# The use of sorbitol– and xylitol–sweetened chewing gum in caries control

**Brian A. Burt, BDS, MPH, PhD**

Dental caries is a bacterial disease in which diet is a major etiologic factor. Given the dominant role that ingestion of sugars plays in caries etiology, caries-control strategies that aim to restrict exposure to sugars have been used for generations. These restrictive strategies often fail because people find them disagreeable. Attempts to quit consuming high amounts of sugar "cold turkey" also fail frequently. Tobacco-use control programs, however, have shown that substitution therapy—replacing a harmful habit with a positive, more culturally acceptable practice—can be effective. In dentistry, the application of this principle to a caries-control strategy involves replacing the ingestion of fermentable sugars—primarily sucrose—with the ingestion of nonfermentable sugar substitutes. Combining this principle with a culturally acceptable habit such as gum chewing can lead to a promising caries-control strategy.

The predominant sugar substitutes used in chewing gum are polyols, which are low-caloric substances sometimes called "sugar alcohols" because their chemical structure is close to that of both sugar and alcohol. The polyols are used to sweeten a number of sugar-free products, the most important of which—in terms of caries control in the United States—is chewing gum. The polyols most frequently used in chewing gum are sorbitol, a hexatol derived from glucose, and xylitol, a pentatol that occurs widely in nature. Mäkinen and colleagues[1] hypothesized that pentatols are more effective than hexatols in preventing caries, and the evidence generally favors that view. Relatively large amounts of these polyols (for example, 7-14 grams per day) can be consumed without untoward side effects, though when ingested in quantity they can act as a laxative. It has been well-known for years that polyols do not promote caries[2] because the polyols are metabolized either slowly or not at all in dental plaque. This con-

## ABSTRACT

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**Background.** The author compared the caries-inhibitory action of sorbitol- and xylitol-sweetened chewing gum and assessed the role of these products in caries prevention.

**Types of Studies Reviewed.** The author reviewed studies including randomized field trials with substantial numbers of participants and observational studies. He did not review case studies. He found studies through a MEDLINE search and by hand searching.

**Results.** When compared with sugar-sweetened gum, sorbitol-sweetened gum had low carcinogenicity when it was chewed no more than three times per day. Xylitol-sweetened gum was noncariogenic in all of the protocols tested. Some studies claimed that xylitol-sweetened gum had an anticariogenic effect, though these claims need further study. There also is good evidence that when mothers of infants and young children chew xylitol-sweetened gum, it will block transmission of mutans streptococci from mother to child.

**Clinical Implications.** The evidence is strong enough to support the regular use of xylitol-sweetened gum as a way to prevent caries, and it can be promoted as a public-health preventive measure. Chewing xylitol-sweetened gum, especially for patients who like chewing gum, can be fitted readily into a regimen that includes frequent fluoride exposure, good oral hygiene and regular dental appointments.

**Key Words.** Caries; sorbitol; xylitol; chewing gum.
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Dr. Burt is a professor, Department of Epidemiology, School of Public Health, University of Michigan, 109 Observatory St., Ann Arbor, Mich. 48109-2029, e-mail "bburt@umich.edu". Address reprint requests to Dr. Burt.

trasts with the metabolizing characteristics of sugar sweeteners such as sucrose and high-fructose corn syrup. The table compares some properties of sorbitol and xylitol with those of sucrose and fructose.[3]

The chewing of any gum stimulates saliva flow, which increases the buffering capacity of saliva and, thus, neutralizes the reduction in plaque pH that normally follows eating.[4] The ability of chewing gum to aid in caries control comes from the chewing action itself—which stimulates saliva flow—and the noncariogenic sugar substitutes used as sweeteners. Sugared gum is cariogenic,[5] so all gums used in caries-control regimens need to include a nonsugar sweetener. The rationale is that when sugar is plentiful in a person's diet, cariogenic bacteria such as mutans streptococci thrive in plaque flora, but they can become suppressed when the person's diet is low in sugars. Xylitol-sweetened chewing gums are being studied for their anticariogenic action—that is, whether they actively assist in remineralizing early carious lesions as opposed to playing just a neutral role. The evidence for cariostasis (the inhibition of the development of caries) is mixed, but either way some degree of dental benefit exists.

