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Original Research Article

Sugar Substitutes in Prevention of Dental Caries: A Systematic Review

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Abstract

Introduction: A dynamic relation exists between sugars and oral health. There are many sugar substitutes available on the market today, both non-caloric and caloric, which have a low or even no cariogenic potential. Even if some of these products have economic, technologic and toxicologic shortcomings, sugar substitution is an important part of caries prevention.

Objectives: To assess the effectiveness of various sugar substitutes on preventing dental caries in children and adolescents.

Materials and Methods: All randomised controlled trials (RCTs), including cluster randomised trials but excluding cross-over trials were included for review. Children and adolescents below 18 years of age who have permanent or deciduous teeth, or both were included in the study. Primary outcomes measured dental caries on use of sugar substitutes. Secondary outcomes measured the harmful effects of sugar substitutes

Results: Lower rate of caries in subjects in the xylitol or sorbitol pellet groups compared to a group of children who were not assigned to a chewing group. Use of sugar substitutes demonstrated reduced incidence of dental caries in children and young adolescents.

Conclusion: The evidence is strong enough to support the regular use of sugar substitute gum as a way to prevent caries.

Keywords: Sugar substitute, Xylitol, Sorbitol, Dental caries.

Introduction

Most of us enjoy eating sweet tasting foods, and some might almost have a psychological need for them. Sweetness is the taste that is strongly identified with affection and reward. Indulgence in sweets has been described as a "universal human weakness", as evidenced by the ubiquity of sugar bowls, candy counters, automatic candy machines, bakery and pastry shops, and the soda fountain. Fruits, berries, and honey were the earliest sweet foods known; a famous Stone Age painting in southern Spain depicts the theft of honey from a bee's nest; dates were cultivated in Mesopotamia and the Nile[1]Valley as early as 3500 BC. Since about seventeenth century, sugar (sucrose) has been the primary sweetening agent[1].

The dental profession shares an interest in search for safe, palatable sugar substitutes. The association between the sugar consumption and dental caries has been well documented.[2] Dental caries is the disease that is manifested as dynamic process in the mouth. Cycles of demineralization and remineralization

continue in the mouth as long as there are cariogenic bacteria, fermentable carbohydrates and saliva present. Whether the demineralization or remineralization is the proceeding at any one time is determined by the balance between the pathological factors and protective factors.[2]

Dental caries is a bacterial disease in which diet is a major contributing etiologic factor. Diet affects the integrity of the teeth; quantity, pH, and composition of the saliva; and plaque pH. A dynamic relation exists between sugars and oral health. Sugars and other fermentable carbohydrates, after being hydrolyzed by salivary amylase, provide substrate for the actions of oralbacteria, which in turn lower plaque and salivary pH. The resultant action is the beginning of tooth demineralization.[3]

There are many sugar substitutes available on the market today, both non-caloric and caloric, which have a low or even no cariogenic potential. Even if some of these products have economic, technologic and toxicologic shortcomings, sugar substitution is an important part of caries prevention.[4]

Table no. 1 Classification of sugar substitutes.

Classification of Sugar Substitutes	
Low Caloric Sweeteners	**Caloric/ Bulk Sweetners**
• Aspartame	• **Polyols** Xylitol, Sorbitol
• Saccharin	• **Starch derivatives** Starch hydrolysates High fructose corn syrup Coupling sugar
• Cyclamate	• **Plant derivatives** Maltol Dihydrchalcones Stevioside Chlorogenic acid Ammoniated glycchrhizin
• Acesulfame K	• **Protein** Thaumatin Monellin Miraculin
• Dulcin	
• Aldoximes	
• Ultrasuss	

Materials and Methods

Criteria for considering studies for this review

Types of studies included in the review: Randomised controlled trials (RCTs), including cluster randomised trials but excluding cross-over trials. Cross-over trials are inappropriate for studies with caries as an outcome.

Types of participants

Inclusion criteria: children and adolescents below 18 years of age who have permanent or deciduous teeth, or both.

