# Prevention policies in the light of the changed distribution of dental caries

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Changes in the distribution of caries in economically developed nations over the last 15–20 years include 1) an overall decline in prevalence and severity in child populations; 2) an increasingly skewed distribution, with most disease now found in a small number of children; and 3) concentration of caries in pit and fissure lesions. Exposure to fluoride is usually seen as the principal reason for the caries decline, with little change in intraoral levels of cariogenic organisms or the annual consumption of sugars. Prevention activities are still most often conducted under policies that were established at a time when caries was a more widespread public health problem, so these policies should be critically examined in the light of modern conditions. While prevention should remain the prime activity of public health agencies, despite the reduced severity of caries, the relative economic efficiency of various procedures should be constantly evaluated. Despite the attractions of targeting, cost-effective prevention should be aimed first at the whole population, with more expensive activities targeted to all children in a chosen geographic area rather than to individually selected children. In the Scandinavian countries the prime population strategies are the regular use of fluoride toothpaste and public education that emphasizes oral hygiene. In selected areas where caries levels are still relatively high (that is, targeted geographic areas), fluoride rinse and tablet programs, provided for a whole classroom at a time, can enhance intraoral fluoride levels where necessary. Fluoride varnish and sealants, though effective, are expensive and need careful selection of locality and teeth to be efficient. Individual children with a persistent caries problem, now relatively small in number, can receive individualized preventive treatment in the clinics of the school dental service. □ *Caries; fluoride; population; sealants; targeting*

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It is a basic tenet of public health practice that disease experience requires constant surveillance because old problems can diminish in importance and new ones can arise. A constant infusion of information is needed to evaluate existing programs and to plan new ones so that the public's health can be maintained at the highest level possible. The purpose of this article is to assess the current status of caries distribution among children in the economically developed world, and to assess whether our prevention strategies are still effective and efficient in the light of the changes that have occurred in caries experience. The emphasis will be on conditions in the Scandinavian countries.

Public health values oblige us not only to be effective in controlling caries but also to be as economically efficient as possible in achieving our program goals. I suggest that economic efficiency is both prudent administration and a social obligation to the public that supports us.

## Background to existing programs

The longest-standing, most highly developed, and most generously funded programs to control dental caries among children are to be found in the Scandinavian countries. They began many years ago when there were virtually no effective means of preventing caries, and thus traditionally were based on clinical treatment. Initial preventive programs were based on the premise that caries was a massive public health problem among schoolchildren, and that the children were uniformly susceptible to the disease. That was a rational assumption until quite recent years, for DMF scores among Scandinavian children into the 1970s were the highest in the world, matched only by those in New Zealand, another nation with a well-developed school dental service. This is illustrated in Fig. 1, which shows Norwegian caries experience for 13- and 14-year-old children relative to that of six other countries from the first International Collaborative Study of Oral Health, conducted during the mid-1970s (1).

## Caries trends

Caries experience among children in the economically developed nations has declined substantially since the 1960s and 1970s. Most authorities attribute this large-scale decline to the various uses of fluoride (2), with little effect ascribed to changes in sugar intake or distribution of cariogenic microorganisms. Despite the presumptive evidence, however, we do not know all of the reasons for the decline in caries (3).

