Dental caries in adolescents associated with caffeinated carbonated beverages

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Abstract

Dental caries is an infectious disease involving all age groups. Adolescence is a period in which the risk for dental caries remains especially high. Many factors, some unique to the teenage years, contribute to the initiation and progression of dental caries in this age group. One factor with the potential for being significant is the adolescent diet, especially the high consumption of sugars. One product that tends to contribute to the amount of sugar ingested is carbonated beverages. Many soft drinks also contain significant amounts of caffeine. Regular caffeine ingestion may lead to increased, even habitual, usage. It is suggested that the combination of the consumption of highly sweetened soft drinks and habitual usage of caffeine may significantly increase a susceptible adolescent's potential for developing dental caries.

Cases are presented demonstrating the early initiation and rapid progression of dental caries in three adolescents. A common factor is the ingestion of high amounts of caffeinated-carbonated soft drinks. (Pediatr Dent 23:198-203, 2001)

During the past few decades, there has been a reduction in untreated dental caries, the major oral disease among children, across many demographic levels of 6- to 18-year-old children.[1-4] Although adolescents have benefited from this progress in the reduction of the prevalence of dental caries in the United States, adolescence is a period during which dental caries is still potentially very active.[5,6] The teenaged years may be a period of heightened caries activity as a result of increased intake of cariogenic substances and inattention to oral hygiene procedures.[7]

Although there are some differences of opinion regarding the development of dental caries,[8-11] it is generally accepted that a combination of sufficient levels of particular bacteria and fermentable carbohydrates over sufficient periods of time may lead to dental caries in susceptible individuals.[5,11-15] Also, it is known that many factors potentially contribute to the caries process, including, but not limited to, plaque formation and retention, bacterial adhesion and activity, sugar fermentation, salivary flow rates, additional dietary exposures to sugar and acids, oral hygiene habits, amount of fluoride usage, hormonal influences, immunity and non-immunity factors, ionic equilibrium at the enamel surface, transmission of and salivary counts of *mutans streptococci* and *lactobacilli*, oral sugar clearance time, and genetics.[13-18]

Adolescents and young adults are subjected to some age-specific factors, which, when combined with those described above, make them particularly susceptible to the caries process. Some of these factors include, but are not limited to:

- Adolescence – During this age period there are many physical, psychological, and social changes which the individual undergoes.[5,6]
- Independence – During the ages of 12 – 20, the individual generally completes school, and then enters college or the work force. Each stage brings with it more individual freedom from the immediate supervision of parents. The teenager is able to choose friends, clothes, habits, foods, and more without supervision.[5]
- Taste – One recent study on decision-making processes for sugar consumption summarized that with adolescents, the immediate pleasurable taste of sugar outweighed and deferred the recognition of dangers associated with its consumption.[19]
- Dental caries in adolescence – Although decreasing over the past two decades, the condition of carious teeth among children still exists and represents an oral health problem.[1] Dental caries continues to be the major infectious disease

Table 1. Amount of Caffeine (in milligrams) Present in Common Foods and Beverages

Coffee, regular (6 oz) =	from 100 to 140 mg
Tea (6 oz) =	from 25 to 40 mg
Iced tea commercially bottled (16 oz) =	20 to 50 mg
Cola carbonated beverages (12 oz) =	34 to 45 mg
Certain non-cola carbonated beverages (12 oz) =	40 to 55 mg
Caffeinated bottled water (12 oz) =	45 to 90 mg
Chocolate milk or hot chocolate (6 to 8 oz) =	20 to 50 mg
Chocolate candy bar (2 to 3 oz) =	25 to 35 mg

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problem for the adolescent. Although declining, the caries rate remains highest during adolescence.[6] Many teens have no active caries, however a smaller percentage of adolescents may present with a high caries rate usually associated with poor oral hygiene and a high frequency of sugar consumption often associated with carbonated beverage consumption.[20]

