SCIENTIFIC ARTICLES

A Comparison of Dental Caries Levels in Two Communities with Different Oral Health Prevention Strategies Stratified in Different Social Classes

Darius Sagheri, PhD; Jacinta McLoughlin, MDS; John J. Clarkson, PhD

Abstract

Objectives: *To compare dental caries levels of schoolchildren stratified in different social classes whose domestic water supply had been fluoridated since birth (Dublin) with those living in an area where fluoridated salt was available (Freiburg).* ***Methods:*** *A representative, random sample of twelve-year-old children was examined and dental caries was recorded using World Health Organization criteria.* ***Results:*** *A total of 699 twelve-year-old children were examined, 377 were children in Dublin and 322 in Freiburg. In Dublin the mean decayed, missing, and filled permanent teeth (DMFT) was 0.80 and in Freiburg it was 0.69. An examination of the distribution of the DMFT score revealed that its distribution is highly positively skewed. For this reason this study provides summary analyses based on medians and inter-quartile range and nonparametric rank sum tests. In both cities caries levels of children in social class 1 (highest) were considerably lower when compared with the other social classes regardless of the fluoride intervention model used. The caries levels showed a reduced disparity between children in social class 2 (medium) and 3 (lowest) in Dublin compared with those in social class 2 and 3 in Freiburg.* ***Conclusions:*** *The evidence from this study confirmed that water fluoridation has reduced the gap in dental caries experience between medium and lower social classes in Dublin compared with the greater difference in caries experience between the equivalent social classes in Freiburg. The results from this study established the important role of salt fluoridation where water fluoridation is not feasible.*

Key Words: adolescence, dental caries, epidemiology, fluoride, fluoridated salt, Germany, Ireland, preventive dentistry, water fluoridation

Introduction

The World Health Organization (WHO) concluded in its report on "Fluorides and Oral Health" (1) that there is "clear evidence that regular, low-level exposure of a population to fluoride can reduce caries prevalence." The knowledge that fluoride works to prevent dental caries led many communities to deploy a combination of different strategies to supply their targeted population with fluoride. Exposure to multiple sources of fluoride is now the norm for the majority of the population in developed countries. Apart from the use of fluoride toothpaste, the two dominant community-based strategies for providing the wider population with systemic fluoride exposure are water fluoridation and salt fluoridation. Worldwide, approximately 350 million people drink artificially fluoridated water and at least a further 50 million drink water whose natural fluoride level is at or around optimal (i.e., 1 ppm) (2). Ireland introduced mandatory water fluoridation in 1964, and approximately 74 percent of Ireland's population reside in fluoridated areas (3). Water fluoridation is considered the preferred community-based fluoridation method (1), because it is the most cost-effective, equitable, and safe means to provide protection from tooth decay in a community (4). However, WHO recommends salt fluoridation as an alternative to community water fluoridation, "where water fluoridation is not feasible for technical, financial, or socio-cultural reasons" (1) and outlines certain requirements for the use of domestic salt fluoridation, such as low levels of fluoride in the domestic water supply, good centralized salt production facilities, and strong technical support for the process. The main advantage of using domestic salt as a means of fluoride delivery is that it allows for individual preferential use. However, the limitations associated with salt fluoridation are that its consumption is lowest when its intake would be most beneficial (i.e., childhood, before the age of 6) and that individuals vary in their salt intake. A number of countries have adopted salt fluoridation as an alternative to water fluoridation. Fluoridated salt (250 ppm) is available in Austria, Costa Rica, France, Germany, Mexico, Switzerland, and a further 30 countries worldwide (3).

In 2000, the Department of Health and Children in Ireland commissioned a comprehensive review of

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water fluoridation in Ireland (3). One of the recommendations made in this review advocated future research in fluoride, eating practices, oral health-related behaviors, and alternative provisions of fluoride delivery. In this context it was decided to compare dental caries levels of schoolchildren with exposure to fluoridated water and those with exposure to fluoridated salt to give an insight on the effects of these two caries preventive measures. The aim of this study was to compare the dental caries levels of schoolchildren stratified in different social classes with lifetime exposure to fluoridated domestic water supplies (Dublin, Ireland) with those living in an area with no water fluoridation, but where fluoridated domestic salt was available as part of an oral health prevention strategy (Freiburg, Germany).

