The Future of the Caries Decline

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Abstract

Dental caries declined in prevalence and severity among schoolchildren in the United States during the 1970s, although it still remains a problem in some areas. The decline could have started well before the 1970s, even though it was only recently identified. Caries should continue to decline as long as fluoride use remains around current levels. Use of fluoride toothpaste seems to be increasing. Sugar consumption is stable, although sucrose consumption as a proportion of total sugar consumption is declining. Increased tooth retention is thought to increase the risk of root caries in older persons, but the continued use of fluoride toothpaste should minimize any such increase. The main growth area for fluoride use may be in toothpastes. Monitoring caries trends in the future will require good data on the epidemiology of caries in young and middle-aged adults.

Key Words: caries, decline, epidemiology, fluoride, sugar

The decline in the prevalence and intensity of dental caries among American children (1) has become a dominant fact of dental life in the United States. The widespread realization that caries is no longer the scourge that it used to be has sent shock waves through all segments of the profession. It underlies the perception of an oversupply of dentists, which in turn has allowed nontraditional forms of financing dental care to develop. The caries decline has also helped promote the "marketing" of dental care because the "drilling and filling" of carious teeth in children, so long a mainstay of dental practice, is no longer needed by many of them. Other developments in organized dentistry that can be attributed at least partly to the decline in caries include the American Dental Association's report on the future of dentistry (2), the attempt to educate the public on periodontal disease through television, growing interest in nontraditional forms of treatment, and perhaps the current tensions between dentistry and its auxiliaries.

In dental public health, the decline in caries has lead to a reassessment of many preventive strategies. For most of its existence, dental public health practice has been preoccupied with the control of caries in children; questions only arose around which preventive or treatment procedures should be employed. At present, lowered prevalence rates present the problem of which procedures make best use of resources, or even whether caries prevention programs for children should be carried out at all in some communities. Dental public health is having trouble in some states in keeping its identity—partly because of budget cuts (3) but also because the specialty is widely identified only with controlling caries in children.

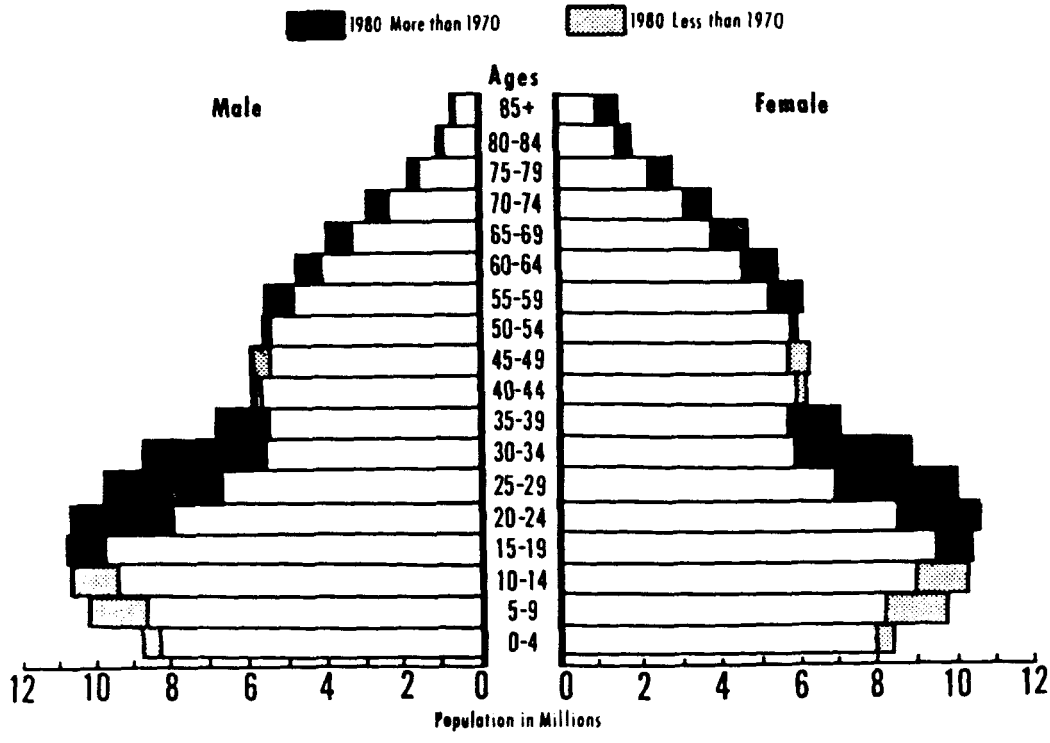
This paper examines the nature of the caries decline, and assesses whether it is a cyclic phenomenon or permanent change. The question is clearly of fundamental importance because policy decisions on supply of personnel, preventive strategies, and the nature of the provision of care depend upon the answers. The approach to this assessment will be to examine the risk factors in caries and to assess whether they are likely to alter over the near future.

