Changing Trends in Dental Caries

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In underdeveloped countries the number of dental caries is increasing at a frightening rate whereas in industrialized countries the caries rate has declined by about 40% in the past 10 years. In 1982, for the first time ever, the average 12-year-old in underdeveloped countries, where 80% of the world’s children live, had a higher dental caries score (decayed, missing, filled—DMF) than those in industrialized countries. The increase in caries is associated with increases in sugar consumption. By 1984, sugar consumption in underdeveloped countries is predicted to exceed that of industrialized countries. The decline in caries is associated with the widespread availability of fluoride toothpaste, changes in the pattern and quantity of sugar consumption and possibly with the frequent use of antibiotics. The declines have been greater in areas with fluoridated water supplies. The trends in rates of dental caries have important public health implications. They include the urgent need for a food policy to limit the consumption of refined sugars, policies to ensure the availability of fluoride, a reduction in the number of dentists in industrialized countries, the greater use of dental therapists and increasing the interval between dental check-ups to two years or more.

For the first time ever, the frequency of dental caries is greater among children in Third World countries than in industrialized countries. Figures from the World Health Organization dental data bank showed that the average number of teeth with caries per 12-year-old child as assessed by the DMF index (D = decayed, M = missing, F = filled) was 4.1 for Third World countries in 1982 and 3.3 for industrialized countries. Twenty years ago the index was less than 1 DMF-teeth for most underdeveloped countries and as high as 10 DMF-teeth for developed countries.1 The change in pattern of dental caries is well illustrated by comparing the disease severity in two contrasting cities—Boston, Massachusetts and Bangkok. In 1960 the DMF in 12-year-olds was 12.3 in Massachusetts and 0.6 in Bangkok. There has been a marked decline in caries in Massachusetts in the past 20 years; the most recent DMF index was 3.5 at 12 years.2 Bangkok children have experienced a deterioration in their dental status since 1960; in 1982, the DMF was 4.4, a sevenfold increase.3

The objective of this article is to review the current trends in dental caries, the possible reasons for these trends and the implications for the prevention and treatment of the disease.

DENTAL CARIES IN INDUSTRIALIZED COUNTRIES

Dental caries were uncommon in Western industrialized countries such as England before 1850.4,5 Thereafter the caries rate increased rapidly due mainly to the rise in sugar consumption from 19 lb/person/year in 1850 to 90 lb/person/year in 1900. The increase in prevalence and severity was interrupted by the two World Wars. Most countries with food rationing experienced decreases of approximately 35% in the severity of caries during World War II.6,7 After the war dental caries increased reaching a peak in the 1960s.8 Since the early 1970s there has been a compound annual reduction ranging from 4.3% in Scottish 5–6-year-olds to 16.7% in Finnish 6-year-olds. Among 11- and 12-year-olds the annual reduction rates were 3.8% in The Hague and in Shropshire, England; 4.8% in Denmark; 5.1% in the USA; 5.0% in Bristol and 8.7% in Finland.9

The decline in caries has not been as dramatic in adults as in children because caries are mainly a disease of childhood and the reductions in children will only be reflected in adults in the next ten years. Nevertheless reductions in caries in young adults have been reported.10 In England, the greatest decline has occurred in those adults attending dentists only when in pain.11

The decreases in dental caries in Western countries are encouraging but they should be considered against a background of high levels of disease in the 1960s. And, despite the decreases, the prevalence of dental
The reduced intake of sucrose in infants does affect the numbers of cariogenic bacteria and the incidence of caries.\textsuperscript{20,21} There are no reliable data on the per capita sucrose consumption among children during the 1970s. Children under 16 years of age constitute about one-fifth of the total population. So a 25% reduction in sugar consumption in that age group would result in a decrease of only 5% of the national average.\textsuperscript{22} In Britain the sucrose consumption has decreased by about 20% in the past 15 years; most of the decrease has occurred since 1974. In the USA, although total sugar consumption has increased since 1965, sucrose consumption has decreased markedly since 1971.\textsuperscript{2} The sugars being consumed more commonly in the USA are the monosaccharides glucose and fructose. Fructose is less cariogenic than sucrose.

