Community Dental Health (2011) **28,** 34–39
Received 28 May 2009; Accepted 1 November 2009

doi:10.1922/CDH_2564Downer06

Estimating the potential impact on dental caries in children of fluoridating a UK city

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Objective To estimate the potential reduction in dental caries among 5-6-year-old children in a city in the South West of England after six years of water fluoridation. ***Method*** Thirteen out of 35 inner city wards and seven out of 43 outer city wards (sharing the same water supply) having the highest mean dmft of 5-6-year-olds (recorded in a census survey in 2005/6) and/or highest indexes of multiple deprivation (IMD) were the principal focal point. Population demographic data and 5-6-year-old caries prevalence and experience were examined. Mean IMD scores and aggregated, weighted mean values for dmft and caries prevalence were referred to previously published regression analyses of caries levels plotted against IMD for 34 fluoridated (F) and 233 non-fluoridated (NF) health districts in England in order to estimate potential caries reductions. ***Results*** Mean dmft of 5-6-year-olds in the 20 wards with the highest caries levels and/or social deprivation was 2.10 (95% CI 1.87, 2.33) and caries prevalence 49% (95% CI 47%, 52%). In three wards, mean dmft exceeded 2.60. Population of the selected wards was ~210,800 with a mean IMD score of 33.70 As a conservative estimate, after six years of fluoridation a caries reduction of >40% could be expected in 5-6-year-olds for the conurbation overall and for the 20 high caries/high IMD wards, with a gain of 12 percentage points in the absolute proportion caries-free. The overall population of the 78 wards served by the three relevant water treatment works identified was ~700,000. ***Conclusions*** On the basis of current caries levels and population demographics, it appears that a comprehensive fluoridation scheme covering the inner and outer city districts would substantially improve the dental health of the city's children.

Key words: Demographics, dental caries, caries reductions, populations, water fluoridation

Introduction

Interest in water fluoridation as an option for substantially improving the dental health of the United Kingdom population was re-kindled by new guidance from central government prompted by fresh legislation introduced in 2003. This led English strategic health authorities (SHA), each of which covers a large region of the country, to consider fluoridation as a realistic strategy for reducing health inequalities. Operationally, this is the responsibility of their constituent primary care trusts (PCT), the local health commissioning and administrative units, within the SHAs' designated regions. In response, the PCTs covering a conurbation in the South West region of England commissioned review and discussion documents, to present to relevant stakeholders, outlining the issues involved in the possible introduction of an operable and efficient water fluoridation scheme for the city and its environs. Efficiency in this context means maximising the value of the benefits produced from whatever resources are allocated to an activity

The advantages of water fluoridation include effectiveness for all, ease of delivery, safety, equity and low cost (Horowitz, 1996). It also demonstrates a differentially greater benefit in terms of caries prevention among multiple deprived segments of the population - with their associated higher caries levels - than among the more affluent sectors of the community. It therefore has the capacity to reduce health inequalities. A predictive tool for estimating the potential effect of water fluoridation on dental caries was recently developed by Foster *et al*. (2009). This was based on regression analyses of scatter plots of caries experience in 5-year-olds, and proportions caries-free, in fluoridated (F) PCTs and non-fluoridated (NF) PCTs in England. (Figs. 1 and 2). Caries data were plotted against mean Index of Multiple Deprivation (IMD) values of the communities served by the PCTs and trend lines for F and non-F populations derived.

The objective of the present report was to estimate the potential reduction in dental caries in the city's 5-6-year-old children after six years of fluoridation using the predictive tool described by Foster *et al*. (2009). The city has been treated anonymously and the benefits are notional. Nevertheless the data are entirely real.

Methods

Study design and data sources

It was established that in order to fluoridate the 78 inner city and neighbouring outer city wards, sharing the same water supplies and containing the 20 high dental caries and/or high IMD wards, it would be necessary to install fluoride dosing, monitoring equipment and secure storage facilities at three water treatment works (WTW). The notional fluoridation project was therefore designated 'the three treatment works scheme'.