Demographic Change

Figure 1 shows the population pyramid for the United States from the 1980 census, with changes in the 1970-80 decade shaded in. Several trends are evident, the most notable being the proportionate shift from youth to older years. The number of children under 15 declined 11.5 percent during that decade, while the numbers aged 65 or more increased 28 percent. The sharpest increase can be seen in the 25-34 age group, the notorious "baby boom" generation of the immediate post-World War II era, which accounted for more than half of the total increase in population during the decade.

The decline in the number of children has implications for dental practice, because restorative care for children has been the keystone of many dental practices for years. At the other end of the scale, there has been the notable and well-publicized increase in the number of older persons, the "graying of America." This increase in numbers of over-65s will continue over the next decade. While each of the bars representing older persons in Figure 1 will be diminished by deaths to some extent, life expectancy is still increasing each year (4), so the proportion of over-65s will continue to increase until the

FIGURE 1
Population changes in the United States, 1970-80



Source: US Bureau of the Census (1970, 1980)

turn of the century. Beyond then, Figure 1 further suggests that the rate of increase may plateau for a few years as the current 40- to 50-year-olds (the birth cohort from the low-fertility depression years of the 1930s) enters the post-65 year-old group, but then will just explode as the "baby-boomers" hit old age. That is a demographic event worth pondering: given the present difficulties facing the Social Security System because of the aging population and spiraling medical care costs, it is hard to imagine how the current approach to Social Security could function at all at that time.

These population trends provide a useful background to any discussion of future developments in caries epidemiology, not only coronal caries in young people but also root caries in older persons, because they help give some perspective to the size of the problem.

The Caries Decline

There could hardly be a dentist in the country who is unaware of the caries decline that has occurred in the United States in recent years. This phenomenon has been observed in many countries in the economically developed world; the proceedings of the Conference on Declining Caries at the Forsyth Dental Center in 1981 were published in a special issue of the *Journal of Dental Research* in November 1982. For the United States, interpretation of data from national surveys suggests that dental caries in children declined about 36 percent during the 1970s (1). The decline has been most noticeable on smooth and interproximal surfaces, but has also been substantial in pit-and-fissure surfaces.

This decline is both a source of pride for the dental profession and a source of anxiety to the business of dental practice. It is usually seen as a recent phenomenon; the picture in many minds was of universal caries throughout our practicing lifetimes and then suddenly it was gone. It is likely, however, that the decline in dental caries among children began earlier than that, though the suspicion of its existence did not cross professional consciousness until recently. Indeed, the first suggestion that caries among children might be in decline was not seen until 1978, and it was a tentative suggestion at that (5).

When Did the Caries Decline Begin?

It has been suggested (6) that the decline in caries really began at least during the 1960s. Certainly there is abundant evidence that caries has declined considerably over the long term, that is from the 1950s and 1960s to the present in the United States (7-10); however, that does not pinpoint its commencement. A study in Columbus, Ohio, suggests that caries there may have been actively declining between 1967 and 1973 (11), and a statewide survey

in Indiana suggests that mean DMFT values among children there dropped about 52 percent between 1971 and 1981 (12). Caries increments in the National Preventive Dentistry Demonstration Project (NPDDP), conducted during the period 1977-81, were less than expected (13). These latter studies confirm that the caries attack rate was in active decline during the 1970s—but again, they do not answer the question of when it all began.