Methods

Sample. Children aged 12 years were selected as the study population because this age group is comparable with earlier Irish studies and with studies conducted internationally as this age group was recommended for study by WHO. The Health Service Executive North West in Dublin [with a total population of approximately 179,000, and a population of approximately 2,200 12-year-olds (5) attending 52 schools] and the District Education Department in Freiburg [with a total population of approximately 205,000, and a population, approximately 1,600 12-year-olds (6) attending 26 schools] provided information on numbers of children in the classes and schools. The vast majority of 12-year-olds in both cities attend state-funded schools in close proximity to their homes. The demographic data permitted determination of the sample size and the random selection of schools for inclusion in the study. The total target sample size required, based on a confidence level of 95 percent with a margin of error of 5 percent, was 328 children in Dublin and 310 children in Freiburg. The study included all state-maintained schools with 12-year-olds on the school roll in both cities. The primary sampling unit was the school. The second stage of the sampling process was the selection of a cohort of students in this age group in one high school class. If a school had more than one high school class available, each high school class has an equal probability of being randomly selected. All children within a high school class were included in the sample.

Training and Calibration of the Examiner. The examiner (DS) and recorder were trained and calibrated prior to the commencement of the fieldwork to ensure reliability on the measurement index used. Dental caries was recorded at the level of cavitation into dentine using WHO criteria (7). The trainer (JMcL), with extensive experience in oral health surveys, provided the standard against which the examiner (DS) was calibrated. The level of agreement between the examiner and the gold standard was calculated and has showed an agreement of kappa = 0.87. A validation exercise was conducted during the fieldwork (re-examination of 10 percent of the subjects) to monitor examiner agreement and consistency during the course of the survey (intraexaminer kappa = 0.89).

Ethical Approval and Consent. The Hospitals Joint Research Ethics Committee reviewed the protocols for training and calibration of the examiner and for the main study and approved the study in December 2001. All parents of participating children were fully informed regarding the nature of the study and the benefits of participating. Consent documentation was sent to parents along with the questionnaires for completion by the parents 1 week before the examination. The consent form required the parents to state the child's current address and all previous addresses and if they were connected to the public water supply. This ensured that in Dublin only children with lifetime exposure to fluoridated water and that in Freiburg only children with no exposure to fluoridated water participated in the study. Questionnaire items were adapted from previous Irish national and regional surveys in order to ensure their validity (8–10). The development and validation of the various items have been reported elsewhere (8). The questionnaire included 15 items regarding the child's current oral hygiene practices, the consumption of different fluoride-containing products, and dietary intake. The survey also included four items regarding demographic information, parents' educational level, and parents' employment as required by the Goldthorpe social class schema (11–13). Clinical examinations were only carried out on the children with completed consent forms ("Positive Consent") and questionnaire. Social class was classified using the Goldthorpe social class schema (11–13).

Social Stratification. The Goldthorpe social class schema (11–13), which is one of the standard approaches to stratify social classes in socioeconomic strata in social science, was selected as an umbrella classification because it was applicable in both populations. Goldthorpe's class schema is arguably the most influential conceptualization and operationalization of socioeconomic strata in European sociology (14) Central to Goldthorpe's class schema are employment relations in industrial societies (11,15). The Goldthorpe class schema has been used as an indicator of socioeconomic position in international comparisons of socioeconomic inequalities in health across Europe (16–18). The Goldthorpe class schema is available for Australia, Canada, England and Wales, France, Germany, Hungary, Ireland, Japan, Poland, Sweden, and the United States.