**TABLE**

**Some comparative properties of sorbitol, xylitol, sucrose and fructose.***

| SWEETENER | % RELATIVE SWEETNESS VERSUS SUCROSE | CALORIES (KILOCALORIE/ GRAM) | LAXATION THRESHOLD (GRAMS/DAY) | U.S. REGULATORY STATUS |
|---|---|---|---|---|
| **Sorbitol** | 60 | 2.6 | 50 | GRAS† |
| **Xylitol** | 100 | 2.4 | 50-90 | Food additive |
| **Sucrose** | 100 | 4.0 | > 100 | GRAS |
| **Fructose** | 117 | 4.0 | 50-70 | GRAS |

* Adapted with permission of SPI Polyols.[3]
† GRAS: Generally regarded as safe.

I conducted a literature review to examine evidence for the use of polyol-sweetened chewing gums in controlling dental caries among patients and the public in general. I conducted a MEDLINE search using "caries" and the names of various polyols as search terms. I chose only clinical trials and observational studies that examined caries outcomes in groups of people. In addition, I hand searched journals that published research articles on caries for recent articles and some older articles, and I conducted a Google search to find Web sites.

## SUGAR

Sugar first became inexpensive and available on a mass scale in the United States in the mid-19th century, when tariffs on sugar imports were lifted. When food distribution methods in the United States became more efficient after World War I, sugar consumption increased and soon exceeded 120 pounds (54.5 kilograms) per person per year. Since then, the rate of sugar consumption has continued to rise; the taste for sweets seems to be insatiable. Soft drinks represent the single largest source of sugar consumption in the United States; Americans drank an average of 52 gallons of soft drinks per capita in 2003.[6]

The generic term "sugar" usually means sucrose, the disaccharide caloric white granular substance that is processed from sugar cane or beets. In addition, some monosaccharides, principally those found in high-fructose corn syrup, are caloric sweeteners that are consumed in about the same amounts as sucrose. Average per capita consumption of all sugars in the United States was 141.5 pounds (64.3 kg) in 2003—one of the highest levels in the world.[7]

Consuming all this sugar could be leading to deleterious health effects. In recent years, sugar has been implicated increasingly as a principal factor in the worldwide epidemic of obesity in children, and there is good evidence that high consumption of sugars is a risk factor for diabetes.[8] Perhaps the most disturbing development in the massive consumption of sugar that is of concern to pediatricians and dentists alike is the extent to which sodas and juices have replaced milk and formula in the diets of infants and young children.[9,10] Soft drink manufacturers have been marketing their products by contracting with cash-poor school districts for the sole right to stock the vending machines in the schools, a practice known as "pouring rights."[11] This too is a trend that is not in the interest of public health, and it has been opposed vigorously by the American Academy of Pediatrics.[11]

Because sugar is caloric, its consumption has long been seen as a factor in weight gain. The marketing of noncaloric (or low-caloric) sweeteners, the first of which was saccharin in the 19th century, is aimed at the weight-control market (for example, diet sodas). Products containing sugar substitutes, promoted as part of people's preoccupation with weight control, are big business in the United States. Their role in caries control is secondary in the view of food manufacturers, but it is one that dentists can use, especially with their more caries-susceptible patients.

## SORBITOL

The most commonly used polyol in the United States is sorbitol, which is the standard sweetener in several sugar-free chewing gums and over-the-counter medicines. Sorbitol is 60 percent as sweet as sucrose (table)[3] and is much less expensive than xylitol. Sorbitol is less effective than xylitol in controlling caries, but its lower cost makes it appealing to food manufacturers.

**Sorbitol is the standard sweetener in several sugar-free chewing gums and over-the-counter medicines.**

In terms of cariogenesis, sorbitol has an advantage over sugars because, in small amounts, it does not lower the pH of plaque to a point where enamel demineralization occurs.[12] Sorbitol, however, should be considered a low-cariogenic sweetener rather than a noncariogenic one because consumption of larger amounts (more than two sticks of chewing gum per day) increases both the acid production in plaque and the number of sorbitol-fermenting microorganisms.[13] Sorbitol in a solution (such as in a soft drink) can be fermented, though slowly, by mutans streptococci.[14] Cariogenic microorganisms can "learn" to metabolize sorbitol when their sugar supply is restricted; this form of adaptation to sorbitol has been demonstrated in animals.[15] Firestone and Navia[15] suggested that this adaptation could have occurred owing to selection by sorbitol-fermenting bacteria or induction by sorbitol-specific metabolizing enzymes. Chewing sorbitol-sweetened gum for about five minutes after receiving a sucrose rinse has been shown to substantially reduce demineralization.[16] Salivary stimulation from sorbitol-sweetened gum also is thought to promote remineralization,[17] though whether it results from the sorbitol or just from mastication is unclear.