Could the caries decline have begun even before the 1960s? Evidence is sparse, but data from the pioneering fluoridation project in Grand Rapids, Michigan, present food for thought. Mean DMFT scores among children in the control city of Muskegon, Michigan, dropped from 1.5 to 4.5 percent per year between the baseline examinations in 1944-45 and the five-year examinations in 1949-50 (14). This apparent decline occurred in the absence of fluoridation or any other fluoride programs (Table 1). The term "apparent decline" is used because the trends shown in Table 1 could be attributed to other factors, such as the use of different examiners who may not all have applied diagnostic criteria the same way. Dean and his coauthors noted, without comment, that baseline scores in Muskegon in 1944-45 were considerably higher than those in Grand Rapids (15), perhaps implying that the Muskegon scores at baseline may have been artificially high. Also, the possibility of sampling error in Muskegon is later suggested (16), meaning that the groups being compared in Table 1 may not have been chosen from the same base population. Nevertheless, the trend seen could also have been real. Probably the spectacular nature of the fluoridation results from Grand Rapids obscured any serious examination of this trend in the control city at the time, for the authors did not comment on it.

In Kingston, New York, the control city for the fluoridation study in Newburgh, also begun in 1945, caries in children showed essentially no change over the first four years (17,18). In Oak Park, Illinois, the control community for the Evanston fluoridation study, there was no change in caries experience among children of the same age between 1947 and 1956 (19). Hill and his colleagues state that they were surprised to find this result because " . . . the consensus seems to be that dental caries prevalence is on the increase except for the fluoride areas" (19). If indeed that was the consensus at that time, what was reported could be an example of a finding being contrary to conventional wisdom, and therefore just not taken seriously. (A perusal of textbooks from that period disclosed many references to the overwhelming amount of untreated caries in American children at the time, but no specific reference to whether or not it was increasing.)

To balance these implications that the caries decline may have begun a lot earlier than commonly believed, there are other reports from the 1970s detecting no such trend of decline. One report suggested that caries rates in Massachusetts did not change between the 1930s and 1956-60 (20). Glass also thought the data from the first national dental survey in the United States in 1960-62 was an underestimate (21) because DMF values were closer to those for fluoridated areas than for nonfluoridated areas. (Perhaps these national survey data gave a hint of decline without its being recognized). Suomi's review in 1978 did not detect any trends in caries in either direction (22).

To summarize these epidemiological findings, there is clear evidence that the caries decline was in full swing during the 1970s, probably started at least in the 1960s, and may have begun earlier. There is some evidence that caries rates were more or less static in the 1940s and 1950s, despite the apparent perception that caries was still increasing at this time.

This brief review of the chronology of the caries decline points up both the need for a system of collecting comparable epidemiological data at regular intervals to monitor disease trends, as well as the open minds to accept the findings, even if they are not always what we want to hear. Data interpretation should always precede conventional wisdom as a basis for policy.

Although current data support the contention that caries is declining on a national level, there are many places where caries is still a problem, as the NPDDP pointed out (13,23). Table 2 clearly shows the differences in average caries rates in control group children from site to site in the NPDDP, both for baseline scores and for caries increments. The NPDDP also found that 60 percent of carious lesions occurred in 20 percent of the children, indicating that in the overall pattern of declining caries rates there are still individual children who are susceptible, and specific communities where caries experience is higher than average.

This examination of the time scale of the caries decline provides a background from which to estimate trends in the major determinants of caries

TABLE 1
Reductions in DMFT and deft per Child, Selected Age Groups, Muskegon, Michigan, 1944–45 to 1949–50

	Mean deft		
Age	1944–45	1949–50	Percent Reduction
Primary teeth			
5	6.8	5.6	17.7
6	7.2	6.0	16.7
9	4.9	4.5	8.2
10	3.1	2.8	9.7
Permanent teeth	Mean DMFT		
6	0.8	0.6	22.2
8	2.8	2.6	8.2
10	4.9	4.4	9.6
12	8.7	7.2	16.8
14	12.0	11.1	7.7

Source: Dean et al., 1950 (15).