Fieldwork and Data Processing. All children were examined in their schools under the same standardized conditions. A transportable halogen lamp [Daray Versatile Medical Light with halogen bulb, 12 volts, 20 watts (Welch Allyn Ltd., Navan, Ireland)] was used to illumi-

Table 1
The Distribution of Dental Caries in Dublin and Freiburg

	Dublin			Freiburg		
n	377			322		
Mean DMFT (SD)	0.80 (1.24)			0.69 (1.19)		
Caries-free (%)	59.9			66.1		
Mann–Whitney rank	359.53			338.84		
Social class	1 (High)	2 (Medium)	3 (Low)	1 (High)	2 (Medium)	3 (Low)
n	102	105	125	48	171	30
Kruskal–Wallis rank	127.49	188.38	179.96	109.03	124.14	155.47

DMFT, decayed, missing, filled permanent teeth; SD, standard deviation.

nate the mouth. The teeth were examined visually for dental caries following the criteria and methods suggested by WHO (7). The teeth were examined wet and a CPITN probe was only used to confirm a diagnosis of cavitation or to remove food debris. A strict cross-infection protocol was followed. Data were collected on schematized charts and processed using the Statistical Package for the Social Sciences, SPSS 12 (SPSS, Inc., Chicago, IL).

Results

In all, 16 primary schools in Dublin and 13 secondary schools in Freiburg were included in the sample. Four hundred sixty-four consent forms and questionnaires were issued in Dublin and 378 consent forms and questionnaires were issued in Freiburg. A total of 699 completed consent forms were returned with the result that 377 children (81.0 percent response) were examined in Dublin and 322 children (85.0 percent response) were examined in Freiburg. The difference between the numbers of consent forms and questionnaires issued and the children examined is mostly made up of children who were not present even at the second visit or who forgot to return the consent forms. Out of these, 194 girls (51.5 percent) and 183 boys (48.5 percent) were examined in Dublin and 164 girls (50.9 percent) and 158 boys (49.1 percent) were examined in Freiburg. The mean age of the children on the day of examination in Dublin was 11.95, and in Freiburg it was 11.66.

The data (Table 1) are presented as the mean values of decayed, missing, and filled permanent teeth (DMFT) in Dublin and Freiburg. In Dublin the mean DMFT for the sample was 0.80 (standard deviation = 1.24) and in Freiburg the mean DMFT for the sample was 0.69 (standard deviation = 1.19). The proportion of children with caries-free dentition (DMFT = 0) was 59.9 percent in Dublin and 66.1 percent in Freiburg. Fisher's exact test was used to examine the association between children with caries-free dentition (DMFT = 0) and children with caries experience (DMFT > 0). The difference in DMFT values between the two cities was considered to be not statistically significant (two-tailed *P*-value = 0.10). As it is typical in low caries populations, the DMFT values are not normally distributed but are positively skewed with the result that reporting the mean DMFT of the sample population gives an incomplete picture of the distribution of dental caries in that population. For this reason this study provides summary analyses based on medians and interquartile range and nonparametric rank sum tests. The nonparametric Mann–Whitney *U*-test showed no statistically significant difference between median scores of children from Dublin and Freiburg (*P*-value = 0.12) as seen by the similar Mann–Whitney ranks for the two child populations. In order to get a further insight of the distribution of dental caries in the two populations the DMFT scores were stratified into different social classes using the Goldthorpe social class schema (11). Three hundred thirty-two parents of the 377 children (88.0 percent) in Dublin and 249 parents of the 322 children (77.0 percent) in Freiburg answered questions concerning their social class. The nonparametric Kruskal–Wallis *H*-test showed a highly significant difference between median scores across the different social classes in Dublin and Freiburg. The association between the DMFT scores and the different social classes in Dublin is considered to be statistically significant (one-way χ^2 = 32.13; *P*-value < 0.0001). In order to make these differences between the DMFT distribution in the three social classes, visible boxplots were used. Boxplots allow the comparing of the different median scores (or median lines) for the three social classes and their variation (length of the box, which represents the middle 50 percent of the DMFT scores, and whiskers, which represents the range of the DMFT scores). The boxplot for the Dublin sample (Figure 1) demonstrates that the significance between median scores (median lines) and spread (length of the boxes or whiskers) across the different social classes is due to social class 1 (highest social class) distribution differing markedly from social class 2 (medium social class) and social class 3 (lowest social class). In Freiburg the association between the

Figure 1
Boxplot of the decayed, missing, and filled permanent teeth (DMFT) distribution for each social class in Dublin. The boxplot allows a comparison of the different median scores (median lines) for the three social classes and their variations (length of the box, which represents the middle 50 percent of the DMFT scores, and whiskers, which represents the range of the DMFT scores).