Only a few clinical trials have been conducted specifically with sorbitol, though some trials have been conducted with xylitol, sorbitol, and mixtures of xylitol and sorbitol together. The cariogenicity of sugar-sweetened chewing gum was confirmed in a 1981 study. Children who chewed gum that included 60 percent sucrose and 20 percent glucose between meals twice daily had 36 percent greater caries incidence than did children who did not chew the gum under study.[5] After the cariogenicity of sugared gum was established, a trial soon followed that tested the effect of chewing two sticks of sorbitol-sweetened gum per day over two years. That study, which used a passive control group (no chewing gum issued as part of the study), was conducted with 540 children, initially aged 7 to 11 years, who lived in an area of New England in which the water was not fluoridated. Study results indicated there was no difference in caries incidence between the groups, which demonstrated that sorbitol did not promote caries at this level of consumption. However, one in vitro study suggested that both sorbitol and xylitol can be broken down by certain strains of lactobacilli, thereby reducing pH sufficiently to demineralize enamel.[18] Even if this does happen in humans, however, a person would have to eat much more sorbitol than is found in two sticks of gum to reduce plaque pH to cariogenic levels.

A clinical trial in Hungary demonstrated the noncariogenicity of sorbitol[19] in a slightly higher dosage than that in the New England trial. The two-year study began with 583 children aged 8 to 13 years and used a passive control group. The test protocol was for the children to chew one stick of sorbitol-sweetened gum for 20 minutes after each of the three meals each day. There were 547 children remaining in the study at its end. Children in the test group had 33.1 percent fewer lesions than did the children in the control group when all types of caries, including noncavitated lesions, were considered. When caries was recorded only with cavitation, the reduction was 38.7 percent.

A trial in Puerto Rico,[20] where the caries level in children was fairly high and there was no water fluoridation, began with 2,601 children in grades 5 through 7. Caries was recorded at the cavitation level. As in the Hungarian study, the protocol for the test group was for the children to

chew one pellet of gum for 20 minutes after each of the three meals each day; the protocol for the control group was no intervention. The benefits of chewing the sorbitol-sweetened gum were more modest in this trial. After three years, the subjects in the test group had 8 percent fewer lesions with decayed, missing or filled surfaces than did those in the control group; when the analysis was restricted to high-risk subjects, the difference was 11 percent.

## XYLITOL

The first field trials for xylitol were conducted in the late 1960s and early 1970s in Turku, Finland.[21] In the first of these studies, 125 volunteer adults substituted the sucrose in their diets with xylitol—a change made possible by having food manufacturers prepare special nonsucrose, xylitol-sweetened foods for the study period of two years. A second test group consumed fructose-sweetened foods through the same protocol, and a third group acted as a control by consuming a conventional sucrose-containing diet. This study deviated from the requirements of an ideal clinical trial because participants were not blinded to their group assignment, but instead they were selected and were aware of their group assignment. During the two-year study period, almost no new carious lesions developed among subjects in the xylitol group, while there were more than seven lesions among subjects in the sucrose group and four among subjects in the fructose group. Lesions in the test subjects, whose average age was 27.5 years, were almost all of the "white spot" variety (reversible early demineralization) on smooth surfaces.

Cariogenic microorganisms do not metabolize xylitol,[22,23] and consuming xylitol does not decrease plaque pH. Salivary mutans streptococcus counts drop with consistent use of xylitol-sweetened gum, probably because replacing sucrose with xylitol "starves" the cariogenic microorganisms.[14,24,25] Evidence also suggests that consistent use of xylitol-sweetened gum reduces plaque accumulation.[26,27] The ways in which xylitol-sweetened gum has beneficial caries-preventive effects are summarized in the box.

Extensive clinical trials conducted in Belize tested the ability of xylitol to prevent new caries or remineralize existing lesions.[28] These trials compared groups of subjects who chewed xylitol-sweetened gum, sorbitol-sweetened gum and gum sweetened with xylitol-sorbitol mixtures with a passive control (no gum) group and a group that chewed sucrose-sweetened gum for the duration of the 40-month trial (a research design seen by some as ethically questionable because some children were given an unhealthy product such as sucrose). Results demonstrated that the gum that was most effective in preventing caries was a 100 percent xylitol-sweetened pellet. Gums sweetened with xylitol-sorbitol mixtures were effective, though less so than the 100 percent xylitol-sweetened pellets, and xylitol was superior to sorbitol.