Thirteen out of 35 inner city wards and seven out of 43 outer city wards (sharing the same water supply)

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with the highest mean dmft of 5-6-year-olds, recorded in a census survey in 2005/6, and/or the highest indexes of multiple deprivation (IMD) were the principal focal point for the investigation. Population demographic data (ONS 2008 mid-year population estimates; Department for Communities and Local Government 2007 IMD scores) and 5-6-year-old caries prevalence and experience were examined. On the basis of the findings, the potential benefits of the notional three treatment works fluoridation scheme, in terms of reductions in dental caries, were estimated.

Data handling

In the census survey between 75% and 80% of inner and outer city 5-6-year-old (school year 1) children received clinical examinations in school by trained and calibrated clinicians. The survey was part of a national dental epidemiology programme (Pitts *et al*., 2007). The likelihood of being able to design an operable and efficient water fluoridation scheme for the city and its environs was examined in light of the survey findings on aggregated mean values of dmft and proportions of children caries-free, together with ward population size summations, water supply coverage and the IMD scores of the population that would be covered by the notional scheme. In order to estimate potential caries reductions among 5-6-year-olds following six years exposure to fluoridation, according to the IMD of their school catchment areas and baseline caries levels, the findings were referred to tabulations published by Foster and co-workers (Table 1). These were derived from regression equations for trend lines (see Figs. 1 and 2) of caries levels plotted against IMD for 34 fluoridated (F) and 233 non-fluoridated (NF) English PCT catchment areas (Foster *et al*., 2009).

Results

Background data

Table 1, abstracted from Foster *et al*. (2009) shows the expected change in mean dmft (with 95% confidence intervals) of 5-year-old children after experiencing water fluoridation from birth. It is apparent that the expected reduction in caries tended to rise as the IMD score of the population increased. With a score of 12, for example, the potential fall amounted to 0.56 units of dmft. With a score of 30, it amounted to 0.94 dmft. With regard to the proportion of children caries-free, the absolute percentage increase did not vary according to socioeconomic determinants but remained constant at 12% irrespective of the population's IMD status. However, the relative increase in percentages caries-free did vary according to the baseline means (see Table 3).

Table 2 presents the total populations of inner and outer city wards having the same discrete, shared water supply from the three water treatment works scheme envisaged, with mean IMD scores, mean dmft of 5-6-year-olds and proportions of 5-6-year-olds caries-free. Separate data are tabulated for those wards with exceptionally high mean dmft and/or IMD scores. For the 35 inner city wards overall, the mean dmft of the 3,092 children examined was 1.47 and caries prevalence 37%. For those children with some caries experience, mean dmft was 3.96, For the 43 outer city wards sharing the common water supply, mean dmft of the 3,043 children examined was 1.55 and caries prevalence 40%. For the 78 wards combined, mean dmft was 1.51 and caries prevalence 39%. For the 20 high caries/high IMD inner and outer city wards combined, mean dmft for the 1,708 children examined amounted to 2.10 (95% CI, 1.96 to 2.24). Nearly half the children (49%) had experienced obvious caries attack in one or more teeth (95% CI, 47% to 51%). Corresponding data for the 1,211 children examined in the 13 high caries/high IMD inner city wards were mean dmft 2.02 (95% CI, 1.86 to 2.18) and caries prevalence 49% (95% CI, 46% to 52%). For the 497 children examined in the seven outer city high caries wards, mean dmft was 2.30 (95% CI, 2.02 to 2.58) and caries prevalence 50% (95% CI, 46% to 54%).

Potential benefit

In Table 3, estimates presented in Table 1 of the expected changes in caries experience and proportions of 5-year-old children caries-free after a lifetime's exposure to a fluoridated water supply, were applied to the Table 2 data on current caries levels in inner and outer city children, and IMD status of the wards containing their schools. For all IMD scores greater than 12 the expected caries reduction was referred to the lower IMD value specified in Table 1 in order for the estimates of potential reduction to be conservative.