TABLE 2
Mean Baseline DMFS Values for Children Aged 6–13, and Four-Year DMFS Increments for Control Group Cohorts (Grades 1 & 2, Grade 5). By Site, National Preventive Dentistry Demonstration Program, 1977 and 1981

	Mean Baseline DMFS	Mean DMFS Increments	
	Ages 6–13	Cohort 1 & 2	Cohort 5
Nonfluoridated sites[1]			
Wichita, KS	3.2	1.8	4.9
Tallahassee, FL	3.9	1.9	4.9
Pierce Co., WA	4.3	2.0	4.1
Billerica, MA	5.4	2.2	4.8
Monroe, LA	5.7	3.6	5.1
Fluoridated sites[2]			
El Paso, TX[3]	1.9	1.3	2.5
Minneapolis, MN	3.0	2.1	4.3
New York, NY[4]	3.2	—	—
Chattanooga, TN	3.5	2.6	2.1
Hayward, CA[5]	4.4	2.7	3.4

[1]0.2 ppm F or less, except Wichita (0.4 ppm).
[2]All at optimal levels.
[3]El Paso naturally fluoridated, rest supplemental.
[4]New York not included in fourth year.
[5]Hayward's F levels varied substantially prior to program beginning.

Source: Bell et al., 1982, 1984 (13, 23).

experience. The major determinants which could be changing over the years are cariogenic bacteria, sugar consumption, and fluoride exposure. Other determinants, such as saliva flow rate and quality (24), might also be changing if drugs for xerostomia are being used more (25), but there are no data against which to examine that possibility.

Cariogenic Bacteria

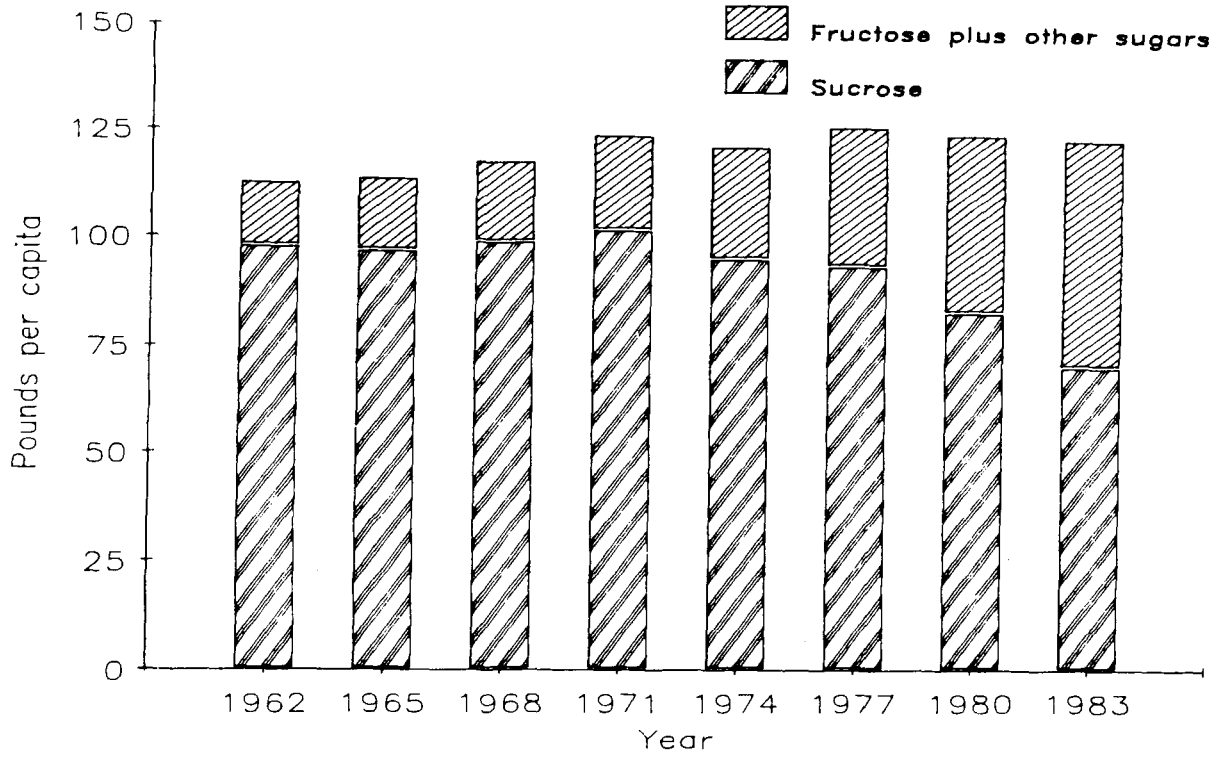
Dental caries is a bacterial disease, in which *Streptococcus mutans* has been identified as the principal pathogen, though not necessarily the only one (26). In a population group, the severity of the carious attack is related to the proportion of total bacteria identified as *S. mutans* in plaque or saliva, though this relation is not so close as to be predictive in the individual (27,28). The multifactorial nature of caries precludes bacterial counts alone from being reliable predictors of future caries activity in individuals.

