

## Adult dental caries and sugar intake

Yoriko Matsuoka, Kakuhiro Fukai

Fukai Institute of Health Science

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**Abstract :** Dental caries affect people throughout their lives, but few previous studies are available on the relationship between dental caries and sugar intake in adults.

The aim of this study was to review the existing evidence concerning the association between dental caries and sugar consumption in adults.

A literature search resulted in 25 studies (including eleven reviews). A positive association was identified between 4-year DMFT increment and intake frequency of sugar-sweetened beverages. Soft drinks in particular had a positive relationship with dental caries. Dental caries are reduced when intake of free sugars is less than 10% of total energy consumption, or less than 15–20 kg/person/yr (40–55 g/day).

Limiting the frequency and amount of sugary food and beverage consumption is an effective measure to prevent dental caries. In the dental field, advising patients to reduce their sugar intake in order to prevent dental caries also indirectly contributes to weight loss and decreased obesity, as well as other non-communicable diseases, in the community.

Key words : Sugar, dental caries, adults

### Introduction

Dental caries is one of the most common childhood diseases, but it is a chronic and cumulative disease that affects people in all stages of life. The severity of dental caries increases with age

(Moynihan P, et al., 2004). Most studies relating to dental caries and sugars have investigated caries in children. Evidence from previous studies suggests that caries rates correlate with the amount of sugar consumed and the frequency of intake of sugary products (Sheiham A, 2001).

Sugars are an essential source of daily energy intake. Nicklas TA, et al. (2001), however, showed that high-calorie foods or beverages such as sweets, snacks, sugar-sweetened beverages, condiments, and carbohydrate food groups are positively associated with high energy intake and body fatness. Overweight children have a 1.5 to two-fold

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#### 【著者連絡先】

〒341-0003 埼玉県三郷市彦成 3-86  
深井歯科医院・深井保健科学研究所  
松岡順子  
TEL&FAX : 048-957-3315  
E-mail : yorikom@wg8.so-net.ne.jp

higher risk of remaining overweight up to 20 years of age (Nicklas TA, et al., 2001). Overweight youth have 2.4 times higher serum total cholesterol level and 43.5 times the rate of cardiovascular risk factors (Nicklas TA, et al. 2001).

Obesity is connected with many chronic diseases including hypertension, type 2 diabetes mellitus, gallbladder disease, cardiovascular diseases, and hypercholesterolemia (Greenwood JLJ, et al., 2008). In 2015, a new WHO guideline to prevent non-communicable diseases and dental caries strongly recommends children and adults reduce their daily intake of free sugars to less than 10% of their total energy or roughly 50 grams (12 teaspoons) per day (WHO, 2015). As an additional recommendation, WHO suggests a further reduction of the intake of free sugars to below 5% of total energy intake or roughly 25 grams (6 teaspoons) per day.

Since sugar consumption is a common risk factor in both medical and dental fields, controlling sugar consumption would provide both general and dental health benefits under the common risk factor approach. Little evidence from previous studies has found a significant correlation between dental caries and frequency and amount of sugar consumption in adults. The aim of this report is to review the previous studies in order to clarify the relationship between sugar and dental caries in adults.

### Methods

Medline databases from 1970 to June 2015 were searched with a combination of MeSH and text-based terms: (“carbohydrates” [MeSH terms] OR “carbohydrates” [All Fields] OR “sugar” [All Fields]) AND (“snacks” [MeSH terms] OR “snacks” [All Fields]) AND (“beverages” [MeSH terms] OR “beverages” [All Fields]) AND (“dental caries” [Mesh terms] OR (“dental” [All Fields]

AND “caries” [All Fields]) OR “dental caries” [All Fields]) AND (“adult” [MeSH terms] OR “adult” [All Fields] OR “adults” [All Fields]) NOT (“child” [MeSH terms] OR “child” [All Fields] OR “children” [All Fields]). Additionally, articles cited in the studies selected from Medline were hand-searched and added to the list if relevant.

### Results

The search strategy resulted in 131 studies. The following cases were excluded: subjects under 19 years old and case reports or studies that did not examine dental caries in adults. In the end, a total of 25 studies were identified.