Sucrose consumption has not decreased significantly in some of the countries where declines in dental caries have been recorded but the high levels of sucrose consumption in those countries is on the plateau section of the S-shaped dose-response curve which represents the sugar/caries relationship.\textsuperscript{15} At those levels of sucrose, the pattern of consumption is more important than the amount.

Fluoride
Fluoride in toothpaste has undoubtedly contributed significantly to the reduction in dental caries.\textsuperscript{22,23} Fluoride toothpastes are not widely available in countries such as Russia and the German Democratic Republic which have not experienced a decline in dental caries. In the UK fluoride toothpaste sales were 4% in 1970, 16% in 1971 and reached 95% of total toothpaste sales in 1977.\textsuperscript{23} Fluoride toothpastes have been shown to be effective in reducing caries in teenagers. The use of a fluoride toothpaste from an early age ensures that a high intra-oral level of fluoride is present when the teeth erupt into the mouth. At that stage the teeth are more caries-susceptible and the therapeutic effect of fluoride is greater. In addition, fluoride may interfere with the metabolism, transmission and implantation of cariogenic organisms.

Declines in caries have occurred in areas without water-fluoridation but in areas with water fluoridation, the declines have been more marked than in non-fluoride areas. In the US, children aged 5–17 years examined in the 1979–80 national dental caries survey, who had a continuous history of water fluoride exposure had 33% fewer carious surfaces than children without water fluoride exposure.\textsuperscript{24} Most of the children in the survey were using fluoride toothpaste so the reduction in water fluoride areas was in addition to

caries is still unacceptably high and in some countries little or no decline has occurred. For example, in England and Wales, where there has been a reduction of about 50% in the proportions of children aged 6 and 7 years and a decrease in the DMF of 1.5 per child between 1973 and 1983, 8 out of 10 children aged 10–13 and 9 out of 10 children aged 14–15 had experienced caries. The 15-year-olds still had about six teeth attacked by caries—about 20% of their teeth.\textsuperscript{12} Within the UK there are large differences between countries in the levels of dental caries and it appears that the decline in caries has not been marked in Scotland and Northern Ireland. Among 15-year-olds in England the DMF was 5.6 compared with 6.7 among 15-year-olds in Wales, 8.5 in Scottish and 9.2 in Northern Ireland 15-year-olds.\textsuperscript{12} So the decay experience in 15-year-olds in Northern Ireland in 1983 is similar to the levels reported in England in 1973.

There are a number of industrialized countries where decreases in dental caries are not occurring. These include Poland, German Democratic Republic, Bulgaria, Russia, Hungary, Italy, Spain and Austria.\textsuperscript{13,14} What are the probable reasons for the marked decline in dental caries in most Western industrialized countries? No single factor has been found to account for the decline and the most likely explanation is that a combination of factors is responsible. Dental caries are a sugar-dependent infective disease.\textsuperscript{15} The demineralizing effect of the cariogenic challenge can be prevented or reduced depending on the strength of the challenge and the availability of fluoride at the site of attack.\textsuperscript{16} Fluoride reduces the enamel’s solubility in acid and it influences the remineralization of lesions as well as the metabolism of the oral bacteria.\textsuperscript{17} Some authors believe that the main mechanism whereby fluoride acts in caries prevention is in promoting remineralization.\textsuperscript{18}

The factors to consider in relation to the decline in caries are sugar consumption, fluorides in toothpaste, fluoride-rinsing, systemic fluoride, improved oral hygiene and the use of antibiotics.