It can be seen that the estimated potential caries reduction ranged between 24% and 50% depending on initial mean dmft and IMD of the ward postcodes of the children's schools. The relative improvements in proportions of children caries-free were around 20%. The comparatively lower expected reduction in the 43 outer

Table 1. Potential improvements in dental caries from water fluoridation according to Index of Multiple Deprivation (IMD)

5-year-old caries	*IMD score*	*mean dmft change*	*95% CI*
Mean dmft	12	-0.56	-0.74 to -0.38
	20	-0.73	-0.85 to -0.60
	30	-0.94	-1.12 to -0.76
Caries-free	All scores	12%	9% to 14%

From Foster *et al*. (2009)

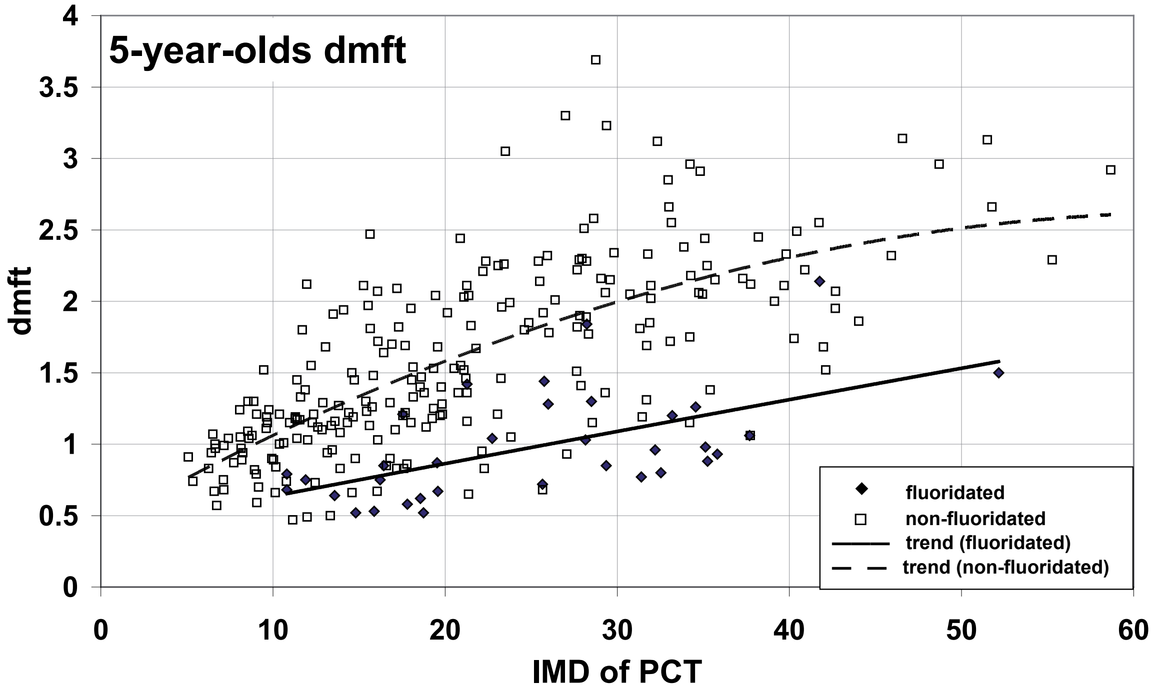
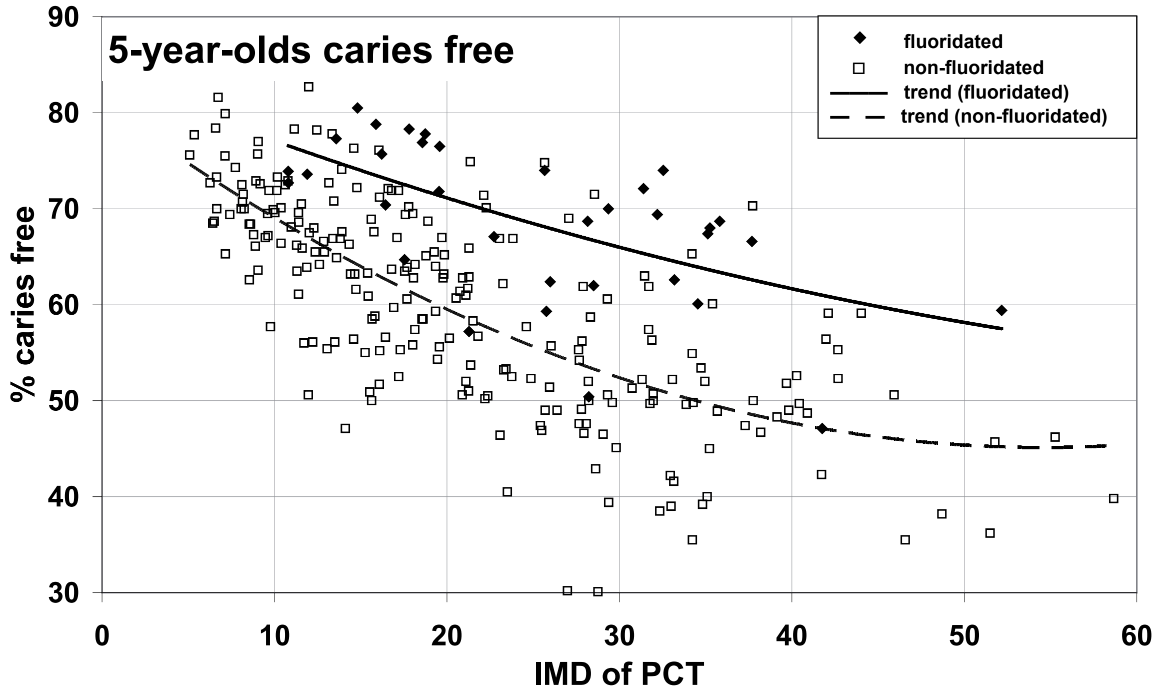