- Oral hygiene – As supervised home tooth-brushing sessions and professional care may decrease in frequency, there may be an increase in potential for dental caries and periodontal disease.[1,5]
- Dietary habits – As the growth process reaches completion, there is an increased demand for caloric requirements with subsequent increases in the ability to consume large amounts of protein and carbohydrates.[1,5] In this age group there is often a pattern of irregular meals, frequent snacking, and consumption of higher amounts of confectionery[20] with a corresponding decrease in consumption of healthier foods. There is further concern that as teens have increased their consumption of soft drinks their consumption of milk has decreased by 40%,[21] which may contribute to a decrease in bone density and subsequent increase in fractures.[22,23]
- Marketing and advertising – Many products, including carbonated beverages, are specifically and aggressively targeted at the teen market.[21] A recent marketing trend has raised concern among individuals and groups within organized dentistry. The American Dental Association, as well as some constituent organizations, has expressed opposition to "pouring rights contracts." These contracts give soft drink companies exclusive rights to place soft drink vending machines on school property, along with other measures to increase students exposure to the beverages, in exchange for money to the individual school or districts. In central Michigan, 34 school districts received a total of $37 million over a seven year contract.[24-26]
- Soft drink consumption – The American thirst for soft drinks is apparently insatiable, and consumption continues to increase steadily.[15] Between 1978 and 1994, soft drink consumption by U.S. teens tripled.[21] By 1998, Americans were consuming 15 billion gallons of soft drinks, equivalent to 558 12-oz. cans per person per year.[21,27] The National Soft Drink Association reports that one of every four beverages consumed in America is a soft drink, currently averaging over 56 gallons per year for every man, woman and child.[28] Consumption among 12- to 19-year old males can be closer to 81 gallons per year.[21]
- Caffeine – Many carbonated beverages contain caffeine.[21,28,29] It is possible that the presence of caffeine in the beverages consumed by adolescents is a major contributor to the tendency for frequent, even habitual, ingestion of such beverages.[21]

Several aspects in regard to the above factors will be discussed in further detail:

Caffeine

Caffeine is naturally present in coffee, tea, cocoa, and chocolate, and is an additive to some medications, many popular carbonated beverages and, more recently, bottled water.[21,29,30] Because its use is so pervasive and socially acceptable worldwide, it has been thought of as being innocuous.[31] However, caffeine is believed to be the world's most widely consumed psychoactive agent.[29,32,33] Low to moderate doses of caffeine tend to produce a certain level of positive subjective effects, such as, increased alertness, feelings of well being, energy, concentration and confidence levels, while decreasing fatigue, boredom, and drowsiness with a low level of side effects, at least in the view of the public, soft drink manufacturers, and some clinicians.[28-32]

Caffeine, a xanthine derivative, belongs to the chemical class of alkaloids. Xanthines (including caffeine, theophyline, and theobromine) are central nervous system stimulants, some of which have legitimate therapeutic applications. However, the most common usage is in caffeine-containing beverages, such as, coffee, tea, and carbonated beverages. Approximately 80% of adults in North America report regular intake of caffeinated beverages. Although per capita intake for the world approaches 70 mg/day, in the United States, this figure exceeds 200 mg. Although unusual, intakes in the 2000 to 5000mg/day range have been reported.[29,30]

The amount of caffeine present in a particular type of food or beverages varies. The Food and Drug Administration allows up to 0.2 mg/mL caffeine in soft drinks. Two of the most popular colas in the U.S. contain < 0.1mg/mL.[27] Soft drink manufacturers state that adding caffeine to their product is based on caffeine being a flavor enhancer.[28] However, in one recent study, only two of 25 subjects were able to detect a flavor difference at a caffeine concentration of 0.1 mg/mL.[27]

The habitual use of caffeine has been a topic of concern from its first widespread popular usage in the 1600s.[34,35] However, for most of the 20th century, caffeine usage was of little concern to the medical world.[29] More recently, caffeine usage has generated more interest, with focus on the popularity and habitual use of caffeinated beverages among children and teens and the physical effects of caffeine.[21,31]

Caffeine consumption is also increasing for even younger children.[36] There is concern that the pattern for caffeine ingestion begins at a very early age, as its use in medications, soft drinks, and other foods for children is common and accepted. Twenty percent of one- and two-year old U.S. children drink soft drinks, with an average consumption of seven ounces per day (containing over 30 mg of caffeine).[21] Also, based on milligrams of bodyweight, a similar sized serving of a caffeinated product will have a greater effect on a child than on an adult. For example, a 70-lb. 10-year-old consuming four bottles of cola and three chocolate bars a day could be ingesting more caffeine per kilogram than a 170-lb. man whose daily intake includes seven cups of coffee.[34]

There is some disagreement as to whether or not caffeine produces a physical dependence in those who regularly consume it. Caffeine has been considered to have stimulant-like effects as it has clear behavioral and pharmacological effects at high doses. However, controversy exists concerning its effects at lower doses present in ordinary food or drink. The scientific literature on the behavioral effects of caffeine is quite extensive and contradictory.[37]

