SPECIAL ARTICLES

HAVE THE BENEFITS OF WATER FLUORIDATION BEEN OVERESTIMATED?

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Summary

There is now a large and growing body of evidence, most of which has been published in the 1980s, that tooth decay has declined dramatically in schoolchildren in both unfluoridated and fluoridated regions of the developed world. In several regions this decline commenced before the use of fluoride in any form became widespread. Possible explanations for these declines include changes in diet and nutrition, improvements in oral hygiene and, through the 1970s and early 1980s, the use of high-concentration topical fluorides, notably fluoride toothpaste.

In the USA, Australia and New Zealand, there is now little difference in average levels of tooth decay between comparable fluoridated and unfluoridated cities of the same country. Re-examinations of many of the early quasi experimental studies on human populations, which once appeared to demonstrate enormous benefits from fluoridation, now suggest that the design and/or conduct of these studies was inadequate for this purpose.

There is also evidence that there may be little benefit in actually swallowing fluoride. Fluoride's principal action is on the surface of teeth, and it appears to be more effective at high concentrations, such as in fluoride toothpaste. Fluoride, at the doses ingested from fluoridated drinking water, is not an essential nutrient.

The benefits of fluoridation are much smaller than traditionally believed. Previous arguments used to justify fluoridation now require revision. In the absence of rational justification, governments and other decision-makers can replace fluoridation with daily toothbrushing in primary schools and the reform of school canteens.

Introduction

Fluoridation involves increasing the fluoride content of drinking water to a concentration of about 1 part per million (ppm), that is, 1 mg of fluoride per litre of water. This concentration results in most people ingesting, both directly from drinks and indirectly from food prepared with tapwater and from other sources, a total of several mg of fluoride per day. The purpose of fluoridation is to try to reduce dental caries (tooth decay) in the population which drinks the water. Fluoridation is widespread in most English-speaking countries, but has been terminated or never implemented almost everywhere in western continental Europe (Table 1), primarily because of concern about its possible health hazards.

Traditionally, it has been believed that fluoridation reduces the prevalence of caries by 40-70 percent[1]. This article reviews recent evidence which suggests that the actual benefits of fluoridation are much smaller than this. The sequel to this review re-examines the evidence that fluoridated drinking water is a health hazard for a fraction of the population exposed.

Is fluoride essential?

A daily dose of several mg fluoride per day is not necessary for life, since most of the world's population lives with much lower intakes. But, is it essential for sound teeth?

Before taking up Western type diets, which are high in sugars, people in the Third World (and Australian Aborigines) generally had very low levels of tooth decay. Most of these peoples also had levels of fluoride in their drinking water ranging typically from one-fifth to less than one-tenth the level of about 1 ppm recommended by the proponents of fluoridation. Tooth decay was also low in Britain and continental Europe during World War II, when sugar was a scarce commodity[2,3], and in the 1950s at the Hopewood orphanage, near Bowral NSW Australia, where the children were fed on wholemeal bread and other "whole" foods[4]. In Britain, continental Europe and Bowral, there was no fluoridation during those times. So, people can have excellent teeth without 1 ppm fluoride in drinking water, and without mg/day doses of fluoride in some other form.

It is also true that some people can have highly decayed teeth when their drinking water is fluoridated. For example, some fringe-dwelling Australian Aborigines, whose diet is high in sugars, have a high prevalence of tooth decay, even where their drinking water is naturally fluoridated from bores[5,6]. Furthermore, in developed countries in general, the poorest members of the community still have the highest prevalence of tooth decay in fluoridated areas[7-9].

Thus fluoridation is neither necessary nor sufficient for sound teeth. Fluoride, in mg/day doses, is no more an essential nutrient than a mouthrinse or a dental fissure sealant. Not a single person has ever been shown to have a genuine "deficiency" of fluoride. On 16 March 1979 the US Food and Drug Administration deleted fluoride from the list of substances on the US Federal Register which were classified as "essential or probably essential".