Diet
Dietary changes and in particular changes in the pattern of sucrose consumption have been reported from a number of countries. One of the important changes in diet has been the increase in breast-feeding, a reduction in the number of parents adding sugars to bottle feeds, a reduction in the use of sweetened comforters\textsuperscript{19} and changes in the composition of baby formula feeds and of processed baby foods. A wider variety of sugar free and low-sugar foods are available.
the reduction from the fluoride toothpaste. Additional benefits from water fluoride were also reported in England between 1970 and 1980. Children in Birmingham (fluoridated) experienced a reduction of 54% compared to a 32% reduction in non-fluoridated Dudley.23

Fluoride supplements such as fluoride tablets and drops, and professionally applied topical fluoride may have been responsible for a very small amount of the decline. In most countries where declines have been reported, such as England, Ireland, Holland, these measures have not been widely used. The additional effect of professionally applied fluoride and fluoride in toothpaste is not clinically significant.26 Neither is there unequivocal evidence that fluoride-rinsing, a widely used measure in Scandinavian countries and in the US, has any additional effect when children are using a fluoride toothpaste.27 Marthaler22 using data from Zurich has attempted to estimate the proportion of the decline in caries which can be ascribed to fluoride. In Zurich, fluoridated salt (250 ppm), supervised toothbrushing with fluoride and fluoride toothpaste are used. He estimated the total effect of fluoride in all forms in reducing the Decayed + Filled Surfaces (DFS) from 26.3 to 11.8 to be in the range of 44–55%.

Oral Hygiene
There is no unequivocal evidence that toothbrushing and good oral cleanliness reduces caries experience.28 The weight of evidence is that improvements in oral hygiene, which has occurred in the past decade, is not a significant factor in the reduction of caries.23

Antibiotics
Antibiotics are widely used both therapeutically and in animal husbandry. Loesche, Eckland and Burr29 found an inverse relationship between caries experience and antibiotic usage in children. The present generation of children have been exposed more intensively to antibiotics than their predecessors.2 The anti-bacterial action of some antibiotics and the increased caries resistance of teeth affected by tetracycline suggests that antibiotics may play an important unintended role in decreasing dental caries in children eating less sucrose and using fluoride toothpaste.

DENTAL CARIES IN UNDERDEVELOPED COUNTRIES
The pattern of dental caries in underdeveloped countries is following the pattern of the disease which was observed in Europe in the 18th and 19th centuries.4,5 An increase in the prevalence and severity, first in the upper income groups then in the urbanized populations followed by changes in disease prevalence in the rural groups. The influence of social class is strong.30,31 In Ethiopia, children from more affluent high social class families had four times more caries in primary teeth than poorer children and twice as many permanent teeth with caries.31

Urbanized populations in underdeveloped countries are more likely to consume refined sugars than those in rural areas. Therefore it is not surprising that caries rates are higher in urban populations. In the Sudan, 15–19-year-old urban children had seven times more caries than children in rural areas where the sugar consumption was below 5 lbs/person/year.32

Deteriorating dental health is seen as a necessary consequence of a certain kind of economic growth because a change to a more refined high-sugar diet is associated with economic growth. Sugar consumption in underdeveloped countries is rising; by 1984 consumption is predicted to be higher than in industrialized countries where consumption is falling.33 Industrialized countries are decreasing their imports of sugar from underdeveloped countries; many of these are sugar-producers and are now consuming four-fifths of what they produce. Previously they exported four-fifths of production. In addition to local production, in some underdeveloped countries, sugar is the second largest food item imported.

The importation and export of sugar is regulated mainly by the International Sugar Agreement (ISA).35 One of the objectives of the 1977 ISA is: ‘To increase sugar consumption and in particular to promote measures to encourage consumption in countries where per capita consumption is low.’ The potential for promoting the consumption of sugar is greater in underdeveloped countries because they are low sugar consumers and most developed countries have either reached saturation levels of sugar consumption or switched to sugar substitutes.

Sugar Availability and Dental Caries
Numerous studies have shown that populations who have changed their diet from locally available agricultural products to one containing manufactured and processed foods, particularly those containing sugar, have experienced increases in dental caries.36

Wilska37 was the first to analyse the relationship between per capita sugar consumption and caries rates; he found a strong positive relationship. Buttner,38 who studied the relationship based on data from 19 countries, reached a similar conclusion. More recently Sreebny39 found a highly significant relationship between availability of sugar and DMF in 47 countries. The linear regression had the form $y = 0.06 + 0.04x$. 