Caffeine, at lower doses (2.5 mg/kg to 5 mg/kg), demonstrates metabolic activation on the cerebral dopaminergic system and fulfills some criteria for drug dependence.[33,38] Caffeine dependence has been reported with caffeine consumption starting as low as 129 mg per day.[39]

Evidence from studies on both animals and humans demonstrates that the cessation of regular ingestion of caffeine produces a distinct, dose-related withdrawal response. Caffeine withdrawal has been demonstrated in a number of studies with reported symptoms including: headache (the most common symptom), drowsiness or sleepiness, impaired concentration, work or school difficulty, fatigue, depression, anxiety, irritability, nausea or vomiting, muscle aches, or stiffness.[29,32,36,40,41] Caffeine withdrawal has been shown to occur with amounts as low as regular consumption of only 100 mg per day, amounts easily attained by drinking one cup of coffee or two cans of a caffeinated soda.[32] Table 1 provides a basis for comparison of the amount of caffeine in various products.[28,29]

Sugar

One epidemiological study revealed a significant positive association between the frequency of soft drink consumption and caries rate, even after accounting for other sugary foods and related variables.[42] Although sugar consumption is not the only, or even the most important, factor in dental caries activity, a relationship between sugar and caries still exists. Sugar in plaque is a contributory cause of dental disease.[15] In many forms of carbonated beverages, the various forms of sugar combine to equal a total of approximately 150 calories, almost 10 teaspoons, per 12 ounces.

Acidity of soft drinks

Many carbonated beverages contain phosphoric, citric, and carbonic acids.[28] Several studies have shown a deleterious effect on enamel after exposure to cola-type soft drinks.[18,43,44] The demineralization of hydroxyapatite by the acids present in soft drinks can eclipse the effects of the acids generated by oral flora from the sugars present in the drinks.[45]

Case reports

Cases will be presented demonstrating the onset and progression of dental caries in three patients. The most obvious common factors are adolescence, habitual consumption of caffeinated soft drinks, and difficulty in attempting to discontinue the practice.

A complete description of each patient's dental history with all radiographs available is impractical for this discussion. Although each patient admittedly has unique aspects to their individual dental condition, the following description will focus on those aspects that were present and consistent in all three cases.

Each of the three patients initially presented for dental evaluation with intact mixed or early permanent dentition with no interproximal caries. All patients had uncomplicated medical histories and maintained a regular schedule of biannual appointments for dental evaluation, prophylaxis, oral hygiene review, and topical fluoride (APF 1.23%) application. Bitewing radiographs were exposed at intervals ranging from six to 12 months. When incipient interproximal caries was detected, and throughout the pattern of increased severity, each recall visit included preventive counseling. Basically, such counseling reviewed oral hygiene instructions, emphasis on flossing, fluoride therapies (including at home usage) with fluoride mouthrinses or prescription fluoride (0.4% stannous fluoride gel), and diet management.

Each patient stated that they had begun a regular consumption of caffeinated soft drinks between the ages of 10- to 11-years old, with amounts significantly increasing around 12- to 13-years old. By this age, each patient was drinking at least 30 to 40 ounces of such beverages per day. As the patients grew older, their consumption increased. In each case, discussions relating to decreasing consumption met with negative responses, as all patients described symptoms such as headaches, irritability, and difficulty concentrating on schoolwork and homework. Parents confirmed these symptoms. The patients were unwilling or unable to effectively decrease their consumption levels.

With increased caries activity, the care and counseling, with emphasis on decreasing consumption, continued on each patient with varied results. Two patients stated that they had stopped drinking carbonated beverages, but they had substituted commercially prepared iced tea or iced coffee drinks (also caffeinated and highly sweetened). One patient was able to decrease consumption by using artificially sweetened colas and eventually caffeinated-bottled water and then no caffeine. Although this patient experienced some withdrawal symptoms, the interproximal caries have not progressed.

Representative radiographs of the three patients indicate caries progression, as indicated.

Case 1

Patient age – 14 years, 6 months (see Fig 1):

- Intact early permanent dentition, with interproximal caries evident on mandibular molars to greater than one-half of the enamel thickness.

Patient age – 15 years, 5 months (see Fig 2):

- Interproximal caries evident on mandibular molars progressing in enamel or penetrating into dentin.
- Early evidence of incipient caries on maxillary posterior teeth.

Case 2

Patient age – 13 years, 3 months (see Fig 3):

- Intact early permanent dentition with no interproximal caries evident.

Patient age – 15 years, 8 months (see Fig 4):

- Interproximal caries, in various stages, on essentially all maxillary and mandibular posterior teeth.