Table 1:
World status of water fluoridation – partial listing

Country	Percent fluoridated	Comments
Australia	66	Queensland 5% fluoridated; other States extensively
Brazil	30	Big promotion from USA
Britain	10	Mostly in W. Midlands & N. regions of England
Canada	50	
Ireland	50	
New Zealand	50	Declining from 65%
USA	50	Birthplace of fluoridation
W. Europe (continental)	<1	Discontinued in Sweden, Holland & W. Germany
The World	3-4	

Since fluoride in mg/day doses is not essential, it is appropriate to consider fluoridation to be an expensive-to-avoid form of preventive mass medication. Moreover, the dose of this medication is not controlled, because it depends on the quantity of tapwater ingested, both directly and indirectly. Both these points have ethical implications which have led many communities to resist the fluoridation of their water supplies.

Levels of tooth decay

In *Australia*, the average levels of tooth decay in 10-year-olds in 1977 and 1987 are shown in Table 2 for each capital city. The data were obtained under Freedom of Information from the Australian Department of Community Services and Health[10]. It is clear that tooth decay in unfluoridated Brisbane is now the same as in fluoridated Adelaide and Perth, and is less than in fluoridated Melbourne. Similar results have been obtained for the other age-groups[10].

These observations cannot be explained by traditional arguments based on the migration of children from fluoridated parts of Australia into Brisbane, and/or the importation of food and beverages prepared in fluoridated areas such as Sydney. From

census data the effect on tooth decay levels in Brisbane of immigration of children into Brisbane has been shown to be very small[10]. Only about 2.3% of Brisbane's children under the age of 13 years migrate into Brisbane each year from fluoridated areas. Taking into account that most of the modest benefit of fluoridation is achieved on the surface of teeth after they have erupted (see below), it turns out that only about 6% of Brisbane's 10-year-olds have experienced the equivalent of so-called "optimal exposure" to fluoridated water in other cities[10]. The main source of imported fluoride in food would actually come from drinks imported into Brisbane. But most of these drinks consist of water and it is expensive to transport water from State to State. So, most of the companies which import large quantities of drinks into Brisbane actually import the concentrate and then add unfluoridated Brisbane water.

It is also observed that there are large differences in tooth decay between the fluoridated cities: for instance, 10-year-old children in Hobart have less than half the decay of children in Melbourne. This must be the result of factors other than fluoridated water—for example, different diets, socio-economic profiles and environmental conditions. But, since average household incomes are similar in Brisbane, Perth and Adelaide, and are slightly higher in Melbourne than in these three cities, it cannot be argued that different socio-economic conditions have somehow cancelled the alleged advantages of fluoridation in Perth, Adelaide and Melbourne[10].

In *New Zealand*, the only major city which is unfluoridated is Christchurch. Colquhoun has obtained the different levels of tooth decay in 12- and 13-year-olds in the major cities of New Zealand in 1984 and 1986 (see Table 3 and Ref[11]). These data cover the dental health status of all schoolchildren in this age group completing their final year of treatment by the School Dental Service. Tooth decay in unfluoridated Christchurch is similar to that in all the major fluoridated cities of New Zealand. This result is true whether one measures tooth decay by DMFT (the number of decayed, missing and filled teeth per child) or by the percentage of children with decay-free teeth.

In the *USA*, Yiamouyiannis has just published a preliminary report based on data obtained under Freedom of Information from the National Institute of Dental Research[12]. This database spans 84 cities, some fluoridated and some unfluoridated, in the USA. There is no significant difference in average tooth decay, as measured by DMFT, between children of the fluoridated and unfluoridated cities, at nearly every age from 5 to 17 years. Recently, the National Institute of Dental Research has analysed the same data set using a different index of tooth decay, DMFS, the number of decayed, missing and filled tooth surfaces per child, and has reported that fluoridated areas have 18 percent less DMFS[13]. But, it should be noted that the early claims that fluoridation reduced tooth decay by 40-70 percent were based on DMFT, not DMFS.