Another report from the Belize trials studied caries development in primary teeth. This two-year study included a group of 510 children, initially aged 6 years. It found xylitol to be modestly superior to sorbitol in terms of caries incidence, and both xylitol and sorbitol groups were superior to the no-gum group in caries reduction. The regimen for the xylitol-sweetened gum in this study was for supervised chewing of a stick or pellet of gum five times per school day for five minutes each instance throughout the school year. Use of the gum outside school days was variable. The risk of new caries in the xylitol group was 0.53 when compared with the no-gum group, while risk in the sorbitol group was 0.7.[29]

Yet another study from this research team found that xylitol-sweetened gum was more effective than sorbitol-sweetened gum in preventing root caries in Veterans Affairs patients after daily use of the gum for two years.[27]

Clinical trials conducted since those in Turku,

**BOX**

### How xylitol in chewing gum works to inhibit caries development.

- Xylitol is not fermented by cariogenic plaque bacteria and, thus, does not lower the pH of plaque. Because plaque pH does not decrease, enamel demineralization is prevented, and plaque bacteria do not proliferate.
- Xylitol reduces the accumulation of plaque on the tooth surface.
- Since plaque pH does not drop when xylitol-sweetened gum is chewed, remineralization is enhanced.
- Regular chewing of xylitol-sweetened gum has specific inhibiting effects on the growth of mutans streptococci in the mouth. This suggests that there may be permanent reductions in oral mutans streptococci levels from this practice.
- Chewing any gum stimulates the flow of saliva, which enhances the buffering effect in plaque. This property is not unique to xylitol-sweetened gum, the chewing effect by itself is seen as beneficial.

Finland, have assessed xylitol's effect on salivary mutans streptococcus counts, as well as on caries increments. The results have been generally favorable, though not consistent. One study analyzed xylitol's ability to maintain low mutans streptococcus levels after they initially had been reduced after following a chlorhexidine regimen.[30] The children in the test group chewed a xylitol-sweetened gum three times per day while under supervision for a minimum of five minutes each time over a three-month period. Children in the control group chewed a sorbitol-sweetened gum while under supervision, and children in a third group did not chew gum under supervision. At the end of the three months, the salivary mutans streptococcus counts were significantly lower in the xylitol group.

A Finnish study demonstrated the effectiveness of xylitol in lowering mutans streptococcus counts in children aged 11 to 12 who chewed xylitol-sweetened gum three times per day.[31] In yet another study, preschool-aged children who chewed xylitol-sweetened gum three times daily for three weeks also showed significant reduction in salivary mutans streptococci.[32]

Further analysis of data from the Turku studies,[33,34] in addition to laboratory research,[35] supports the hypothesis that xylitol promotes remineralization. More intriguing is the claim that xylitol can arrest established dental caries in children with rampant caries.[36] This suggests that xylitol, in addition to its noncariogenic effect, may have therapeutic anticariogenic effects. Further studies are needed to support these claims, but existing evidence shows that chewing xylitol-sweetened gum several times per day has caries-inhibitory benefits.

Not all xylitol field trials have shown favorable results. In a three-year study in Lithuania, there was no statistically significant reduction in caries increments among subjects in the xylitol-sweetened gum–group, subjects in the sorbitol-sweetened gum–group and subjects in a positive control group who chewed gum sweetened with acesulfame potassium and saccharin.[37] The authors concluded that the mechanical action of chewing, and not the polyols or other sugar substitutes in the gum, produced the caries inhibition. In addition to this study, several field trials conducted in developing countries demonstrated limited caries reductions in children who chewed xylitol-sweetened gum compared with children in control groups.[38,39] These field studies, however, were not as well-controlled as the clinical trials, which makes it difficult to interpret the findings accurately.