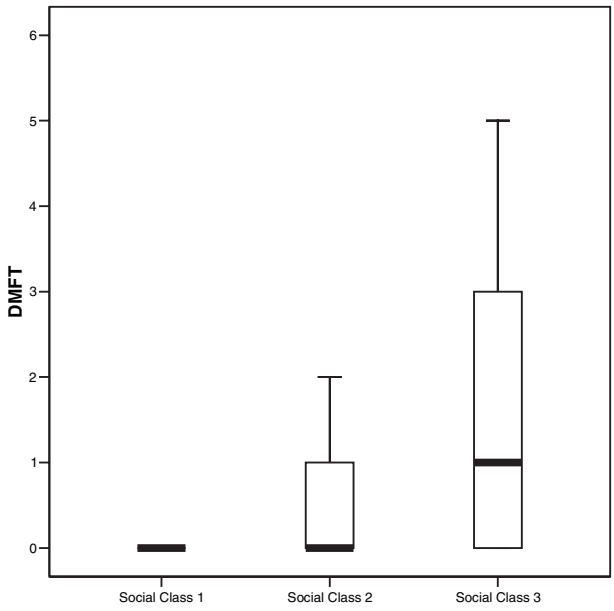
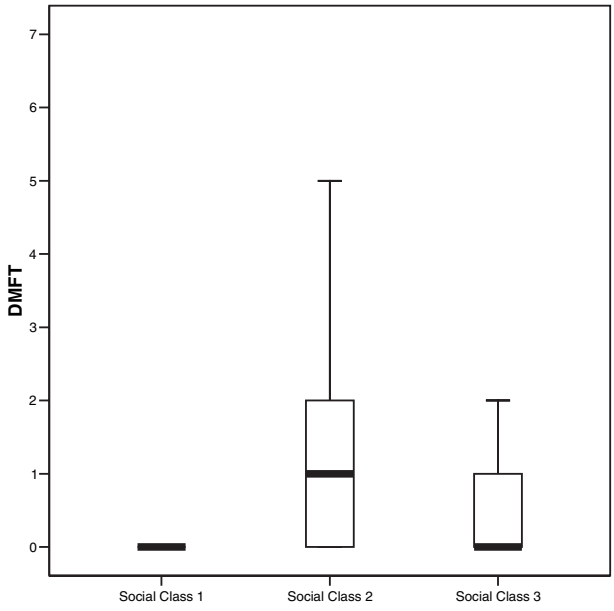


Figure 2
Boxplot of the decayed, missing, and filled permanent teeth (DMFT) distribution for each social class (total sample) in Freiburg



DMFT scores and the different social classes is considered to be statistically significant (one-way $\chi^2 = 11.27$; *P*-value = 0.004). The boxplot for the Freiburg sample (Figure 2) demonstrates that the significance between the median scores and spread across the different social classes is due to social class 1 distribution differing markedly from social class 3. In both cities dental caries levels in children in social class 1 were very similar and considerably lower when compared with the other social classes. The caries levels showed a reduced disparity between children in social classes 2 and 3 in Dublin, compared with those in social classes 2 and 3 in Freiburg.