Exclusion criteria: studies in which the majority of participants are undergoing fixed or removable orthodontic treatment, the intervention is provided for less than one year, and groups of children are selected as they have underlying health conditions.

Types of interventions

Sugar Substitutes-containing gels, toothpastes, varnishes, mouthrinses,

chewing gums and sprays will be compared with placebo or no intervention (which includes routine care). We will also include trials comparing one Sugar Substitutes-containing product with another. The interventions must be provided for at least one year.

Search methods for identification of studies

We attempted to identify all relevant studies regardless of language or publication status (published, unpublished, in press, and in progress)

Electronic searches

For the identification of studies included or considered for this review, detailed search strategies were developed for each database to be searched. These search based on the search strategy developed for MEDLINE but revised appropriately for each database.

The following bibliographic databases and trials registers were searched:

- The Cochrane Oral Health Group's Trials Register (to present)
- The Cochrane Central Register of Controlled Trials
- (CENTRAL) (*The Cochrane Library*, current issue)
- Medline
- Embase
- Hinari
- k-hub

Searching other resources:

Hand searching

We contacted searching in National medical library and other dental college's library in Jaipur also.

Reference lists

We examined the reference lists of relevant trials, reviews, articles and text books in an attempt to identify any other studies or those not identified in previous searches.

Data collection

Identification of reports produced by the searches

The downloaded set of records from each database imported and merged into one core database to remove duplicate records and to facilitate retrieval of relevant articles.

Selection of studies

All records identified by the searches printed off and checked on the basis of title first, then by abstract or keywords or both. Records that obviously irrelevant were discarded and the full text of all remaining records were obtained. The full reports obtained from all the electronic and other methods of searching assessed independently. If more than one publication of a trial was identified, all publications were reviewed and the paper with the first publication date included as a primary version. All studies meeting the inclusion criteria then underwent data extraction and a quality assessment.

Data extraction and management

Data from all included studies was extracted independently by two review authors using a pilot tested data extraction form. Extracted data entered separately by each of two review authors into the 'Characteristics of included studies' table and automatically checked for differences. Data included if there is an independently reached consensus. Disagreements were resolved by a third review author until consensus was obtained.

Results

In Turku, Finland, the caries increment, plaque formation, and plaque flora were compared in adults, average age 27.5 years, on diets using sucrose, fructose, or xylitol as the sweetening agent. In this clinical trial, the specific sugars were used as sweeteners in about 100 products, such as tea, juices, soft drinks, porridges, jams, marmalade, pastries, sweets, chocolates, bonbons, chewing gum, marinated herring, pickles, mustard, and cough mixture. After

only one year, a dramatic reduction in caries increments was found in group consuming xylitol containing products (about 90% less caries than the sucrose group). Patients in xylitol group had less plaque and lower colony counts of *S.mutans* in their plaque. Large intake of xylitol containing soft drinks did produce transitory loose stools, usually not a problem with the solid products. Only one of the more than 50 persons using xylitol products dropped out of the study because of diarrhoea.[1]

Several studies have provided dietary xylitol, in the form of xylitol sweetened chewing gum, as an "add-on" (1 to 10 g/day) without attempting to restrict sucrose intake. Alternatively, partial substitution of xylitol for dietary sucrose (maximum 20 g/day) in candy, chewing gum, ice lolly, chocolate, gum drop, and wafer has been tested in institutionalized Hungarian and non-institutionalized Polynesian children. Although the design of these field studies does not conform to the requirements of standardized clinical trials (nonrandomized populations with differing baseline caries prevalence, examiners were not blinded), the results have consistently shown that even relatively small amount of xylitol reduce formation of new caries.

Primary Outcomes

Change in dental caries increment (dental caries is denied as clinical or radiographic lesions or both recorded at the dentine level), determined by change from baseline in the following.