Case 3

Patient age – 11 years, 11 months (see Fig 5):

- Intact early permanent dentition with no interproximal caries present.
- Caries – occlusal surface mandibular left permanent first molar (with existing buccal restoration).

Patient age – 13 years, 6 months (See Fig 6):

- Occlusal restoration – mandibular left permanent first and second molars.
- Interproximal caries (50 to 100% of enamel thickness) on most mandibular posterior teeth.
- Early interproximal caries (25 to 50% of enamel thickness) on some maxillary posterior teeth.

Discussion

Although the overall caries rate may be declining, the rate can remain high during adolescence.[1,6,20] Consumption of sweets

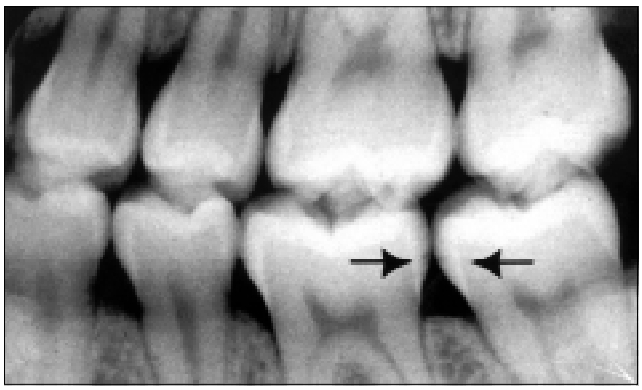

Fig 1. Case 1: 14 years, 6-month-old female. Left bitewing radiograph.

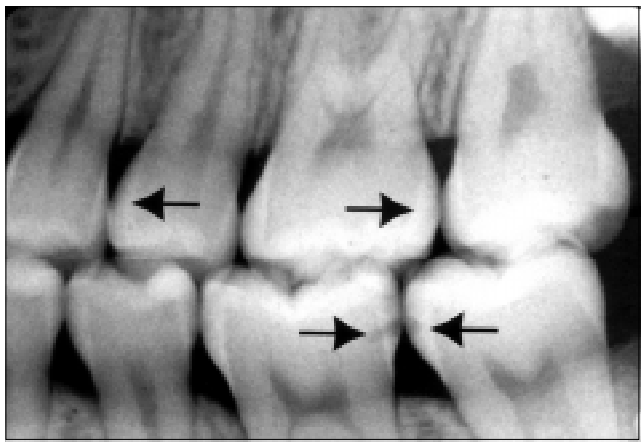

Fig 2. Case 1: 15 year, 5-month-old female. Left bitewing radiograph.

Fig 3. Case 2: 13 year, 3-month-old male. Left bitewing radiograph.

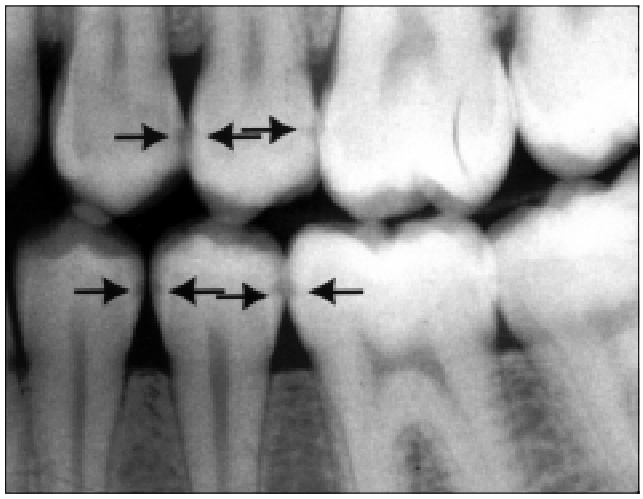

Fig 4. Case 2: 15 year, 8-month-old male. Left bitewing radiograph.

Fig 5. Case 3: 11 year, 11-month-old male. Left bitewing radiograph.