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The average annual per capita sugar consumption level increased in underdeveloped countries from 22.3 kg in 1968 to 27.4 kg in 1981. African countries had the largest increase—39% in annual per capita consumption over that period. Asia had an increase of 24% whilst Latin American countries showed an increase of 21%.

All the countries where the DMF had increased had increases in mean per capita sugar consumption. Those countries where the dental caries rate had decreased had, with the exception of Fiji, reduced their sugar consumption. They were Uganda—DMF reduced from 2.4 to 1.5 and sugar consumption from 8.3 to 1.2 kg; Cuba—DMF reduced from 5.6 to 4.8 and sugar from 66.6 to 56.9 kg; and Sri Lanka where the DMF decreased from 3.0 to 1.9 and sugar consumption from 18.5 to 8.3. These data support the findings from detailed studies which suggest that the dose-response relationship between sugar and caries approximates an S-shaped curve. The curve rises more steeply when sucrose containing foods are eaten frequently by young children with newly erupted teeth. When the frequency of ingestion is low and the teeth are more mature (beyond four years post-eruption) the curve rises more gradually and does not reach the same height as the high frequency curve. Takeuchi claims that the dose-response relationship holds up to 35 kg/person/year. Beyond that level the curve flattens. Takeuchi showed that for increases in sugar consumption from 0.2 to 15 kg/person/year, the annual caries incidence rate was positively correlated with sugar consumption \((r = +0.8)\). The rate of attack increased at sugar levels above 10 kg/person/year. And there was a further increase in the intensity of the attack at consumption levels of 15–21 kg/person/year. At annual levels of consumption below 15 kg, most sugar consumed is visible sugar. Beyond that level an increasing percentage of sugar consumed is in more cariogenic manufactured products such as soft drinks, sweets and biscuits.

### IMPLICATIONS FOR PREVENTION AND TREATMENT

The main conclusions that can be drawn from the different trends in industrialized and underdeveloped countries are:

1. Sugars are implicated as the principal cause of dental caries. To achieve further improvements in dental health in industrialized countries and prevent the increase in caries in underdeveloped countries, a food policy directed at achieving an annual per capita sugar intake of 10 kg or less in areas without water fluoride or fluoride toothpastes is needed. In areas with fluoride, 15 kg of sugar/person/year will ensure a low prevalence of dental caries.

2. Water fluoridation should be encouraged. Where this is not feasible for practical or political reasons, salt fluoridation should be considered. In areas with optimal and sub-optimal levels of fluoride in the drinking water, toothpastes should contain fluoride. Other topical applications are not recommended when large percentages of children are using fluoride toothpaste.

3. Because the rate of progression of dental caries is generally very slow and the rate is even slower at the levels of caries being experienced in most industrialized and underdeveloped countries, the intervals between dental check-ups should be increased to two years for teenagers and to even longer intervals for adults. There is no scientific basis for six-monthly intervals between dental examinations.

4. Many fewer dentists than exist at present will be needed in industrialized countries in future. Dental caries which do occur can easily be treated by dental therapists. In future more therapists and fewer dentists, to deal with the more complicated problems, will be required.

5. There are about 1500 million children in the world under the age of 15 years; 80% of them are in underdeveloped countries. Every increase of 1.0 in the DMF would require about 200 dental operators per million children. Even if the trend in dental caries is halted, there will be a need for 1000000 dental personnel compared to the present 200000. If the trend is not arrested, the need for dental personnel will be much greater. The cost of training and employing such a dental workforce is beyond the educational or financial capabilities of most underdeveloped countries. Therefore, primary prevention aimed at controlling the availability of refined sugars and sugar containing foods, drinks and sweets is needed.

6. The effectiveness of dental health education will be...
greatly enhanced if sugar control, sensible use of fluoride and oral cleanliness to reduce periodontal disease, are encouraged by all primary health care workers.

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