These profound changes in caries distribution in the

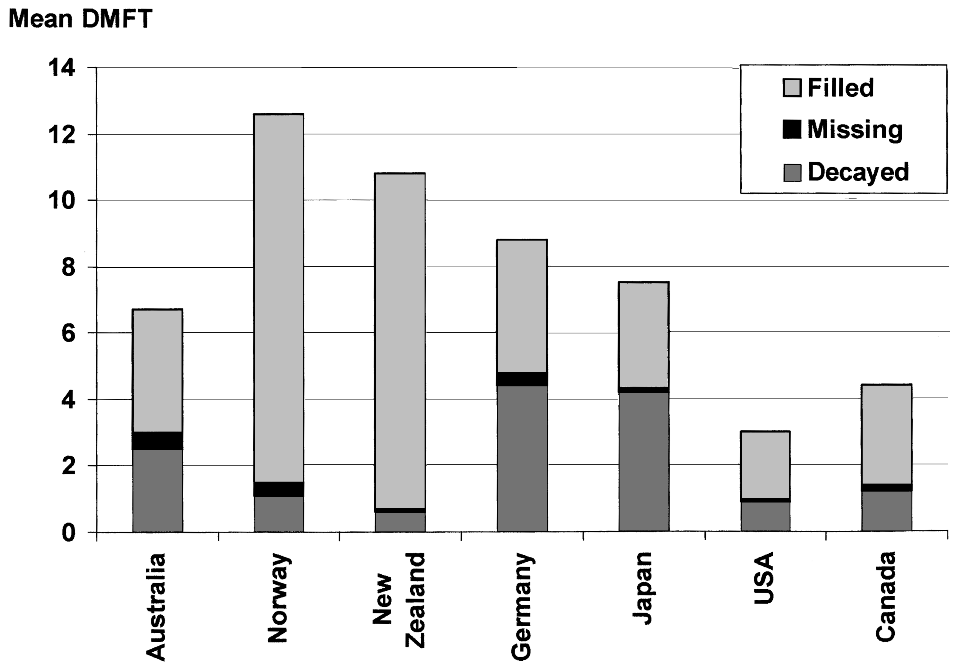


Fig. 1. DMFT scores for 13- and 14-year-old children from the first seven countries in the International Collaborative Study, 1973–77. Source: Arnljot et al. (1).

economically developed nations are now well documented. They first became evident around the end of the 1970s, though they may have begun before then and simply not been detected. There are essentially three aspects to these changes, as follows:

- *There has been an overall decline in the prevalence and severity of caries in child populations and a slowing of the rate of progression of existing lesions.*

The decline in caries experience among children in the economically developed nations was documented in a special issue of the *Journal of Dental Research* published in November 1982. The caries decline in the permanent dentition among children in the developed nations has continued since then (4–10), so that it is now common for mean DMFT levels among 12-year-old children in these countries to be below the World Health Organization's global standard of 3.0 for the year 2000. There is mixed evidence with regard to whether caries experience in the primary dentition has leveled out (6, 11, 12) or is continuing to decline (13).

- *The distribution of the disease, while never completely normal, has become increasingly skewed.*

The skewed distribution of caries means that a high proportion of lesions is concentrated in relatively few children. A broad categorization of this distribution for 12-year-old children in the United States is shown in Table 1, and similar polarized distributions are seen in other countries when overall caries experience is low (5, 14, 15). It has also been long observed, and is now documented (16), that as overall caries experience declines, it does so first in the least susceptible surfaces (that is, free smooth and approximal surfaces) and last in the most susceptible surfaces (pits and fissures on first and second molars). When caries experience increases, not only are fewer children caries-free but the polarized distribution is reduced (17). The characteristics of the caries distribution in the economically developed countries are shown in Table 2, and that is how the caries distribution is increasingly looking in Scandinavia.

- *The disease that does occur has become increasingly concentrated in pits and fissures; approximal lesions have become a smaller proportion of the total caries burden and in some places are now rare in primary schoolchildren.*

In Phase 1 of the NHANES III national survey in the United States in 1988–91, only 12% of lesions in children aged 5–17 years were in mesiodistal surfaces (12). In a Swedish study around the same time, the figure was 21% (17).

We could add to this list the recognition that caries can be reversed in its early enamel stages. Many early enamel lesions develop no further, and others apparently disappear. While this has helped our understanding of the disease, it has no direct effect on prevention policies in public health.

## Issues raised by the caries decline

While the caries decline is good news, it is not an unmixed blessing in dentistry. For example, it raises uncomfortable issues with regard to whether caries is the same public

Table 1. The nature of caries distribution among 12-year-old children in the United States

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|---|
| Fifty percent of the children are caries-free. |
| Twenty-five percent of the children have 25% of all carious lesions. |
| Twenty-five percent of the children have 75% of all carious lesions. |

Source: Kaste et al. (12).