Given the fundamental role of bacteria in caries etiology, however, it would be useful to know if *S. mutans* counts and proportions were increasing or decreasing in the population. Unfortunately, there are no baseline data with which to compare current values, so the question has to remain speculative. Several recent studies in which bacterial counts were obtained from groups of schoolchildren will have to be the baselines for future studies. Loesche has suggested, however, that *S. mutans* counts may be falling in children because of more widespread fluoride use, more restorative dental treatment (which reduces the open lesions that harbor bacteria), and perhaps the widespread and liberal use of antibiotics in pediatric practice (26). This argument is plausible, and if it is true, then antibiotics could be a factor in the caries decline. Can a time be reached when *S. mutans* virtually disappears? It is theoretically possible, if some other organism replaces *S. mutans* in its ecological niche in the oral cavity, but there is no practical application of this potentiality at present. For now, control of *S. mutans* cariogenic activity is best carried out by fluoride therapy and low sugar intake, which are both standard items in preventive dentistry.

Sugar Consumption

Sugar consumption is a primary determinant of dental caries activity in the community, though again the multifactorial nature of caries weakens its predictive value for individuals. While sugars may not be the only dietary component involved in caries etiology, they are by far the most important. Although the evidence implicating sugar as a major causative factor in caries development is overwhelming (29-33), the relation between total sugar consumption and caries experience holds only at the population level. Countries with high sugar consumption generally have higher caries rates than those with lower levels of sugar consumption (34). At the individual level, frequency of consumption of sugars is a more reliable indicator of caries activity than is total consumption, although obviously the two are linked. What emerges as the criti-