Figure 1. *Scatter plot and trend lines for mean dmft in 5-year-olds in fluoridated and non-fluoridated English PCTs*



From Foster et al. (2009)

Figure 2. *Scatter plot and trend lines for caries-free in 5-year-olds in fluoridated and non-fluoridated English PCTs*

Table 2. Population demographics and dental caries at 5/6 years

City wards	*No. of wards*	*Population on water supply*	*IMD score*	*Mean dmft*	*Caries-free (%)*
All inner city wards	35	410,500	27.76	1.47	63
Inner city high caries/ IMD wards	13	157,100	40.38	2.02	51
All outer city wards	43	288,500	9.49	1.55	60
Outer city high caries/ IMD	7	53,700	14.14	2.30	50
All inner & outer city wards	78	699,000	20.22	1.51	61
All high caries/IMD wards	20	210,800	33.70	2.10	51

Table 3. Dental caries at 5/6 years - expected benefit from fluoridation after 6 years

City wards (number of wards)	*Mean dmft present*	*Mean dmft after 6 years*	*Difference (%)*	*Percent dmft=0 present*	*Percent dmft=0 after 6 years*	*Relative Difference (%)*
All inner city wards (35)	1.47	0.74	0.73 (50)	63	75	+19%
Inner city high caries/ IMD wards (13)	2.02	1.08	0.94 (47)	51	63	+24%
All outer city wards (43)	1.55	0.99	0.56 (36)	60	72	+20%
Outer city high caries/ IMD wards (7)	2.30	1.74	0.56 (24)	50	62	+24%
All inner and outer city wards (78)	1.51	0.78	0.73 (48)	61	73	+20%
All high caries/IMD wards (20)	2.10	1.16	0.94 (45)	51	63	+24%

city wards (36%) and, in particular, the seven high caries outer city wards (24%) can be accounted for by their having relatively low IMD scores which were referred to the lowest demarcation point in Table 1, giving a 0.56 unit dmft reduction. The predicted reduction was thus likely to be conservative and would tend to underestimate the true value. For the remaining wards, a substantial caries reduction of at least 45% could be expected.