Table 2. Characteristics of caries distribution when overall caries prevalence and severity are low

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|---|
| Disease will be concentrated in a minority of children (for example, some 25% of the children will have 75% of all carious lesions). |
| Caries will be predominantly pit and fissure lesions, with relatively few approximal surfaces affected and virtually no free smooth surfaces affected. |

health problem that it used to be, and therefore whether its control merits the same allocation of public resources that it traditionally has received. This is particularly true in Scandinavia, where the long-established public dental services directed at children are the most generous in the world. Improved technology in dentistry, allied to the caries decline, means that the treatment needs for child populations can often be met in much shorter time, or in the same time with fewer staff members, than was the case a generation ago.

In terms of cost-effectiveness, the first question that arises is whether we should be continuing our preventive efforts in caries control. Has caries prevalence become so low that we are wasting a lot of time and money on prevention? For some diseases (tuberculosis is one example) for which 'prevention' means early case-finding (secondary prevention), the cost of mass screening to find just a few cases can easily exceed the cost of treating people who develop symptoms, and treatment costs much the same either way. For dental caries, however, we have highly effective and relatively inexpensive means of primary prevention, and we are speaking of a disease that at its peak affected a substantial majority of the population. With regard to caries, we should certainly be continuing public health prevention; effective prevention of dental caries is more cost-effective than its treatment.

While we promote the preventive philosophy to the public and to our politicians, there is a second level of cost-effectiveness that should be constantly reexamined within dentistry. This is the recognition that some procedures are most cost-effective than others. When caries was highly prevalent and severe, even modest prevention activities led to considerable reductions in disease levels; cost-effectiveness was not an issue. The reduced severity of caries we see today, however, means that further reductions in disease levels require greater commitment of resources to make any impact. We get trapped in the 'diminishing returns' phenomenon: costs remain fixed but returns diminish, and more and more resources are required to make incremental advances. There is no question that we must give serious thought to the *relative* cost-effectiveness of our caries-preventive measures.

For the most part, caries prevention is still conducted under policies that were established at a time when caries was a more widespread public health problem than it is now. One response to the altered caries distribution is the emergence of 'targeting' as a way of effectively controlling caries in a cost-effective manner. Targeted programs are aimed at specific groups seen to be at high risk of disease, in contrast to a 'population' strategy, which means programs aimed at the whole population regardless of risk. These terms are widely used these days, and so require some definition.

## The population approach

A population strategy means that public health administrators set program goals and objectives for the whole population for which they are responsible. This can be a country, a region of the country, or a smaller jurisdiction like a city or county. Resources are allocated for this plan, and activities are directed toward achievement of the planned objectives. The essence of a population strategy is that the program is aimed at everyone in the population, whether diseased or healthy, whether they attend public health facilities or private practitioners for their health care needs, and whether or not they practice healthy behavior. Examples of caries-preventive strategies that by their very nature apply to the whole population include fluoridation of public water supplies, dental health education through the mass media, and the use of fluoride toothpaste.

The advantage of a population strategy is that no administrative expense is directed toward the identification of who will and who will not receive the preventive program. The disadvantage is that much of the effort will be directed at people who will not benefit much from it because they already enjoy excellent dental health and maintain good oral health habits.

## The targeting philosophy

The feature of present-day caries that most affects our preventive activities is the skewed distribution (Table 1). Targeting means concentrating our resources on the 25% or so of children with the most disease, rather than mounting programs aimed broadly at the whole population. The thinking behind targeting is that scarce resources can now be concentrated on those children who most need care, and that overall caries prevention can thus be more efficiently conducted. The concept is logical, though I would suggest that it has not yet been well tested.

Targeting has been interpreted to mean the selection of individual children from classrooms as the result of a predictive test, such as one measuring cariogenic bacteria and consumption of sugars. In this approach all children are tested and some picked out for special preventive attention on the basis of the test results. Sometimes the concept is extended to include a whole classroom as the unit, rather than individual children.

The targeting philosophy thus presents us with two primary issues: 1) Can we identify the 'high-risk' children with sufficient precision to make targeting practical? 2) Even if we can, are 'targeted' programs really more economically efficient than programs directed at the whole population?