Decayed-missing-filled tooth surfaces (DMFS) and decayed-missing-filled teeth (DMFT) d(e)fs d(e)ft indices and relation to sugar substitutes. Number of children with and without dental caries increment.

In a clinical trial in Puerto Rico, 2,601 schoolchildren were randomly assigned to two study groups. One examiner evaluated caries in the permanent dentition at baseline and after two and three years of follow up with the use of artificial light, mirror, explorer, and radiographs. After baseline exams, classrooms were randomly assigned to receive no gum or sugar-free chewing gum (Extra Orbit, Wrigley) with sorbitol (40-60 percent), mannitol (4-15 percent) and aspartame (<0.6 percent) sweeteners. Children were instructed to chew three times per day for twenty minutes. The change in DMFS index was evaluated adjusting for age, sex, baseline scores (DMFS), and baseline surfaces at risk, school, treatment by classroom, and within treatment by school. The mean age was 11.65 years in the control group and 11.72 years in the treatment group. Subjects in the chewing gum group had 6.4 percent fewer new DMF surfaces than controls. These differences were statistically significant.

Another study in Belize evaluated the effect of xylitol and sorbitol chewing gums on caries rates in primary teeth with six-year-old subjects. This study demonstrated a lower rate of caries in subjects in the xylitol or sorbitol pellet groups compared to a group of children who were not assigned to a chewing group, with relative risks reported as 0.35 (.21-.59) and .44(.30-.63) respectively.

A demonstration project in Madagascar in which school children were randomly assigned to polyol chewing gum or control group included children in grades one and four in six schools.

All children received a school-based oral health education program that included daily supervised toothbrushing. The test group also received a chewing gum that contained 55.5 percent sorbitol, 4.3 percent xylitol, and 2.3 percent carbamide that they received three to five times per day. Dental examinations were performed by three calibrated dentists at baseline and after three years of follow-up using a standard explorer, mouth mirror, and daylight. After three years of follow-up, the overall DMFS scores did not differ significantly among any of the study groups. The only statistically significant finding was a

decrease in occlusal caries in children in grade one in the xylitol group. It is interesting to note that the findings were different from the other studies cited in this review. The daily supervised tooth brushing that all children participated in may have made the groups more similar in terms of oral hygiene status, thus reducing the detectable difference in caries rates.

Xylitol is approved for foods, cosmetics, and pharmaceuticals in about 40 countries. In the United States, xylitol has been approved for special dietary use since 1963. It is used as a sweetener mainly in non-cariogenic confectionery (chewing gum, candies, gum drops) and less frequently in dietetic food (for diabetics), in pharmaceutical products (tablets, throat lozenges, vitamin tablets, cough syrup), and occasionally in dentifrices. Use in soft drink is limited because the intake of excessive quantities of polyol-sweetened liquids would tend to exceed threshold dose, causing gastrointestinal side effects (laxation). A significant deterrent to the widespread use of xylitol as a sweetener is its cost, currently ten times that of sucrose.

Secondary Outcomes

The following secondary outcomes were observed in sugar substitutes, Discoloration, pain, discomfort, Quality of life (QOL), patient satisfaction, cost (including use of health service resources (such as visits to dental care units, length of dental treatment time)), adverse effects, gastrointestinal complaints and adverse effects, any specific adverse effects related to any clinically diagnosed reactions to any of the active interventions for individual sugar substitutes.

Much literature is available on the adverse effects of artificial sweeteners; however, it is difficult for the general public to decipher the research, especially when researchers themselves disagree. The use of artificial sweeteners remains controversial. Their consumption has been shown to cause mild to serious side effects ranging from nuisance headaches to potentially life-threatening cancer. Recent reports of selected sweeteners suggest they are not efficacious in weight loss and may promote weight gain.

Discussion

Sugar And Dental Caries

Dental caries results from the interaction of plaque, fermentable carbohydrates, saliva and fluoride content of surface enamel. Freedom from caries or low caries increments can be achieved either by complete daily eradication of plaque, by reducing the frequency of sucrose consumption and by substituting non- or less-fermentable or non-nutritive sweeteners for easily fermentable dietary saccharides.