In the American State of Missouri, Hildebolt and co-workers have recently shown that there is no difference in average levels of tooth decay between fluoridated and unfluoridated areas[14].

In *Canada*, Gray has reported that average tooth decay (DMFT) in the province of British Columbia, which is only 11 percent fluoridated, is less than in other provinces which are 40-70 percent fluoridated[15].

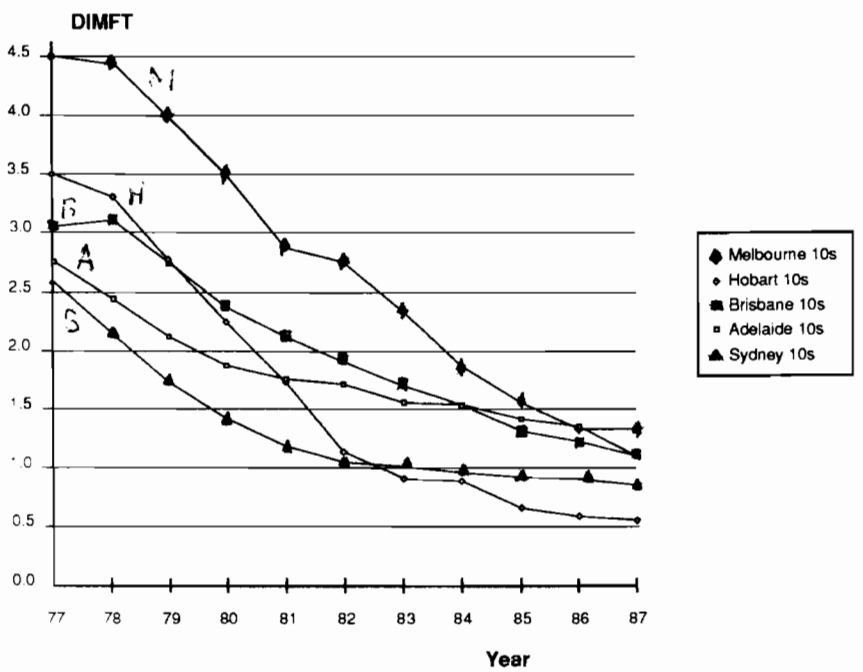
The decline in tooth decay

Over the past 20-30 years there have been large declines in tooth decay in both fluoridated and unfluoridated communities in the western world. Today, 99.5% of people in western continental Europe, 91% in Britain and 50% in the USA, do not consume fluoridated water. But, still, there have been very large reductions in tooth decay in the unfluoridated regions of all these countries[16].

Some of the results for 10-year-olds in Australian capital cities are shown in Figure 1 and Table 2. Specifically, tooth decay in unfluoridated Brisbane has declined by 65% over the 10-year period. Similar results are obtained at other ages[10].

Incidentally, in the fluoridated capital cities (except Melbourne and Adelaide), fluoridation commenced so long ago that essentially all the declines in these cities shown in Figure 1 occurred too late to have been caused by water fluoridation. This is because 10-year-olds in these cities already had the "optimal exposure" of consuming fluoridated water from birth in 1977. So, generations of 10-year-olds examined after 1977 would still be "optimally exposed", the best they can get from fluoridation. Therefore, any additional reduction in tooth decay after 1977 could not be the result of fluoridation. (Strictly speaking, 10-year-olds in Sydney and Perth, which were both fluoridated in 1968, would get one additional year of fluoridation, 1977, and thereafter they would be "optimally exposed". But this single year out of a total exposure of 10 years is unlikely to have made much difference to their teeth.)

Figure 1: Decline in tooth decay in the permanent teeth of 10-year-olds in Australian capital cities[10]



In Melbourne, which was fluoridated in 1977, there was a 72% decline in tooth decay in 10-year-olds from 1977 to 1987 (see Table 2). But, in Hobart, there was an 84% decline in the same age-group over the same period, and this occurred much too late to have been caused by water fluoridation. Hobart was fluoridated in 1964, and so by 1974 10-year-olds were already "optimally exposed" to fluoridated drinking water. So, if fluoridation was working in Melbourne over 1977 to 1987, what was responsible for the approximately equal decline in tooth decay (in both DIMFT and percentage terms) in Hobart?