With regard to the first question, it is well documented that the best predictor of future caries is past caries. This was concluded at a 1977 conference in Niagara Falls, N.Y., USA, devoted to caries prediction (18), and it has been consistently found in more recent studies as well (19, 20). This means that children with a lot of caries now are likely to have more caries in the future, and thus could be identified for inclusion in a targeted program. The drawback is that children have to be screened first to find those with the disease.

Much research into caries prediction has been in microbiology, with tests based on the assumption that high counts of *Streptococcus mutans* and lactobacilli indicate high risk of subsequent caries (21–23). While the causative role of these bacteria in caries is unquestioned, the direct association between bacterial counts and caries incidence is found only within groups, rather than in individuals (24), and even then the strength of the association is often modest. Bacteriologic tests, in general, are highly specific (25), meaning that a low *S. mutans* count accurately predicts low caries experience, but they have low positive predictive value, meaning that a lot of people with high *S. mutans* counts will not subsequently develop caries. Healthy children can thus be included in the targeted group, and some diseased children can be excluded.

The second issue is that even if we could identify precisely those children with the greatest need, we would still face the question whether the concept could be applied in a practical fashion. The economic costs of identifying the target group and providing preventive care for them can often be overlooked. The predictive tests themselves clearly have a direct cost, and there is extra record-keeping required. There is also the cost of bringing the identified children into the program, which cannot be ignored because the children identified as needing targeted prevention are usually the hardest ones to reach in a community.

## Predicting caries

As caries experience continues to decline in the economically developed world, it becomes more difficult to predict the susceptible minority in a population (26). It is also likely that the cost-effectiveness of public health efforts to identify susceptible individuals will diminish as the proportion of such individuals diminishes (27). A combination of tests is more effective than any single test (28). From current knowledge, it seems unlikely that there will be an inexpensive single test to predict future disease susceptibility; researchers are increasingly accepting that prediction with the necessary power will come only from the right combination of tests. But the more tests that have to be used, the higher the cost. The rationale for a targeted program is to improve cost-effectiveness by identifying those who are highly susceptible to caries. If it becomes too expensive to identify susceptible persons, then that rationale collapses.

The result is that prediction of caries susceptibility at the individual level will continue to be uncertain. There is, perhaps, a possibility that advances in molecular biology will lead to an ideal predictive test, though at present we cannot say how this might happen. The philosophic base for much predictive research can also be debated, for outcome cannot be used to determine risk (29), and deterministic models do not allow for random effects (30). Methods of caries prediction are still imprecise.

As mentioned earlier, caries on approximal surfaces is becoming increasingly uncommon (31). If a preventive program targeted to a group of the most caries-susceptible children is really wanted, perhaps just selecting those children with any approximal caries would do as well as any other test.

## Targeting or population strategies?

I suggest that both a population strategy and a targeted approach have their place in a public health program, as does individual patient care (which can be seen as targeting when there are relatively few patients). Having just criticized our methods of targeting individuals, however, I must explain this statement.

The targeting strategy that seems to work most efficiently is that of targeting particular geographic localities, those pockets of high caries experience in a generally low-caries area. This approach is perhaps something between a population strategy and selection of individual high-risk children. It requires good data collection and presentation to identify such areas positively, though any good public health administrator knows where they are. They can be a number of schools in the poorer part of a city, or a section where immigrant populations, with their usually higher caries experience, have settled. These geographic pockets of high disease need special attention, so what eventuates is a population strategy directed at a targeted population group. This avoids the need for individual testing or screening, since the epidemiologic data used to select the area are usually collected in any case.

## Population-based preventive strategies

Assuming that there is a place for prevention based on both population- and geographically targeted philosophies, as well as individual patient care, we should look briefly at the advantages and disadvantages of the current


Fig. 2. Individual care and geographic targeting are built on a base of population strategies.

preventive strategies that are used in each approach. I see these strategies as being ordered in sequence, as shown in Fig. 2. Population strategies come first, so they form the base of the triangle. When population strategies are in place, geographic areas can be selected for targeted prevention actions. Individual patient care for the most caries-susceptible patients can then be added to these measures where resources exist.