The use of freely available fluoride-containing oral health care products was recorded in order to report on the consumption patterns in the two populations. The results of this study revealed that 96.6 percent of the parents in Dublin and 93.8 percent of the parents in Freiburg reported that their children use fluoride toothpaste and 15.1 percent of the children in Dublin and 9.3 percent of the children in Freiburg use regular fluoride mouthrinse. Apart from the availability of fluoridated toothpaste and mouthrinse in both cities, consumers in Freiburg have the choice of using fluoride gel, tablets, and fluoridated salt as well. Approximately 21.4 percent of the parents in Freiburg reported using fluoride gel, approximately 36.0 percent reported using fluoride tablets and approximately 64.0 percent reported using fluoridated salt (Table 2). Exposure to multiple sources of fluoride is now the norm for the majority of the population in developed countries. Table 3 shows the extent of multiple fluoride use in the two cities. In Dublin 81.2 percent of the parents reported to use at least one fluoride-containing oral health care product in addition to the use of fluoridated water, and 77.0 percent of the parents in Freiburg reported to use two or more such products. It is interesting to examine the correlation between DMFT scores and multiple fluoride use in Dublin and

Table 2
The Percentage of 12-Year-Old Children Whose Parents Reported Using Fluoride Toothpaste, Fluoride Gel, Fluoride Tablets, and Fluoridated Salt in Dublin and Freiburg

	Toothpaste		Mouthrinse		Salt	Tablets	Gel
	Dublin	Freiburg	Dublin	Freiburg	Freiburg	Freiburg	Freiburg
n	377	322	377	322	322	322	322
Fluoride (%)	96.6	93.8	15.1	9.3	64.0	36.0	21.4
Nonfluoride (%)	1.6	2.2	79.0	86.3	32.0	62.7	75.5
"Don't know/No answer" (%)	1.8	4.0	5.9	4.3	4.0	1.2	3.1

Table 3
The Percentage of Reported Multiple Fluoride Exposure in Dublin and Freiburg

	Dublin*	Freiburg
n	377	322
No fluoride products (%)	1.3	2.5
One fluoride product (%)	81.2	19.9
Two fluoride products (%)	15.1	38.5
Three fluoride products (%)	0.5	28.2
Four fluoride products (%)	–	8.7
Five fluoride products (%)	–	1.6
"Don't know/No answer" (%)	1.9	0.6

* All children in this sample in Dublin had lifetime exposure to fluoridated drinking water.

Table 4
Correlation Matrix of DMFT Scores and Multiple Fluoride Use in Dublin and Freiburg

	Dublin		Freiburg	
	DMFT	Multiple fluoride use	DMFT	Multiple fluoride use
Correlation coefficient	1.000	−0.055	1.000	−0.147*
Significance (two-tailed)	–	0.245	–	0.002
n	377	377	322	322

* Correlation is significant at the 0.01 level (two-tailed).
DMFT, decayed, missing, filled permanent teeth.

Freiburg. Table 4 reports the Kendall tau rank correlation between DMFT values and multiple fluoride use in the two cities. In Dublin, the correlation matrix showed no statistical significance. In Freiburg, the correlation matrix revealed a statistically significant coefficient of −0.147 at the 0.002 level (two-tailed). The negative sign indicates that high scores on the variable "multiple fluoride use" result in low scores on the variable "DMFT." Fisher's exact test was then used to examine the influence of regular use of fluoridated salt on dental caries levels because salt fluoridation is considered as a cornerstone in the strategy to prevent dental caries in Freiburg. The Freiburg sample was divided into "fluoridated salt consumers" and "nonfluoridated salt consumers" in order to examine the association between children with caries-free dentition (DMFT = 0) and children with caries experience (DMFT > 0). One-hundred forty-seven children of the "fluoridated salt consumers" had a caries-free dentition, and 59 children had DMFT values higher than 0. Fifty-nine children of the "nonfluoridated salt consumers" had a caries-free dentition, and 44 children had DMFT values higher than 0. The difference in DMFT values between "fluoridated salt consumers" and "nonfluoridated salt consumers" was considered to be statistically significant (two-tailed *P*-value = 0.02).