Unfortunately, there is little data from the School Dental Service from before 1977. But, early data from the NSW Health Commission and from Barnard shows that tooth decay was already declining substantially in Sydney in the early 1960s, *before* fluoridation was imposed in 1968[16]. (Incidentally, the use of fluoride toothpaste was negligible in the 1960s in Australia; it only became widespread over the 1970s.)

Once again, similar results have already been published from New Zealand, where, for decades, 5-year-olds have had their teeth checked upon entering school. In New Zealand, most fluoridation commenced in the mid-1960s, but Figure 2 shows that large reductions in tooth decay occurred well before this[17]. These reductions also commenced before the use of fluoride in any form became widespread.

In Gloucestershire, England, there is also a report that tooth decay was already declining in the early 1960s, before fluoride in any form was used widely[16].

So, there is evidence from at least three countries — Australia, New Zealand and England — that the decline in tooth decay began before the use of fluoride in any form became widespread. In other words, there must be an important non-fluoride factor which has been reducing tooth decay.

What has caused the declining tooth decay?

My hypothesis is that the non-fluoride factor(s), whose presence was deduced from evidence presented in the previous Section, has operated over the past three decades and so has been responsible for much of the decline in tooth decay in unfluoridated areas and in "optimally exposed" children in fluoridated areas.

Possible non-fluoride factors are:

(i) improved diet and nutrition;
(ii) improved dental health education leading to better oral hygiene (flossing, plaque removal and more effective toothbrushing); and
(iii) changes in the immune status of the population.

Unfortunately, the predominance of the fluoride paradigm has meant that there has been little modern research into the relationship between diet, nutrition and tooth decay. The consumption of sugar has decreased slightly in several developed countries, such as Australia, over the past decade or two, but not enough to explain the enormous reductions in tooth decay which cannot be attributed to fluoridation. The consumption of

Table 2:
Average tooth decay in 10-year-olds in Australian capital cities in 1977 and 1987[10]

City	Tooth decay 1977 (DIMFT)	Tooth decay 1987 (DIMFT)
Unfluoridated		
Brisbane	3.1	1.1
Fluoridated		
Hobart	3.5	0.6
Canberra	1.8	0.8
Sydney	2.6	0.9
Adelaide	2.8	1.1
Perth	2.3	1.1
Melbourne	4.5	1.3

Note:

(i) DIMFT is the number of decayed, indicated (for extraction because of decay), missing and filled permanent teeth per child. To a good approximation, it is equal to the more common measure of tooth decay, DMFT, used in Table 3.

(ii) Canberra and Hobart were fluoridated in 1964, Sydney and Perth in 1968, Adelaide in 1971 and Melbourne in 1977. 10-year-olds in all the fluoridated capital cities except Melbourne and Adelaide were "optimally exposed" (see text) by 1978.

cheese has increased steadily and substantially in Australia from 1959 to 1985, and there is a growing body of evidence, from epidemiological studies on laboratory animals and experiments conducted in the test-tube and within the human mouth, that cheese reduces tooth decay[18]. There is also a pilot study which suggests that eating wholemeal bread rather than white bread also reduces tooth decay[19]. So, changes in diet and possibly nutrition are clearly playing a role, but more research is required to quantify them.

In addition to non-fluoride factors, fluoride toothpaste is likely to have played a significant role in the 1970s and early 1980s, but not in the 1960s. The effectiveness of some fluoride toothpastes has been demonstrated by randomised controlled trials[1]. (In contrast, there are no well designed experiments to prove the effectiveness of fluoridated drinking water — see below.)