Fluoride is most effective in caries prevention when small amounts are constantly present in the oral cavity, so public health policies should be aimed at achieving that state for the whole population. In saying that fluoride should be in everyone's mouth at all times, I exclude only those without teeth, namely, newborn infants and edentulous adults (fluoride in the oral cavity will not hurt either group, but there are fewer places for it to reside and it cannot have much beneficial effect). Maintaining fluoride in everyone's mouth is clearly a population-based goal.

In the Scandinavian countries, this goal of having fluoride in everyone's mouth at all times is best reached by regular use of fluoride toothpaste, accompanied by public education on oral hygiene to encourage this use of fluoride toothpaste. I would include commercial advertising as a major part of this education. Fluoride toothpaste has probably done more than any other fluoride vehicle, on a global basis, to bring about the decline in caries among our younger populations. It is inexpensive (in the developed countries), and it takes advantage of a practice that is a social norm. Fluoride from toothpaste is taken up by remaining plaque, saliva, soft tissue, and the enamel surface, and when toothbrushing is practiced regularly these reservoirs of intraoral fluoride are constantly being replenished. This means that fluoride is always available in the mouth to inhibit demineralization of enamel and to promote remineralization when needed.

Toothbrushing with fluoride toothpaste is close to an ideal public health method, in that its use is convenient, inexpensive, culturally approved, and widespread. It falls short of ideal in that those who do not use fluoride toothpaste regularly are usually the people who need it most, and it does depend on human behavior for its effectiveness. While certain problem groups or individuals should receive special attention from time to time, fluoride toothpaste is clearly a population-based approach to caries control. One problem with young children's use of fluoride toothpaste at the standard concentration of 1000 parts per million is that it has been identified as a risk factor for fluorosis (32, 33). Parents should be urged to use only small amounts of fluoride toothpaste for young children, but the best answer to this problem seems to be the marketing of child-strength toothpastes (34, 35).

I have always hesitated to call dental health education a preventive procedure because its effectiveness is so difficult to demonstrate. At the same time, I do not doubt that dental health education has had a substantial beneficial effect on the oral health of the public, though the effects are seen only over a long period of time. I believe that dental health education has worked because in the major Western nations over the last 50 years or so we have had a favorable environment of increasing affluence, constantly increasing standards of acceptable personal hygiene and grooming, greater public expectations of health and beauty, and the development of sophisticated methods of commercial advertising. I suggest that the educational effort carried out in Scandinavia would not have had anything like the same effect in the impoverished countries of Eastern Europe over recent years because they have many more basic needs, dental and otherwise, to be met before being in a position to respond to the educational messages with which we are familiar.

Looking at our faith in dental health education, we have to ask ourselves honestly if things would have been much different today if we had not done so much of it through the years. This faith is not based on strong science. Dental health education is one of those things that is held as a value in our profession, a part of our code of professional behavior. We simply believe that everyone has the right to know the facts of good oral health, even if they do not always act on that information. Dental health education, whatever its impact, is primarily a population strategy, though it can also be targeted and individualized. How much of our resources should go into dental health education? This is a good discussion point that has no clear answer. I would say some, but not too much.

Fluoridation of drinking water is by definition a population strategy in those countries that use it, as is salt fluoridation. Neither is used in Scandinavia.

## Preventive strategies for geographically targeted areas

For the geographically targeted areas—that is, those pockets of high disease within a community of generally low caries experience—programs of school-based fluoride rinsing are appropriate. It was a 1965 Swedish study, reporting a nearly 50% reduction in caries increment over 2 years (36), that sparked interest in fluoride mouthrinsing. Because mouthrinsing is a convenient way of maintaining fluoride levels in the mouth, it is not surprising that early clinical trials gave mostly positive results (37). Fluoride mouthrinsing soon became a standard preventive program in many countries, most often applied as a population strategy.

A major attraction of fluoride mouthrinsing in public health programs has been its presumed cost-effectiveness. While true costs are almost certainly higher than first thought (38), these costs would probably still be acceptable if the procedure were as effective as the early studies suggested. Doubts about the effectiveness of fluoride mouthrinsing as a population measure began to be expressed in the mid-1980s, soon after the recognition of the modern caries pattern (39), and economic analyses challenged its presumed cost-effectiveness (40).