Table 1 summarizes the results of the reviews and meta-analyses reviewed in this study. In the studies by Moynihan P, et al. (2004, 2014), it was demonstrated that consumption of less than 15–20kg/yr (<40–55g/day, <10% total energy) of free sugars correlates with lowered risk of dental caries. Hendriksen MA, et al. (2011) showed that consumption of carbonated soft drinks containing sugar substitutes was linked with reduced dental caries and body weight.

As seen in Table 2, a 4-year cohort study by Bernabé E, et al. (2014) showed an association between dental caries and consumption frequency of sugar-sweetened beverages (sugary coffee or tea, sugared juices, fizzy drinks, or cocoa) in Finnish adults. A positive association was identified between 4-year DMFT increment and intake frequency of sugar-sweetened beverages. Adults drinking 1–2 sweetened drinks per day had 31% greater (Incidence Rate Ratio: 1.31; 95% CI: 1.02–1.67), and those drinking 3+ sweetened drinks per day had 33% greater (Incidence Rate Ratio: 1.33; 95%DI: 1.03–1.72) DMFT increments compared with those who did not drink such beverages.

In the ten cross-sectional studies, sugar-sweetened beverages such as sweetened tea or coffee

Table 1 Reviews on the association between dental caries and consumption of sugar in adults

Authors	Year	Study design	Main topics	Main results
Burt BA, et al.	2001	systematic review	relationship between sugar consumption and caries risk	2 papers: strong relationship (ORs 2.5 or higher) 16 papers: moderate relationship (ORs 1.5-2.4) 18 papers: weak to no relationship (ORs 1.4 or lower)
Sheiham A	2001	review	dietary effects and dental caries	Adult dental caries increase with age. Reasonable recommendation of sugar intake levels is about 60g/person/day for teenagers and adults. There is no evidence to support cariogenicity of fruits.
Touger-Decker R, et al.	2003	review	sugars and dental caries	Elderly people of the highest quartile sugar intake had significantly more root caries and consumed twice as many sugary drinks (sweetened coffee or tea) and sticky sugars (Papasa A, et al., 1995)
Moynihan P, et al.	2004	review	diet, nutrition, and prevention of dental caries and dental erosion	Dental erosion is related to dietary acids (major source: soft drinks). Free sugars consumption <15-20kg/yr lowers the risk of dental caries. Maximum frequency of consumption of foods containing free sugars is 4 times a day.
Coombes JS	2005	review	sports drinks and dental erosion and dental caries	One study reported a relationship between sports drinks and dental erosion. Evidence does not support an association between sports drink consumption and dental caries.
Palacios C, et al.	2009	review	nutrition and health: guidelines for dental practitioners	The main determinant of caries risk is high frequency of intake of sugars of the type which remains in the mouth for long periods of time.
Hendriksen MA, et al.	2011	review	consumption of drinks containing sugar substitutes and dental caries	Reduction of dental caries was identified as a benefit of drinking soft drinks containing sugar substitutes.
Moynihan PJ, et al.	2014	systematic review	sugar intake and dental caries	Caries are reduced when free sugars intake is <10% of total energy intake (<15-20kg/person/yr). Caries development is slowed when free sugars intake is <5% of total energy intake (<10kg/person/yr).
Lussi A, et al.	2004	review	diet and aetiology of dental erosion	Dietary PH alone is not predictive of dental erosion. Three other factors are chemical (adhesion, chelating properties, calcium, phosphate, and fluoride content), behavioural (eating and drinking habits, lifestyle, excessive consumption of acids), and biological (flow rate, buffering capacity, composition of saliva, pelanatomy)
Noble WH, et al.	2011	review	sports drinks and dental erosion	Enamel dissolution from sports and energy drinks is 3-10 times greater than that from cola drinks (von Fraunhofer JA, et al., 2005).
Li H, et al.	2012	meta-analysis	dietary factors and dental erosion	The following drinks were associated with dental erosion: soft drinks (OR=2.41, 95%CI=2.03-2.85), vitamin C (OR=1.16, 95%CI=1.10-1.22). No association was found for juice, sports drinks, milk, and yoghurt.