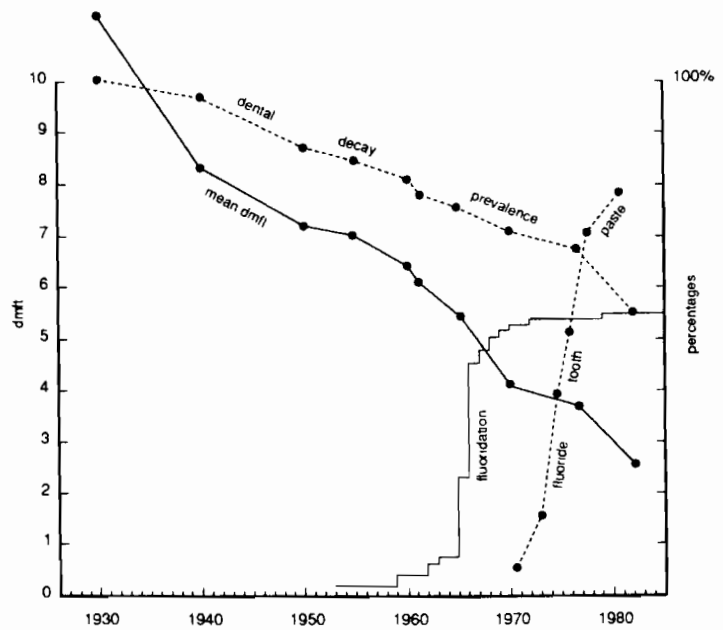
However, it cannot be deduced from the effectiveness of fluoridated toothpaste that fluoridated water must be equally or more effective, because fluoride toothpaste has 1000 times the fluoride concentration of fluoridated drinking water. Fluoride toothpaste acts on the surface of the teeth, apparently improving the remineralisation of the enamel, and also damages the bacteria in dental plaque which convert sugars into the acids which produce cavities. The latter mechanism is likely to be far more effective at 1000 ppm than at 1 ppm, and so fluoride toothpaste could be more effective than fluoridated water. The next section introduces another reason why fluoridated water is apparently much less effective than previously believed.

There is little benefit in actually swallowing fluoride

The original theory was that drinking fluoridated water reduced tooth decay by incorporating fluoride into the tooth structure, allegedly strengthening the teeth. This "systemic" mechanism was subsequently supplemented with the theory that fluoridated water also acted by means of a "topical" mechanism: i.e. on the surface of the teeth. But, in the 1980s, experiments on humans[20,21] and on animals[22] have suggested strongly that there is little or no reduction of tooth decay from actually swallowing fluoride:

Figure 2: 50-year decline in tooth decay in the deciduous teeth of 5-year-olds in New Zealand.

Solid line: Average Nº decayed, missing and filled primary teeth per child (dmft).
Broken line: Dental decay prevalence (100 minus percent caries-free)
Fluoridation. Solid line: Percent of population with fluoridated water.
Fluoride toothpaste. Broken line: Percent of total toothpaste sales.
(Graph kindly made available by Dr. John Colquhoun)



In humans:

- No significant relationship has been demonstrated between the tooth decay experience of the individual and the fluoride content of the teeth's enamel[20].
- The difference in fluoride content of the surface enamel in low and "optimal" fluoride regions is reported to be too small to produce a significant reduction in caries prevalence[20,21].

In animals:

Experiments are often much better designed and controlled than with humans. In the laboratory rat, which seems to be generally regarded as a good model for caries in humans, the following observations are relevant:

- The anti-tooth-decay effect of fluoride is observed primarily after the teeth erupt[22,23].
- No decay reduction could be obtained from an implanted subcutaneous device which released fluoride slowly into the bloodstream (and from there to the saliva)[22].
- The anti-decay effect at 1 ppm fluoride was considerably smaller than at 10 ppm[23].

A large systemic benefit from fluoridated water also seems unlikely on physiological grounds, because ingesting 1.2 ppm fluoridated water produces a fluoride concentration in human saliva of only about 0.016 ppm[24].