It should be borne in mind, as the 95% confidence intervals included indicate, that all the dental health data presented are subject to margins of error, and possible confounding as discussed hereafter. Nevertheless, the findings represent pragmatic, conservative estimates of the likely effect that fluoridation could achieve in the conurbation within six years of its implementation.

Discussion

Dependability of the data

The dependability and limitations of the estimates of potential caries reduction utilised here - based on caries levels in fluoridated (F) and non-fluoridated (NF) health districts according to IMD status - were discussed in depth by Foster *et al*. (2009). They argued that a number of confounding factors and effect modifiers were, within the limitations of the data sources, already taken into account, notably the important effects of age, dentition, socioeconomic status and location. As regards other possible confounding factors, Foster and co-workers were confident that these would tend, if anything, to underestimate the effect of fluoridation. For example, lower than optimal concentrations of fluoride ion in some F areas (fluoridated areas are generally defined as those having 50% or more of the population receiving fluoridated water) and possible interruptions in delivery of the agent from the need to divert water supplies from elsewhere in emergencies; a low level of natural fluoride in most areas designated as NF; limited periods of residency in F areas of some individuals and migration into F areas by other individuals, the latter tending largely to be away from NF areas; and so-called halo effects from the consumption in F areas of food and drink products manufactured in NF areas. Other factors, such as differential consumption of sugar, use of fluoride containing toothpaste or exposure to other fluoride agents, and receipt of dental treatment, which might be influenced by socioeconomic circumstances, would tend to be ironed out by the scatter plots of caries levels in F and NF districts being computed in relation to the IMD scores of the districts. Again, classification of children examined according to the postcodes of the schools rather than their home postcodes (for which the data were incomplete) would have little influence since it is unlikely that the home and the school would be receiving a different water supply. However, there is a possibility of discrepancies between school and home IMD scores although what effect this might have had is unknown.

An investigator using the predictive tool described by Foster *et al*. (2009) might be tempted to simply read off the dmft after fluoridation by measuring the interval on the Y-axis at a particular value of IMD on the X-axis between the regression lines presented in Fig. 1 or Fig. 2. However, calculations using the regression equations alone to determine the absolute difference between F and non-F PCTs at a particular value of IMD do not yield a confidence interval. For this reason, the predictive tool developed by Foster and co-workers used calculations performed at representative IMD values of 12, 20 and 30. The same procedure was adopted for the current study.

As regards possible sources of bias in the caries data, the likelihood of systematic over-estimation of caries levels in the NF districts and under-estimation in the F districts would also be unlikely. The examiners were all trained and calibrated, and any examiner variability would tend to be randomised across the districts. Moreover, the inherent tendency towards false-positive diagnosis where disease is of low prevalence – in this instance dental caries prevalence at individual tooth sites (Downer, 1993) - would militate towards over-estimation of caries experience in F districts and vice versa in NF districts. The results of the original training and calibration exercise undergone by the examiners were not available to the present investigators. The exercise was part of a national programme (Pitts *et al*., 2007).

With regard to the water supply network, it was difficult to establish precisely which wards within the PCTs' catchment areas fell within the particular water supply zones of the designated three water treatment works. This was because the ward and water supply zone boundaries were not coterminous and there were considerable overlaps. Also there was some ambiguity in the naming of the various districts involved. In the absence of a detailed feasibility study it would be impossible to derive a totally accurate listing of the populations that would receive 100% coverage by the three WTWs.

Interpretation of the findings

The study was designed as a worked example of the use of the predictive tool described by Foster *et al*. (2009) to provide a pragmatic indication, for planning purposes, of the expected improvements in dental health from fluoridating the water supplies of the city and its environs. The findings in terms of improved dental health represent 'intention to treat' estimates. The study was not intended to prove that fluoridation is effective. The efficacy (as well as the safety) of water fluoridation has been investigated extensively elsewhere and fully established (Australian Government National Health and Medical Research Council, 2007; Newton, 2009).