Table 2 Studies on the relationship between dental caries and sugar intake in adults

Authors	Year	Study design	Country	Participants		Exposure	Adjusted factors	Outcome	Main results
				Number	Age/Gender				
Johansson A-K, et al.	1996	cross-sectional	Saudi Arabia	n=95	20.9 years (range: 19-25 yrs.) males (military)	consumption of sugar-sweetened beverages (type of drinks)	toothbrushing habits, dental attendance	dental caries dental erosion	<ul style="list-style-type: none"> <li>DMFT and DMFS of Arabian military males were higher than those of Western population.</li> <li>Mean intake of cola drinks before starting military service was higher (1.6 times).</li> <li>Sweetened tea (44%), soft drinks in combination with other beverages (23%), sweetened tea in combination with water (21%), regular cola drinks (73%)</li> </ul>
Milosevic A, et al.	1997	cross-sectional	UK	n=45	18 years (range: 13-23 yrs.) males and females (swimmers and cyclists)	consumption of sports drinks (intake terms, frequency, and concentration)	—	dental caries tooth wear	<ul style="list-style-type: none"> <li>cyclists: DMFS and tooth wear was significantly frequent (p&lt;0.05).</li> <li>Cyclists had more upper palatal wear (p&lt;0.001).</li> <li>Cyclists had greater degree of consumption of sports supplements (p&lt;0.05).</li> <li>No association was found between consumption pattern of sports drinks and caries or erosive tooth wear.</li> </ul>
Jensen ME, et al.	2000	crossover	USA	n=15	8 males (mean 38 years); 7 females (mean 36 years)	consumption of sugar-sweetened beverages and snacks	—	remineralization/ demineralization of enamel and dentin	<ul style="list-style-type: none"> <li>Caries progression was observed for apple juice, cola beverage, and sweetened strawberry yogurt.</li> <li>Remineralization of enamel was observed for cheddar cheese, skim milk, 2% milk, whole milk, chocolate milk, and orange juice.</li> <li>Demineralization was observed for apple juice, cola beverages, and yogurt snacks.</li> </ul>
Heller KE, et al.	2001	cross-sectional	USA	n=30,818	2-75+ years	consumption of sugary soda (frequency)	age, gender, poverty	dental caries	<ul style="list-style-type: none"> <li>highest consumption of sugary soda: 17-24 year age group</li> <li>significant associations between DMFS and soda consumption: persons aged 25 and older</li> </ul>
Mathew T, et al.	2002	cross-sectional	USA	n=304	18-28 years (mean 19±1.4) males and females (39%) athletes	consumption of sports drinks (frequency and quantity)	race, toothpaste, history of health problems, iron supplements	dental erosion	<ul style="list-style-type: none"> <li>sports drink usage: 91.8%</li> <li>total prevalence of erosion: 36.5%</li> <li>no association between dental erosion and sports drinks</li> </ul>
Sriramaharaj V, et al.	2002	cross-sectional	Australia	n=508	18-60 years male and female athletes (39.2%)	consumption of acidic foods and drinks (frequency and timing)	age, toothbrushing habits, patterns of dietary habits	dental erosion	<ul style="list-style-type: none"> <li>between dental erosion and consumption frequency of soft drinks or sports drinks: NP</li> <li>between dental erosion and age group: p=0.004</li> <li>consumption frequency of juice: p=0.05</li> <li>tooth sensitivity: p=0.001</li> </ul>
Forshee RA, et al.	2004	cross-sectional	USA	—	17-60+ years males and females	consumption of sugar-sweetened beverages (frequency)	age, gender, race/ethnicity, region of the country, education, income, number of meals, dental care	dental caries	<ul style="list-style-type: none"> <li>Regular carbonated soft drink consumption was associated with higher DMFS for the 25-40 yr. and over 60 yr. groups (p&lt;0.05).</li> <li>Coffee consumption had a statistically significant relationship with DMFS among 41-60 yr. and over 60 yr. groups (p&lt;0.05).</li> <li>Regular fruit drinks/aides had a negative association with DMFS in adults 41-60 yrs.</li> </ul>

Table 2 Studies on the relationship between dental caries and sugar intake in adults [continued]