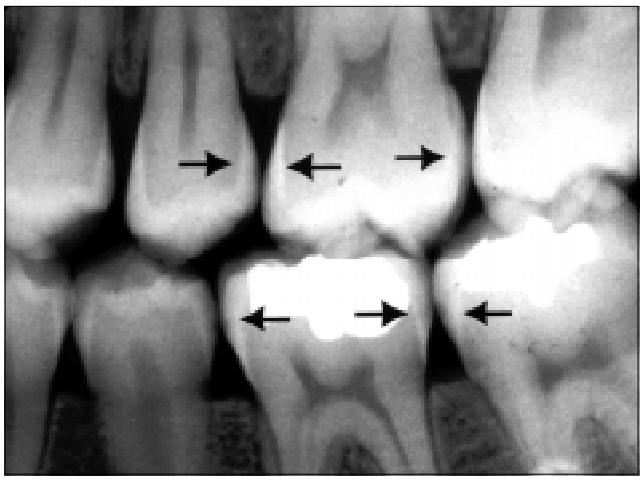

Fig 6. Case 3: 13 year, 6-month-old male. Left bitewing radiograph.

should still be considered an important caries-related factor and particularly harmful when oral hygiene is poor and consumption of other sugary products is high.[14] Total intake of sugars, especially between meals, still appears to be a risk factors in children who are susceptible to interproximal caries.[11]

Identifying one specific factor as the definitive cause of caries in any patient is impossible. However, recognition of the presence of accepted factors is one aspect of beginning to control the caries process. In the cases presented, several common factors existed. Admittedly, the overlying conditions might have been circumstantial. However, they are difficult to ignore.

When considered in context, the habitual ingestion of sweetened beverages is likely to have contributed to increased caries susceptibility in these individuals.

The consumption of highly sugared, acidic, caffeinated carbonated beverages contributes to the potential for rapid initiation and progression of caries in a multi-factorial manner. However, when the habit-forming potential of the caffeine is considered, another factor is added.

Teenagers like to drink soft drinks for the taste alone. In general, dietary modification, especially restriction of sucrose intake, is not well accepted by patients.[46] Such counseling requires an intensive effort to have an effect. Various approaches for a decrease or total cessation of consumption of caffeine have been suggested. Many such attempts are neither simple nor successful, as the individual may minimize the effects of caffeine, may be willing to accept the negative components in order to continue the drug's reinforcing qualities, or may become discouraged by unpleasant manifestations of attempted withdrawal. It is not uncommon for the individual to give up one source of caffeine by substituting an alternative source.[30]

Clinical observation, or even basic common sense, would allow one to realize that not all consumers of sweetened, caffeinated beverages experience rapid caries progression or caffeine-related symptoms. It is more likely that a relatively small percentage of individuals are so affected. However, with the increasing levels of consumption of such beverages, especially among teens, there is considerable potential for the percentages to have a proportionate increase.

Some preventive protocols targeted at dental caries may seem inadequate for susceptible patients. A significant disadvantage of some preventive measures is that many are dependent on patient cooperation. As in the presented cases, the patients reported attempts to decrease consumption and to increase dental home care. It is difficult to monitor actual compliance. Patients and their caregivers must be extremely motivated for maximum benefit. As teens become more independent, this becomes increasingly difficult to achieve.

Current and future research efforts are focusing more on individual susceptibility to dental caries. Expansion of research concepts based on more comprehensive understandings of the complete nature of the dental caries process includes topics such as DNA-based testing of cariogenic bacteria present, the virulence of the particular strains present, caries vaccines and systemic caries immunization, bacterial replacement therapy, blockage of plaque buildup, augmentation of host resistance, and the importance of the genetic composition of the host/patient.[16,46]

Conclusions

Adolescents consume a high amount of soft drinks, generally highly sweetened, acidic, and often containing caffeine. The habitual ingestion of such beverages could be a significant factor in the development and progression of dental caries in susceptible individuals.

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Abstract of the Scientific Literature

Effect of EDTA and a non-rinse conditioner on primary enamel and dentin

A non-rinse conditioner (NRC) has been recently introduced in the market for etching of enamel and dentin prior to composite resin restorations. The purpose of this *in vitro* study was to investigate the effect of NRC or 17% EDTA on the micromorphology of primary tooth enamel and dentin, and compare them with 36% phosphoric acid. Scanning electron microscopic analysis demonstrated that the etching pattern of enamel conditioned with NRC for 20 seconds was similar to the one obtained with 36% phosphoric acid applied for 15 seconds. Although all conditioners removed dentin smear layer to varying degrees, the overall performance of 17% EDTA was weaker than phosphoric acid or NRC.

Comments: This study demonstrates that a 20-second application of NRC to primary tooth enamel and dentin promotes an etching pattern that is similar to a 15-second application of 36% phosphoric acid. These results obtained *in vitro* still need to be confirmed *in vivo* in randomized clinical trials.

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Etching effect of 17% EDTA and a non-rinse conditioner (NRC) on primary enamel and dentin. Cehreli ZC, Altay N. Am J Dent 13: 64-68; 2000.

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