In retrospect we can see that the original Swedish study that sparked all the interest reported such high efficacy only because prevailing caries experience was so high. When caries experience diminished, fluoride mouthrinsing became less effective. Program costs do not diminish with caries, however, so again we see the 'diminishing returns' phenomenon in action. The current view is that fluoride mouthrinsing should not be used as a population strategy because its low effectiveness naturally means that it is not cost-effective, but that it is appropriate for special groups such as schoolchildren at high caries risk in geographically targeted areas (41).

Fluoride varnishes have been used in Europe for a number of years, and recent research evidence continues to demonstrate their efficacy (42, 43). They have been shown to slow the progression of existing enamel lesions (44) and to be at least as effective as acidulated phosphate fluoride (APF) gel when applied semi-annually (45).

Varnishes need to be reapplied at regular intervals to maintain their cariostatic effect (42, 46), and investigation continues into the optimum application frequency. Several studies have suggested that intensive use, meaning applications three times a week each year, may be more effective than the conventional twice-per-year regimen (47, 48). Varnishes are clearly effective, though they are inherently more expensive than self-applied fluorides since they require professional application. They cannot be recommended as a population strategy today because the use of expensive professional time in one-to-one contact with all schoolchildren in the population, many of whom have little or no need for dental care, would be very expensive and provide little benefit in return. Varnishes are thought to produce some of their effect by introducing fluoride into the oral cavity for a period of time, presumably benefiting all teeth, not only those to which they are applied. However, toothpaste does this much less expensively. It is not yet clear whether varnishes would be most efficiently used in geographically targeted locations or best reserved for individual patients on an ad hoc basis.

Dental sealants also are both highly effective and relatively expensive to apply. They too, I suggest, are best used in selected geographic areas where caries experience is high and, within that context, are most efficiently applied to first and second permanent molars with incipient lesions, rather than to all molars (49).

The only clinical trials that have shown fluoride tablets to be effective have been carried out with schoolchildren. Studies in which the supplements were chewed, swished, and swallowed under supervision have reported good caries reductions over several years (50–52). But there is no good evidence that fluoride tablets provide a pre-eruptive benefit, so they should not be used for young children because of the risk of fluorosis. The best use of fluoride tablets would seem to be in geographically targeted areas where they can be used instead of fluoride rinsing. Primary schoolchildren are past the risk age of esthetically bothersome fluorosis, and the benefits from fluoride tablets and fluoride rinsing are about the same (53).

Despite the great improvements in oral health we have seen over recent years, there are still individuals who, for whatever reason, remain highly susceptible to caries. They need special clinical attention. In addition to whatever they are receiving from population strategies, they can be given intensive fluoride therapy with high-concentration gels, additional varnishes and sealants, and chlorhexidine treatment as needed. Bacterial counts can be monitored and dietary restrictions introduced if thought appropriate. In other words, these caries-susceptible patients, relatively few in number these days, can be given the full blast of all that modern preventive dentistry has to offer. This is expensive treatment, but if the program goals are to reduce caries across the whole population, then such individual treatment is appropriate.

## Conclusion

The demand today is for efficiency, which makes the targeted strategy immediately attractive. However, a targeted strategy that involves selecting individuals from a classroom is likely to be expensive when the costs of testing and administration are added. I have therefore suggested that the best use of a targeted strategy might be

Table 3. Strategic choices in caries prevention

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| Basics for all: |
| Water fluoridation if feasible |
| Fluoride toothpaste |
| Education for good oral health habits |
| For high-risk individuals: |
| Fluoride gels, varnishes, CHX, sealants, and intervention for dietary restrictions |
| For selected areas: |
| Public health fluoride rinses or fluoride supplements only in geographic areas with high caries |
| Sealants only on incipient caries in permanent molars |
| Public health use of fluoride varnishes (?) |

a geographically based approach that is relatively inexpensive to implement. I suggest, too, that there is still plenty of room for population-based prevention, and there probably always will be, because in dental public health we have an obligation toward the whole population. Table 3 summarizes the different uses of these strategies. Efficiency in dental prevention will best be preserved with a mix of all approaches.

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