Authors	Year	Study design	Country	Participants		Exposure	Adjusted factors	Outcome	Main results
				Number	Age/Gender				
Burt BA, et al.	2006	cross-sectional	USA	n=1,021	14-55+ years males and females	consumption of sugar-sweetened beverages and foods (frequency)	toothbrushing habits, plaque deposits, age, education, income, employment status	dental caries	<ul style="list-style-type: none"> <li>•DMFS was significantly related to soft drink consumption (p&lt;0.01).</li> <li>•Age, frequency of soft drink consumption, and presence of gingival plaque were significantly related to caries prevalence (p&lt;0.05).</li> <li>•Soft drink consumption and presence of gingiva plaque were positively associated with caries severity.</li> <li>•19% of all energy from sugar came from soft drinks alone.</li> </ul>
Du MQ, et al.	2009	cross-sectional	China	n=1,080	35-44 years 65-74 years	consumption of sugar-sweetened beverages and foods	age, ethnicity, smoking status, dental attendance, family income	root caries	<ul style="list-style-type: none"> <li>•mean Root Caries Index (RCI) middle-aged: 6.29; elderly: 11.95</li> <li>•Non-tea drinkers had higher root caries prevalence: 40.3% (p&lt;0.01).</li> </ul>
Issa AI, et al.	2011	crossover	UK	n=10	37.2 years males and females (40%)	consumption of fruits and vegetables	—	enamel demineralization	<ul style="list-style-type: none"> <li>•significant enamel demineralization: raisins, tomatoes, tomato juice, apples, apple juice, oranges, orange juice, carrots, and carrot juice (p&lt;0.01); grapes and grape juice (p&lt;0.001)</li> </ul>
Tsiveenjav B, et al.	2011	cross-sectional	Finland	n=4,361	30-64 years	consumption of sugar-sweetened beverages and snacks (frequency)	age, gender, education, toothbrushing habits	dental caries	<ul style="list-style-type: none"> <li>•DT was stronger outcome variable of dental health.</li> <li>•sugar-sweetened beverages in DT: RR=1.2 (95%CI: 1.1-1.3; p&lt;0.001)</li> <li>•sugar-sweetened beverages for women in DT: RR=1.3 (95%CI: 1.1-1.4; p&lt;0.0001)</li> <li>•Sugar-sweetened beverage consumption was more frequent in men.</li> </ul>
Saramucci T, et al.	2012	single-blind crossover	USA	n=10	39±12 years males and females (60%)	consumption of orange juice	—	dental erosion	<ul style="list-style-type: none"> <li>•most erosive solutions: LPP (linear sodium polyphosphate) and negative control (p&lt;0.05)</li> </ul>
Bernabé E, et al.	2014	cohort (follow-up: 4 yrs.)	Finland	n=939	48.2 years (range: 30-89 yrs.) males and females (54%)	consumption of sugar-sweetened beverages (frequency)	age, gender, education, toothbrushing frequency, dental attendance, use of fluoride toothpaste	dental caries	<ul style="list-style-type: none"> <li>•4-year DMFT increment: 0.76 (SD: 1.22, range: 0-12)</li> <li>•fully adjusted model drinking 1-2 sugar-sweetened beverages/day: IRR (Incidence Rate Ratio) 1.30 (95%CI: 1.02-1.67) drinking 3+ sugar-sweetened beverages/day: IRR 1.33 (95%CI: 1.03-1.72)</li> </ul>
Jain P, et al.	2014	cross-sectional	USA	n=76	28.5 years (range: 15-85 yrs.) males and females (50%)	consumption of sugar-sweetened beverages and snacks (quantity)	age, toothbrushing habits	dental caries	<ul style="list-style-type: none"> <li>•dental caries outcome: only sugar-sweetened beverages consumption: 33% (p=0.004) sugar-sweetened beverages+snacks+oral hygiene+age: 52% (p=0.0041)</li> <li>•Sugar-sweetened beverage consumption was much stronger indicator of dental caries.</li> </ul>

and particularly soft drinks were shown to have a positive relationship with dental caries. Heller KE et al. (2001), identified significant associations between DMFS increments and more frequent daily consumption of sugary soda in Americans over 25 years old ( $p < 0.05$ ). In the report of Forshee RA, et al. (2004), regular carbonated soft drinks were correlated with higher DMFS for the 25–40 year and over 60 year age groups of Americans ( $p < 0.05$ ). Burt BA, et al. (2006) identified that DMFS scores were significantly associated with soft drink consumption ( $p < 0.01$ ). Additionally, frequency of soft drink intake and presence of gingival plaque were positively correlated with caries prevalence and severity ( $p < 0.05$ ).