Only an estimated 20 to 25 per cent of the population will participate successfully in some plaque control program. This relatively small oral hygiene-minded fraction of the population also has an intelligent and disciplined attitude regarding overweight and consumption of sucrose substitutes. Preventive dentistry should recognize the inadequate oral hygiene awareness of the majority of people and the unconcerned consumption of carbohydrates. Oral preventive medicine should, therefore, strive for and support the substitution of frequently consumed fermentable carbohydrates by non-acidogenic or hypoacidogenic replacements or, where possible, by non-caloric sweeteners in order to decrease dental caries and perhaps to decrease obesity, diabetes and vascular disease.

Some sugar substitutes, such as aspartame, saccharin, and xylitol, also have the potential to inhibit bacterial growth (Grenby and Saldanha, 2006)[5], with saccharin and xylitol being particularly effective against mutans streptococci (Best and Brown, 1987)[6]. Delivery of xylitol with glucose to a consortium of oral bacteria resulted in a reduced rate of acid production and a selective suppression of *S.*

mutans under conditions where this species would otherwise flourish (Bradshaw and Marsh, 1994)[7]. Clinical studies using xylitol-containing products, ranging from chewing gum to dentifrices, have also reported a selective inhibition of mutans streptococci (Isokangas*et al.,* 1991[8]; Petersson *et al,* 1991[9]; Svanberg and Birkhed, 1991[10]).

Sugar-free gums can stimulate saliva, increasing the clearance of sugars and other fermentable carbohydrates from the teeth and the oral cavity and increasing buffer capacity. Tooth-friendly polyols include sorbitol, xylitol, mannitol, erythritol, and isomalt. However, xylitol a 5-carbon sugar that oral microflora cannot metabolize has additional anticariogenic effects attributable to antimicrobial action, stimulation of saliva resulting in increased buffer activity and an increase in pH, and enhanced remineralization. Sorbitol-sweetened gums simulate saliva without causing a drop to the critical pH and have been shown to be equal to xylitol gum in terms of caries control.

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. 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 remineralization, enhance remineralization of early lesions and reduce mutans streptococci counts.

Researchers have evaluated only the caries preventive effect of xylitol on proximal surfaces, their results indicating that xylitol might not be effective in caries prevention on those surfaces. This could also be due to the difficulty of xylitol's gaining access to the dental plaque on proximal surfaces. According to Thylstrup and Fejerskov, the effect of preventive procedures, such as cleansing solutions, fluoride, and toothbrushing, is more evident on smooth surfaces than on proximal surfaces, where access to the dental plaque is more difficult. Since xylitol has the ability to decrease the volume and acidity of plaque, the results found by these studies are easily explained.

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. Sorbitol, however, should be considered a lowcariogenic 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. Sorbitol in a solution (such as in a soft drink) can be fermented, though slowly, by mutans streptococci. Cariogenic microorganisms can "learn" to metabolize sorbitol when their sugar supply is restricted; this form of adaptation to sorbitol has been demonstrated in animals. Chewing sorbitol-sweetened gum for about five minutes after receiving a sucrose rinse has been shown to substantially reduce demineralization. Salivary stimulation from sorbitol-sweetened gum also is thought to promote remineralization, though whether it results from the sorbitol or just from mastication is unclear

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 and fits easily into most patients' daily routines.

Conclusion

Sugar substitutes have been introduced into human diets over the past few decades. Oral health care professionals are often called upon to provide knowledgeable advice regarding the importance of diet and the role of sugars and non-nutritive sweeteners in caries formation and weight control. As such, they must be familiar with alternatives to sugar and the types of food products that are available with substitute non-low caloric, non-cariogenic sweetening agents.

Although Sugar substitutes do not generally promote dental caries, a program to prevent dental decay and promote oral health must also include good oral hygiene habits, regular dental professional care, and exposure to fluoride. 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

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