The above evidence, from humans, animals and basic physiology, suggests there is little or no benefit from swallowing fluoride, and so the argument for fluoridating drinking water is weakened even further. At best a small topical benefit from exposure to 1 ppm fluoridated water can be expected. But a large topical effect can probably be obtained, with fewer risks, by rinsing the mouth with a high-concentration fluoride solution and then spitting it out. (The risks of ingesting fluoride will be discussed in the sequel to this article.)

This is, in effect, what children do when they brush their teeth with toothpaste having a fluoride concentration of 1000 ppm. So, a daily toothbrushing program in kindergarten and primary schools should have at least the same effect as drinking fluoridated water, but with less risk. This may be the secret of the excellent teeth in the schoolchildren of unfluoridated Brisbane, Australia. The daily toothbrushing is conducted by schoolteachers as part of the children's health education and so does not add any significant costs to the School Dental Service.

The poor scientific quality of the pro-fluoridation studies

Traditionally it has been claimed that there are scores of studies on fluoridated communities from around the developed world which prove or "demonstrate" that water fluoridation has enormous benefits[1]. In practice, those studies which have been re-examined critically have been found to be very badly designed and/or executed. At best

Table 3: Average tooth decay in 12- to 13-year-olds in the major cities of New Zealand in 1984[11] and 1986[33]

City	Tooth decay 1984 DMFT[b]	% decay-free	Tooth decay 1986 DMFT[b]	% decay-free
Unflouridated				
Christchurch[a]	3.2	21%	2.9	27%
Fluoridated				
Dunedin	2.9	18%	2.9	24%
Wellington	3.0	21%	2.6	26%
Greater Auckland	3.1	20%	2.8	25%
Palmerston North	3.2	20%	3.1	20%
Hamilton	3.5	15%	2.9	22%

a. Excludes the small part of Christchurch which was previously fluoridated.
b. DMFT is the number of decayed, missing and filled permanent teeth per child.

they show that tooth decay has been declining in fluoridated regions, but the evidence summarised above shows that there are over 20 studies showing that tooth decay has also been declining in unfluoridated areas.

The early cross-sectional surveys of tooth decay in naturally-fluoridated communities in the USA by Dean and co-workers claimed to find an "inverse relationship" between fluoride concentration in drinking water and tooth decay (DMFT). But, although Dean studied hundreds of communities, he published the results for only 21[25]. Such highly selected data are unlikely to give unbiased results.

The early "trials" of artificial fluoridation in North America have been severely criticised in a detailed scientific monograph by Sutton[26], on the grounds of major failings in experimental design, statistical analysis and selective quoting of results. Most reviews of the alleged benefits of fluoridation still cite the early trials as if they were "gospel", and omit to cite Sutton's critique of these trials. The design inadequacies of some of the well-known fluoridation trials conducted in various parts of the world are summarised as follows:

- In not one of the Australian fluoridation trials has there been simultaneous observation of changes over time in tooth decay in the test community and an appropriate unfluoridated control population[27]. In particular, in the Tamworth trial, which has been used to promote fluoridation widely in Australia, the major part of the large percentage reduction in tooth decay from 1963 to 1979 occurred too late to have been caused by water fluoridation[16,28], but this fact was not mentioned in the results or the official publicity of the trial.
- In the two trials held in Anglesey, Wales, in the 1970s and 1980s, the "control" was chosen 19 years after fluoridation of Anglesey, from a known high-tooth-decay area. This negated the benefit of the blind examinations of teeth. Moreover, the test population was rural while the "control" was urban, and so they are not comparable[29,30].
- In the Hastings, New Zealand, trial, the decline in tooth decay resulted mainly from instructions to dental therapists to find and fill fewer cavities. The instructions, which were never mentioned in published reports of the trial, were revealed recently in material obtained by Colquhoun by means of a request under the Official Information Act in New Zealand[31].
- In the Grand Rapids, USA, study, almost all the reductions in tooth decay occurred in the first year. The official results also imply that tooth decay was decreasing with increasing age or, in other words, that fluoridation was actually filling cavities. Since these results are impossible, they must reflect sampling errors[32].

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