Discussion

Water Fluoridation, Salt Fluoridation, and Social Class. The comparatively low and similar dental caries levels found in Dublin and Freiburg demonstrates that different community-based strategies in the prevention of dental caries can result in overall comparable dental caries levels. However, the findings of this study show a significant difference between the median DMFT scores across the different social classes in Dublin and Freiburg and that children in social class 1, when compared with their peers in social classes 2 and 3, experienced much lower levels of dental caries in both cities regardless of the fluoride-intervention model used in the population. At the same time, the results of this study suggest that water fluoridation has reduced the gap in dental caries experience between social classes 2 and 3 in Dublin compared with the greater difference in caries experience between social classes 2 and 3 in Freiburg. McDonagh and coworkers in their systematic review of water fluoridation (19) confirmed that water fluoridation significantly narrows the gap between caries levels of young children in

lower and those in higher socioeconomic groups. They demonstrated in their study that this social class gradient is steeper in the low-fluoride areas, when compared with the high-fluoride areas. The present study noted a similar gradient in 12-year-olds. This finding suggests that water fluoridation led to a decrease in caries levels across the social classes and reduced the gap in dental caries experience between middle and lower social classes in Dublin when compared with a steeper social class gradient between the same social classes in Freiburg. Riley and coworkers stated in their study on water fluoridation and social inequalities (20) that the ability of water fluoridation to reduce health inequalities may be a function of its passive mode delivery and that most other strategies, such as salt fluoridation, in contrast rely upon the compliance of the individual.

Use of Different Fluoride-Containing Products. The results for the use of different fluoride-containing oral health care products by the child populations in Dublin and Freiburg revealed that the vast majority of children in both cities use fluoridated toothpaste. Consumers in Freiburg have the choice to use fluoride gel, tablets, and fluoridated salt as well. The findings of this study indicated that about 64.0 percent of the parents in Freiburg reported regular consumption of fluoridated salt. This level of fluoridated salt use is considerably lower than the 84.0 percent reported for Switzerland (21) and suggests the opportunity to increase the uptake to similar levels in Freiburg through an oral health promotion program on the use of fluoridated salt. Schulte et al. (22) found in their comparative study on caries experience in 12-year-old children in Heidelberg (Germany) and Montpellier (France) that approximately 40.0 percent of their German sample consumed fluoridated salt. They concluded that a decrease in the caries experience of 12-year-old children in Heidelberg may well be obtained by increasing the use of fluoridated salt. The use of fluoride gel and tablets in Freiburg is lower when compared with the use of fluoridated toothpaste and salt. However, consumers in Freiburg have more of a choice to combine different fluoride-containing oral health care products than in Dublin. The vast majority of parents in Freiburg reported the use of two or more such products compared with Dublin. Furthermore, the results of this study demonstrated a clear correlation between the number of regularly used fluoride products and dental caries levels. These findings demonstrate that a strategy based on different sources of self-administered fluoride products must ensure that all groups of the society have sufficient access and are aware of the benefits of these products. Lennon (23) pointed out that the pricing policy of fluoride products is a factor in determining their influence on levels of dental caries, because low-income families – the group in the population at greatest risk of dental caries – might not purchase these products. The steeper social class gradient in dental caries levels reported earlier for Freiburg should be seen in this context, because low-income families are mostly aggregated in the lower end of the social stratum.

The Role of Fluoridation in an Oral Health Promotion Strategy. The importance of fluoridated salt as a cornerstone in a strategy based on multiple fluoride products has been underpinned by the comparison of the DMFT values between the "fluoridated salt users" and "nonfluoridated salt users." Our comparison facilitated a closer evaluation of the effects of fluoridated salt on dental caries levels. The analysis of the data revealed a statistically significant difference in the dental caries levels between the two subgroups and demonstrated a real difference between the oral health status of children who regularly consumed fluoridated salt and children who did not. A range of publications have demonstrated the effectiveness of fluoridated salt in reducing dental caries levels (24–26). In order to achieve the desired overall reduction of dental caries on a population level, all groups of the society need to consume fluoridated salt (21) or have sufficient exposure to alternative fluoride-containing products. This requires a comprehensive oral health policy and oral health promotion program on the use of fluoride-containing products.

The evidence from this study confirmed that water fluoridation has reduced the gap in dental caries experience between medium and lower social classes in Dublin compared with the greater difference in caries experience between the equivalent social classes in Freiburg. The results from this study established the important role of salt fluoridation where water fluoridation is not feasible.

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