FIGURE 2
Sugar consumption by type of sugar in the United States, 1962-83



Source: U.S. Department of Agriculture, Personal Communication, April, 1984

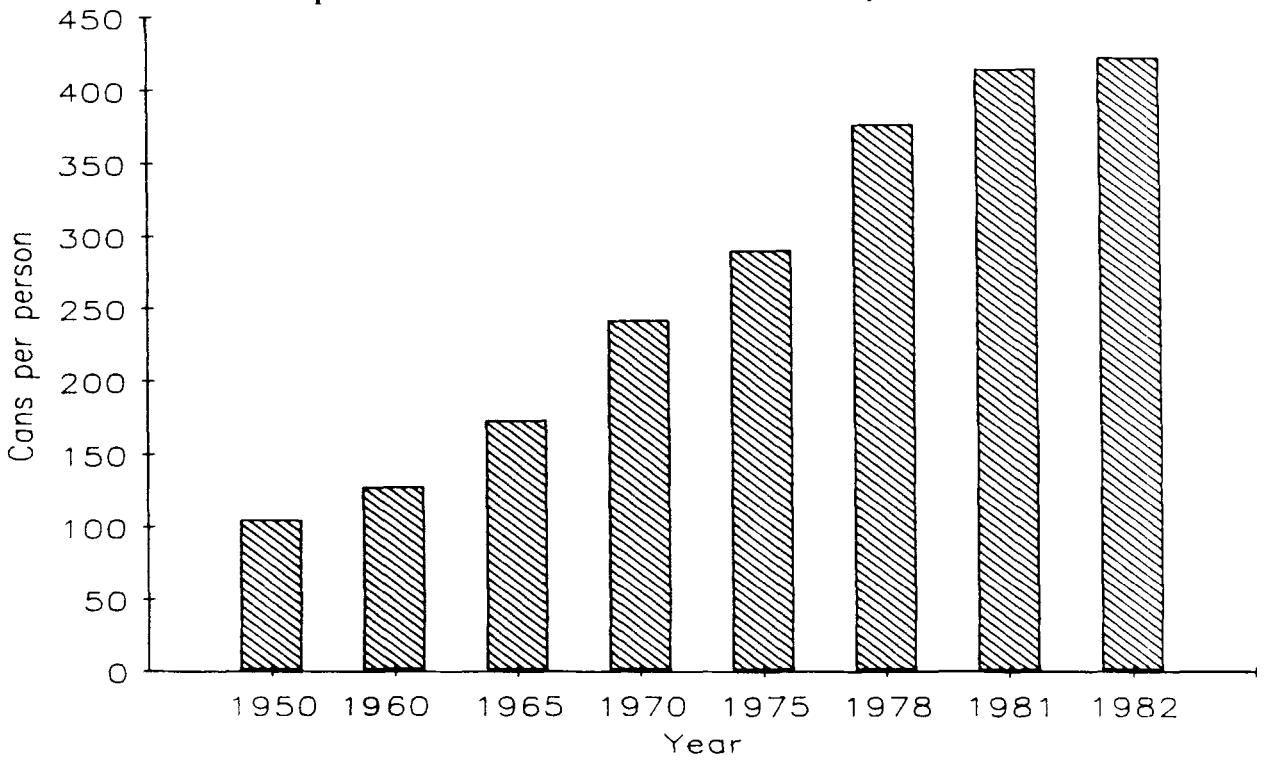
cal factor is the length of time that sugars, and perhaps other low-molecular-weight carbohydrates, are in the oral cavity and available to be retained in plaque and metabolized by acid-forming bacteria. Hence, frequent consumption of sugary drinks may be just as conducive to caries as infrequent consumption of sticky candy (35).

There are some interesting trends in sugar consumption in the United States. Figure 2 shows annual sugar consumption in the United States from 1962 to 1983. Total annual sugar consumption averaged almost 120 lbs. per person in the 1920s (36), so total consumption has not changed much since then; perhaps it has risen slightly in recent years. The interesting shift in consumption patterns is that from the disaccharide sucrose to monosaccharides (Figure 2), especially to fructose because of the increasing use of High Fructose Corn Syrup (HFCS) in food manufacturing. What effect this trend has had on the caries decline is conjectural. Recent evidence suggests that fructose and sucrose differ little in their potential to be metabolized by cariogenic bacteria (37,38,39). If sucrose is specifically required for the production of extracellular polysaccharides by acid-producing bacteria (40), however, then it is possible that reduced sucrose consumption may contribute to the sharp decline in interproximal and smooth-surface caries. The use of HFCS by food manufacturers is predicted to remain high for economic reasons; indeed, 1985 may be the first year when sucrose comprises less than 50 percent of all sugars consumed. The decision by major soft drink manufacturers to replace all sucrose with HFCS in their sugared products is a major factor in reduced sucrose consumption (41).