Acidic soft drinks including sports drinks had no association with dental caries or erosive tooth wear (Milosevic A, et al., 1997; Mathew T, et al., 2002; Coombes JS, 2005). Though the causes of dental caries are multifactorial, Jain P, et al. (2014) concluded that sugar-sweetened beverage consumption was a much stronger indicator of dental caries than oral hygiene or snack food consumption.

Eight studies have examined the consumption frequency of sugar-sweetened beverages (Milosevic A et al., 1997; Heller KE, et al., 2001; Mathew T, et al., 2002; Sirimaharaj V, et al., 2002; Forshee RA, et al., 2004; Burt BA, et al., 2006; Tseveenjav B, et al., 2011; Bernabé E, et al., 2014). Two studies examined the intake quantity of sugar-sweetened beverages (Mathew T, et al., 2002; Jain P, et al., 2014). Three studies were conducted regarding consumption type, terms, concentration, and timing.

Eight studies included dental erosion, tooth wear, root caries, and remineralization or demineralization of enamel and dentin (Johansson A-K, et al., 1996; Milosevic A, et al., 1997; Jensen ME, et al., 2000; Mathew T, et al., 2002; Sirimaharaj V, et al.,

2002; Du MQ et al., 2009; Issa AI, et al., 2011; Scaramucci T, et al., 2012).

### Discussion

WHO (2015) remarks that “sugars” includes intrinsic sugars like intact fruit and vegetables; sugars from milk (lactose and galactose); and free sugars which include monosaccharides and disaccharides added to foods and beverages by the manufacturer, the cook, or the consumer. Free sugars also include the sugars naturally present in syrups, honey, fruit juices, and fruit juice concentrates. Oral bacteria mainly utilize sucrose, glucose, and fructose to produce acids.

The studies reviewed in this article examined foods such as biscuits, chocolates, cake, cookie, chocolate candies, tartar sauce, and snack foods as well as beverages such as sweetened tea or coffee, soft drinks, cola, fruit juice, milk, diet soda, and cocoa. Of these possible factors, the search results suggest that sugar-sweetened beverages promote dental caries development and excessive weight gain in children and adults (Malik VS, et al., 2013). This is because it is easier to consume larger amounts of sugars in liquid form, despite poor satisfaction in terms of appetite reduction compared with chewing solid foods.

Concerning the effectiveness on dental caries of restricting sugar intake as per the WHO guideline, Moynihan PJ et al. (2004, 2014) show evidence that dental caries are reduced when intake of free sugars is less than 10% of total energy intake or less than 15 to 20 kg/person/yr (<40–55 g/day or <10% total energy). Burt BA, et al. (1988) reported that every 5 g of additional sugar consumption was resulted in a 1% increase in the probability of developing dental caries. Additionally, reduction of sugar consumption is associated with a decrease in body weight, which is reported in five of the studies in this meta-analysis (0.80 kg, 95% Confi-

dence Interval: 0.39–1.21;  $p < 0.001$ ) (Morenga LT, et al., 2012). The study durations were from ten weeks to eight months. In four studies, participants were advised to limit their intake of foods with added sugars, and in one study they were asked to replace their usual rich sugary foods with low-sugar options.

Most of the evidence in previous studies has established a relationship between dental caries and sugar intake while focusing on the prevention of dental caries in children rather than adults. Consumption of foods and beverages with added sugars between meals directly links to the development of dental caries in children, who tend to be very fond of rich, sugary items. Intake of sugar-sweetened beverages and foods is significantly associated with obesity in adults. Further cumulative studies with adults are required to firmly establish a relationship between dental caries and consumption of sugary foods and beverages.

### Conclusion

Limiting the frequency and amount of sugary foods and beverages consumption is an effective measure to prevent dental caries. In the dental field, advising patients to reduce their sugar intake in order to prevent dental caries indirectly contributes to weight loss a decrease in obesity as well as other non-communicable diseases in the community. It may be very difficult to achieve the sugar consumption goal suggested by WHO in 2015. Closer cooperation between the dental field, where caries prevention is the goal, and the medical field, where non-communicable disease prevention is the goal, will be essential in order to successfully reduce the excessive consumption of sugary foods and beverages.

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