## XYLITOL AND MATERNAL TRANSMISSION OF CARIOGENIC BACTERIA

It is well-established that infants commonly become infected with mutans streptococci through oral transmission from their mothers.[40,41] These findings led to the preventive strategy of suppressing the mutans streptococcus counts in mothers of infants, typically with fluoride and chlorhexidine, to block transmission. Because xylitol-sweetened chewing gum has been shown to reduce mutans streptococcus counts, a question that arose was whether xylitol-sweetened gum chewed by mothers of infants would prevent the maternal transmission of cariogenic bacteria. Early evidence is promising,[42-45] though only one study to date has used caries experience in the children as the outcome measure.[42]

A study in Finland recruited 195 mother-infant pairs in which all of the women had high levels of salivary mutans streptococci.[42] A statistically significant reduction in colonization of mutans streptococci was observed in the teeth of the children whose mothers regularly chewed xylitol-sweetened gum compared with those of the children whose mothers received fluoride or chlorhexidine varnish treatment. The children themselves received no preventive treatment and were examined annually for caries until 5 years of age. In children aged 5, the caries rate for those in the xylitol group was about 70 percent lower than for those in the fluoride or chlorhexidine group. Mutans streptococcus colonization in children aged 2 years was related significantly to each child's age at the first caries in the primary dentition.

A Swedish study of similar design followed 169 mother-child pairs over a two-year period.[43] All mothers showed high salivary levels of mutans streptococci during pregnancy. The 106 mothers in the xylitol group chewed xylitol-sweetened gum at least two or three times per day, starting three months after they delivered their infants. In the two control groups, the remaining 63 mothers received chlorhexidine or fluoride varnish treatments at six, 12 and 18 months after delivery. The children themselves did not chew gum or receive varnish treatments. When the children were 2 years of age, those whose mothers had chewed xylitol-sweetened gum had significantly lower salivary mutans streptococcus counts. In a

follow-up study, the children's mutans streptococcus counts were assessed one year and four years after the mothers' gum-chewing had been discontinued.[44] Even in children aged 6 years, the salivary mutans streptococcus counts were significantly lower in those in the xylitol group.

Another study with 173 mother-child pairs with high salivary mutans streptococcus counts used the protocol of chewing a stick of gum for five minutes, three times per day.[45] The protocol was initiated when the children were six months old, and it was terminated one year later. As in the previous studies, those in the xylitol group showed significantly lower salivary mutans streptococcus counts than did those in the control group.

Collectively, these four clinical studies provide evidence of the effectiveness of xylitol-sweetened gum in reducing maternal transmission of cariogenic bacteria.

## USE OF XYLITOL-SWEETENED GUM IN DENTAL PRACTICE

Since 1963, the U.S. Food and Drug Administration has approved xylitol for use in special dietary foods. It is not used much, and it is not as well-known as other sugar substitutes that are marketed more extensively. Xylitol is more expensive than sucrose and sorbitol, and it cannot be used in cooked food products because it is destroyed by heat. Its use likely will be restricted to products that require only small amounts of sweetener, like chewing gum. Xylitol-sweetened gum is not as universally available in the United States as are sucrose- and sorbitol-sweetened gums, though it can be purchased on the Internet.

Evidence supports the view that xylitol-sweetened gum offers more benefit in terms of reducing caries risk than does sorbitol-sweetened gum, but chewing sorbitol-sweetened gum several times per day is better than chewing sugared gum in reducing caries. Sorbitol-sweetened gum, however, has been tested only up to three times per day. Therefore, because sorbitol is a low-cariogenic sweetener rather than a noncariogenic sweetener, dentists should advise their patients who chew sorbitol-sweetened gum to do so no more than three times per day.

In patient education, dentists should ask about gum-chewing habits as part of taking patients' histories. Patients who chew gum regularly should be encouraged to chew gums sweetened with sorbitol or xylitol. Because sorbitol-sweetened gums are easier to obtain than are xylitol-sweetened gums, dentists should consider the patients' interest in their oral health and susceptibility to caries. Practitioners may wish to acquire samples or an inventory of xylitol-sweetened gums to distribute to interested patients. Dentists should stress that chewing xylitol-sweetened gum is a supplemental practice, not a substitution for a preventive dental program that includes the use of fluoride, consciously applied oral hygiene practices and regular professional visits.

## CONCLUSIONS

Data increasingly support the regimen of chewing xylitol-sweetened gum three to five times per day for a minimum of five minutes after meals to inhibit plaque accumulation and enamel demineralization, enhance remineralization of early lesions and reduce mutans streptococci counts. Field trials have not firmly established whether xylitol can arrest carious lesions; additional in vitro and field studies are needed to confirm that possibility. Xylitol-sweetened gum and, to a lesser extent, sorbitol-sweetened gum are a useful part of caries control. Gum-chewing, for the most part, is culturally acceptable in the United States and fits easily into most patients' daily routines. ■

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