Two related trends of interest to oral health are that confectionery consumption is declining while soft drink consumption is increasing. Confectionery consumption declined from 18.7 pounds per person in 1972 to 15.4 pounds in 1980 (42). In the absence of data on age-related patterns of confectionery consumption, this decline may reflect the drop in the number of 5- to 17-year-olds (if children are the chief eaters of confectionery); but whether these figures really mean a per capita drop in consumption by children is not known. By contrast, there is no doubt that soft drink consumption continues to go up, up, up, regardless of demographic change, economic recession, or anything else (Figure 3). Annual consumption in 1982 averaged 419.5 cans (12-ounce)—or more than one per day—per person (43). As stated earlier, the upward trend of soft drink consumption probably is associated with the sharp increase in HFCS use.

The critical factor in sugar consumption and cariogenicity seems to be the length of time that sugar is present in the mouth. Current trends in overall sugar consumption suggest that a lot of sugar is

FIGURE 3
Consumption of soft drinks in the United States (selected years, 1950-82)



Source: National Soft Drink Association, 1983

being retained for significant periods in a lot of mouths, and will continue to be so retained. Caries is thus unlikely to disappear in the near future, although its continued decline is likely with increasing use of fluoride.

Fluoride Exposure

Fluoride has been the cornerstone of preventive dentistry for many years now. Water fluoridation began as a public health measure in January 1945, and by the end of 1980 nearly 116 million persons, or just over half the population of the United States, were receiving fluoridated water (44). School fluoridation programs have been established in 500 schools in nine states, reaching nearly 168,000 students (44). Dietary fluoride supplements reportedly are prescribed by 60 percent of dental practitioners and 82 percent of child patients are reported to receive fluorides topically in the dental office (45). Sales surveys show that the per capita purchase of toothpaste is rising again in recent years (Table 3), and fluoride toothpastes continue to dominate this market (46).

The value of fluoride is that it interferes with the cariogenic process in a variety of ways. Fluoride absorbed systemically prior to tooth eruption is incorporated into the developing hydroxyapatite crystal; professional application of high-concentration fluoride leaves an available reservoir of fluoride ions to respond to the acid challenge, and consistent introduction of low concentration fluorides provides fluoride ions to interfere with glycolysis in plaque, and to aid remineralization (47-50). Fluoride in high concentration (i.e., APF gels) may also have a bactericidal action against cariogenic bacteria (26), and its long-term use in low concentrations (most commonly toothpastes) may have created over time a "hostile environment" for aciduric cariogenic bacteria (51). So long as fluoride use continues at its current levels, it is hard to see any reversal in the caries decline. The challenge in promoting appropriate use of fluoride is to extend the way it is enjoyed by middle-class suburbanites (typically through water fluoridation, dentifrices, and office treatment) to those communities where caries is

TABLE 3
Per Capita Purchases of Toothpaste, Toothbrushes, and Dental Floss, in Constant 1983 Dollars, United States, 1977–1983

Year	Toothpaste	Toothbrushes	Dental Floss
1977	4.28	0.94	Not Recorded
1978	4.12	1.04	0.25
1979	4.03	0.96	0.23
1980	3.92	1.00	0.21
1981	3.95	0.98	0.21
1982	4.09	1.00	0.20
1983	4.25	1.05	0.21

Source: *Drug Topics*, various issues.

"To summarize these epidemiological findings, there is clear evidence that the caries decline was in full swing during the 1970s, probably started at least in the 1960s, and may have begun earlier."

still unnecessarily high. The challenge does not seem to lie in getting more fluoride to those favored communities, for there is evidence that the mildest forms of fluorosis are now being reported even from nonfluoridated communities (52). The research challenge is to determine just how much fluoride is enough, what the best delivery combinations are, and how to get the fluoride to those who need it most.

With the vital role of fluoride in determining caries levels, it is worth assessing what the future use of fluoride might be. Water fluoridation may grow only slowly beyond its current status. Although at present 41 of the 50 largest cities in the country are fluoridated, progress in the remaining cities is difficult. Few communities today are willing to fluoridate without a referendum, and referenda seem to be getting harder to win. Federal funds to initiate fluoridation projects, which were responsible for a surge of new projects during 1979-81, are now buried in preventive block grants, so that fluoridation must now compete with other worthwhile public health priorities for funds. Overall, it is hard to be optimistic about significant growth in the population being reached by fluoridated water while America's social and political attitudes remain as they are today. Professional applications tend not to reach many who could benefit most because the communities where these needy individuals are commonly found often have limited access to professional services. Funds for dental public health services, through which the needs of these deprived communities could best be met, continue to be scarce. Probably the main growth area in fluoride use is going to be in fluoride toothpastes. If fluoride toothpastes continue to be used by more and more people, then caries levels overall are likely to continue their decline.

