using the sorbitol-containing chewing gum for three years, the chewing gum group experienced a modest, but statistically significant, reduction in the incidence of dental caries of 7.9

percent when compared with the control group. When only the subjects at higher risk of developing caries (that is, those subjects who were not caries-free at baseline) were considered, the participants in the chewing gum group experienced an 11.0 percent decrease in the incidence of dental caries when compared with the control group.

In Budapest, Hungary, researchers conducted a two-year clinical trial of the use of a sorbitol-containing chewing gum involving schoolchildren.[31] The 547 subjects were students in grades three through five and were 8 to 13 years of age; most subjects received two meals per day at their schools. The children were examined for dental caries by an examiner by means of a visual-tactile procedure with fiber-optic transillumination at baseline and after one and two years. After the baseline examinations, the subjects were assigned by classroom to either a no-gum control group or a sorbitol-containing chewing gum group. The subjects in the sorbitol-containing chewing gum group were expected to chew for 20 minutes after each meal; on school days, these chewing sessions took place after breakfast and lunch and were supervised.

Table 2 summarizes the results of this study. After two years of partially supervised daily use of the sorbitol-containing chewing gum for 20 minutes after each meal, the subjects in the chewing gum group experienced significantly fewer new carious lesions than did the subjects in the control group. The magnitude of this difference was 38.7 percent when the white-spot lesions were excluded and 33.1 percent when these white-spot lesions were included.

The determination that the caries-preventive effect of so-called sugar-free chewing gum is due to saliva rather than to sorbitol was demonstrated in a controlled clinical trial.[32] In this three-year investigation, groups of children aged 9 to 14 years were assigned to one of five regimens: sorbitol-/carbamide-containing chewing gum, sorbitol-containing chewing gum, xylitol-containing chewing gum, chewing gum containing no sugar or polyol sugar substitutes (for example, sorbitol or xylitol) (the control) or no chewing gum. In the chewing gum groups, the children

TABLE 1

Impact of chewing gum after meals in children in Puerto Rico.*

EXPERIMENTAL REGIMEN	TWO-YEAR RESULTS			THREE-YEAR RESULTS		
	No. of Subjects	DMFS† Increment	Reduction %	No. of Subjects	DMFS Increment	Reduction %
All Subjects						
Control group	944	6.08	—	746	8.72	—
Chewing gum group	874	5.69	6.4‡	657	9.03	7.9‡
High-Risk Subjects§						
Control group	808	6.68	—	632	9.54	—
Chewing gum group	759	6.12	8.4‡	572	8.49	11.0‡

* Source: Beiswanger and colleagues.[30]
† DMFS: Decayed, missing and filled surfaces.
‡ Statistically significant ($P < .05$).
§ Baseline caries score greater than zero.

TABLE 2

Impact of chewing gum after meals in children in Budapest, Hungary.*

EXPERIMENTAL REGIMEN	TWO-YEAR RESULTS			THREE-YEAR RESULTS		
	No. of Subjects	DMFS† Increment	Reduction %	No. of Subjects	DMFS Increment	Reduction %
Not Including White Spot Lesions						
Control group	278	0.350	—	278	1.327	—
Chewing gum group	269	0.621	43.6	269	0.814	38.7
Including White Spots						
Control group	278	1.502	—	278	2.914	—
Chewing gum group	269	0.875	41.7	269	1.951	33.1

* Source: Szöke and colleagues.[31]
† DMFS: Decayed, missing and filled surfaces.

were instructed to chew five pieces of chewing gum daily for 10 minutes each, preferably after meals; teachers supervised the chewing period after lunch on school days. The results indicated that the caries increments in the sorbitol-containing chewing gum, xylitol-containing chewing gum and control chewing gum groups were statistically significantly lower than that in the no-gum group and were not significantly different from one another. The results for the sorbitol-/carbamide-containing chewing gum group were not different from those for the no-gum group. From these findings, the investigators concluded that the appreciable benefits from the chewing gums were attributable to the chewing process rather than to the presence of the sorbitol or xylitol.

A clinical trial conducted in China evaluated the possible benefits of an oral health education program with and without the addition of a sugar-free chewing gum regimen.[33] Children aged 6 to 7 years were recruited from nine schools. Those attending three schools were assigned to each of the three groups: a school-based dental health education program, a school-based dental health education program plus sorbitol-containing chewing gum or neither the education program nor chewing gum (the control). The children in the sorbitol-containing chewing gum group were provided with four pieces per day and instructed to chew one piece after lunch, one piece after dinner and one piece at each of two teacher-supervised chewing sessions each morning on school days.

Dental caries was assessed at baseline and after two years. The caries increments were essentially identical for the children in the education group and in the control group. However, a significant reduction (42 percent) in the incidence of caries was observed in the education plus chewing gum group when compared with the control group. The investigators concluded that chewing the sugar-free gum was beneficial for caries prevention.

CONCLUSIONS

In seven clinical trials, investigators compared the effect of chewing a sorbitol-containing chewing gum on the development of dental caries, and most of these studies were cited in a recent review.[34] Six of these studies reported statistically significant decreases in the incidence of dental caries associated with the instructed and partially supervised use of a pellet or stick of chewing gum after each meal.[27,29-33] In the study in which this effect was not observed, only two pieces of gum were recommended each day, and no apparent attempt was made to chew the gum after meals.[28] These data indicate that chewing a pellet or stick of sugar-free gum after each meal may reduce the development of dental caries significantly.

The role of saliva in the neutralization of acids produced within the dental plaque and its involvement in the remineralization of demineralized enamel areas is well-documented. The results of six controlled clinical caries studies have indicated that chewing sugar-free gum after meals results in a significant reduction in the formation of dental caries. This effect also is caused by increased salivary flow attributed to the chewing process rather than to the sorbitol in these chewing gums. ■

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