An important benefit of fluoridation is its effect in reducing the need for tooth extraction in children with a corresponding reduction in the provision of general anaesthesia which is often a necessary adjunct. The city's university dental hospital offers a general anaesthetic extraction service four mornings per week covering the inner city and neighbouring areas. In 2007, 667 general anaesthetics were administered to children aged six years and under, some being less than a year old. The cost of this service amounted to £558 per anaesthetic. The cost for the year for anaesthetics administered to children of six years and under amounted to £372,744. The total cost for children of all ages under 16 was £714,798. The potential saving in general anaesthetic administration and dental extractions, and avoidance of the, albeit very small, possible risks involved constitute an important factor in assessing the impact of fluoridation. Apart from the economic considerations, there would be unquantifiable, intangible benefits from a reduction in extractions under general anaesthesia. Bridgman *et al*. (1999) reported distress, psychological trauma and other symptoms of morbidity among 80 children they studied who had experienced extractions under general anaesthesia in three dental practices.

The effect of fluoridation in terms of reduced dental disease would not be confined to children, although those exposed to a fluoridated water supply from birth would be the first to receive the maximum benefit. All children - and adults with some natural teeth – would have the opportunity for improved dental health as a result of fluoridation (British Fluoridation Society, 2004). Elderly people, in particular those receiving long term medication, can suffer from dry mouth and the subsequent occurrence of dental decay in the exposed roots of the teeth. This is exacerbated if the medicinal products are sugar-based. There is evidence that the incidence of root caries is reduced by exposure to fluoride (Griffin *et al*., 2007). Also, although this report has centred principally on deprived inner and outer city wards with high dental disease levels in young children, in all but three of the 35 inner city wards, for example, over 10% of 5-6-year-olds had two or more decayed, missing or filled teeth.

It would be instructive to apply Foster and co-workers' predictive tool to a population of adolescents; an important – and arguably the most accessible – age group for studying the potential benefit of fluoridation in reducing caries in the permanent dentition. Hardwick *et al*. (1982) studied a cohort of 12-year-olds in a randomised controlled trial with a four year follow up in which children from a newly fluoridated town were examined, clinically and radiographically, against a non-fluoridated control. The investigators were blinded as to the subjects' place of residence. The results indicated that the reduction in caries increment amounted to approximately 25 percent over the period of the study in the children exposed to water fluoridation compared with the control group. However, in order to obtain the requisite data to replicate the present study in, for example, 14-year-olds it would first be necessary to conduct a census survey in the city's secondary schools.

Economic evaluations of water fluoridation have suggested that it is likely to achieve dominance, in terms of dental health benefits against costs, over other possible alternatives such as targeted interventions and those requiring participants' compliance. Even in small communities with populations of fewer than 5,000, fluoridation may still be an attractive investment for local decision makers when considering several potential public health interventions (Griffin *et al*., 2001; Wright *et al*., 2001). The latter studies, and other earlier examinations of the economic aspects of fluoridation, suggest that for larger populations and those where caries levels are high there are economies of scale (Birch, 1990; Sanderson, 1998).

With regard to the potential economic efficiency of the three treatment works scheme, there were multiple areas of the conurbation where mean dmft exceeded 2.00 while a more detailed breakdown of the data showed that in three wards mean dmft exceeded 2.60. The overall population in the water supply zones served amounted to around 700,000 people, averaging a population of more than 200,000 per treatment works. A crude, provisional, unofficial estimate of the current capital cost of the scheme, provided by the relevant water company, amounted to £2m (US$2.94m, 2.24m EUR). These data are clearly insufficient for a formal economic assessment. Such an exercise would require a full feasibility study which would constitute a later stage in any substantive project to fluoridate the conurbation.

In conclusion it appears that substantial improvements in dental health and a consequent reduction in health inequalities could be expected from a fluoridation scheme covering the city and neighbouring urban areas.

Acknowledgement

The authors are indebted to Professor Stephen Birch, McMaster University, for his valuable comments on health economic aspects of this study.

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