A rapid and substantial drop in dental caries would occur if dental practitioners used fissure sealants appropriately and frequently. For a variety of reasons, however, use of fissure sealants remains low (45). It is hoped that with continued promotional efforts and improved reimbursement prospects (53) their use will improve in the future.

Root Caries

The aging of the population and the improvements in tooth retention (54) have raised the possibility that root caries will become a greater problem over the next decade. A difficulty in addressing this question is that there is sparse information on the extent of root caries at present (55,56). Root caries is part of the national survey of adults taking place in 1985, so good national data should be available soon. In the meantime, a few local surveys give some information. Between 20-60 percent of several adult populations are reported to have some root caries, and the mean number of lesions per person is reported as 1.1-1.9 (57-59). A recent study in Finland of a representative sample of adults aged 30 and over reported a lower prevalence: 21.6 percent of men and 14.5 percent of women (60). The pathology of root caries is not well understood, although it does appear to be associated with different bacteria, chiefly *A. viscosus,* when compared with coronal caries (61). This bacterial association is not surprising in view of the close relation between root caries and periodontal recession.

As today's 45-and-older generation ages (62), the aging of the population and the predicted increase in periodontal disease in the near future favor the development of increased levels of root caries. From the public health viewpoint, the magnitude of the problem will increase to some extent because of the sharp increase in the numbers of older people and increased tooth retention (54). But root caries, like coronal caries, is inhibited by fluoridated water (63,64), and presumably by fluoride toothpastes also. If the widespread use of fluoridated toothpaste continues, the prevalence of root caries in the older population may not increase much above present levels. In addition, the improved oral hygiene status in today's young adults, if maintained as expected (62), will likely reduce periodontal disease over the medium- to long-term, and will thus reduce the risk of root caries even further.

To Be Determined

The present generation of young adults and teenagers is the "caries-free generation"—if not literally, then at least one in which low caries experience is commonplace. It is not known whether this group has been saved permanently from caries, or whether the caries decline currently being witnessed is the first phase in changing coronal caries from a childhood to an adult disease. It is possible that many young adults, now virtually free of caries, could develop what was considered a childhood pattern of caries in their later adult years if their lifestyle changes to one that favors development of caries. Good habits of diet and oral hygiene probably depend largely on a stable life situation, a stability that may be readily threatened by the

stress of moving, a divorce, a career change, or some other major life event. Much of the future of caries epidemiology will be the study of caries patterns in today's relatively caries-free generation.

Conclusions

1. Overall caries experience will continue to diminish from present levels in young people. Fissure caries will show some decline from present rates, and a slightly higher proportion of all lesions than at present will be pit-and-fissure lesions.
2. Smooth surface and interproximal caries will continue to diminish in young people, so that in the future these lesions will be seen less frequently than at present.
3. Root caries prevalence will increase only slightly from current levels, and then will show gradual long-term decline.
4. Oral hygiene status will continue to improve, and the consistent use of fluoridated toothpaste in achieving good oral hygiene will continue to develop an intraoral environment hostile to cariogenic bacteria, thus furthering the caries decline.
5. Continued reduction of caries prevalence in children, when combined with the decrease in the number of children over the last decade, will continue to reduce the magnitude of caries in children as a public health problem.
6. The increasing number of older persons, most of whom are retaining their natural teeth, will increase the magnitude of root caries as a public health problem, even though the number of lesions per capita is unlikely to increase much.
7. As the present low-caries generation of young adults ages, the epidemiology of caries will require study to determine if the caries decline in today's children is permanent or rather more of a delayed nature.

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