# Caries status in 16 year-olds with varying exposure to water fluoridation in Ireland

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Most of the Republic of Ireland's public water supplies have been fluoridated since the mid-1960s while Northern Ireland has never been fluoridated, apart from some small short-lived schemes in east Ulster. *Objective:* This study examines dental caries status in 16 year-olds in a part of Ireland straddling fluoridated and non-fluoridated water supply areas and compares two methods of assessing the effectiveness of water fluoridation. The cross-sectional survey tested differences in caries status by two methods: 1, Estimated Fluoridation Status as used previously in national and regional studies in the Republic and in the All-Island study of 2002; 2, Percentage Lifetime Exposure, a modification of a system described by Slade in 1995 and used in Australian caries research. *Methods:* Adolescents were selected for the study by a two-part random sampling process. Firstly, schools were selected in each area by creating three tiers based on school size, and selecting schools randomly from each tier. Then random sampling of 16-year-olds from these schools, based on a pre-set sampling fraction for each tier of schools. *Results:* With both systems of measurement, significantly lower caries levels were found in those children with the greatest exposure to fluoridated water when compared to those with the least exposure. *Conclusions:* The survey provides further evidence of the effectiveness in reducing dental caries experience up to 16 years of age. The extra intricacies involved in using the Percentage Lifetime Exposure method did not provide much more information when compared to the simpler Estimated Fluoridation Status method.

**Key words:** *dental caries, fluoridation, lifetime exposure, adolescent, DMF Index, Ireland, environmental exposure*

## Introduction

The Republic of Ireland started its water fluoridation programme in 1963. Northern Ireland has never been fluoridated apart from a few small short-lived schemes in the eastern region. In 2005 a cross-border body, Co-operation And Working Together, comprising the health authorities that provide services in the Irish border region sponsored a major study of oral health in the border region, one part of which was the impact of water fluoridation on dental caries. Two health authorities took part in this survey, the North Western Health Board (NWHB) and Western Health and Social Services Board (WHSSB). The NWHB covers the north west of the Republic and has a population of 210,000, approximately 70% of whom live in fluoridated areas. The WHSSB covers the west of Northern Ireland and has population of 280,000. The health authorities selected for the study are geographically continuous with the populations being separated by a border that has been in existence only since 1921. Deprivation indices are high in both regions, although there is considerable variation within each region.

There has been a tradition of methodical measurement of dental disease in the Republic, starting with the first regional studies conducted by the Medical Research Council in 1952 (Department of Health and Children, 2002). Since the advent of water fluoridation in the Republic, studies on dental caries have tended to examine differences in caries experience in 5-, 8-, 12- and 15-year-old children, using the classifications 'fluoridated', 'part fluoridated'

or 'non-fluoridated' (O'Mullane *et al*., 1986; Whelton *et al*., 2003). The current study is novel in terms of Irish studies in two respects: the children are older than in previous studies and the comparison of caries status is made based on the lifetime percentage of exposure to optimally fluoridated drinking water.

The importance of the age of the sample is twofold. Firstly, this is possibly the oldest age group there that can be conveniently surveyed using school-based examination systems. There is also a possibility that measured differences in caries experience might decrease as children become older, either due to a real decrease in difference or due to a saturation effect of the DMFT index used to measure decay experience. This saturation effect arises from the fact that the number of teeth available is finite and that the DMFT does not capture the number of times an individual tooth has had to be restored. Surveys of adult dental health have reported improved dental health among fluoridated populations, but have used more appropriate measures such as the presence of sound untreated teeth or the prevalence of root caries.

This study examines the dental caries status of 16 year-olds in a Ireland straddling fluoridated and non-fluoridated water supply areas and compares two methods of assessing the effectiveness of water fluoridation.

## Methods

Children were selected for the study by a two-stage random sampling process endorsed and recommended

by the British Association for the Study of Community Dentistry (BASCD). Firstly, schools were selected in each area by creating three tiers based on school size, and selecting schools at random from each tier. As fluoride exposure was an important factor, and as this was only relevant to the schools in the Republic of Ireland, a further criterion was introduced that the schools should be located in fluoridated areas. Twenty schools from Northern Ireland and 21 schools from the Republic were selected for the sample. The second stage of sampling involved random sampling of 16-year-old students from these schools, based on a pre-set sampling fraction for each tier of schools.

The aim was to generate a sample of at least 600 cases in each region to produce a confidence interval of ±4%. It is important to note that the sample was selected to answer questions regarding the impact of fluoridated drinking water; it is not meant to be representative cross-sectional sample of each area.

One dentist carried out all examinations and this dentist was assisted by the same dental nurse throughout the exercise. The dentist was standardised for recording dental caries status at the Dental Health Services Research Unit at the University of Dundee. Children were examined in their own school on a portable couch with a Daray lamp attached. Radiographs were not taken.

Obvious decay experience ($D_{3cv}MFT$) was assessed using the BASCD guidelines, which entails a clinical examination which identified filled surfaces and decay into dentine separately (Mitropoulos *et al*, 1992). Caries status was recorded for each tooth surface using a plane dental mouth mirror, a CPITN3 probe (blunt ball-ended probe of 0.5mm diameter) and cotton wool rolls to clear plaque, saliva and debris. The probe was also used for differentiating between visual (showing shadow) and cavitational (may admit round probe) caries, and to assist in the detection of fissure sealants. The examinations were conducted under standardised conditions. One person in each group of ten examined was re-examined later on the same day to test examiner reliability. Intra-examiner reliability was assessed using the Kappa statistic and was shown to be excellent. A score of 0.8 or higher indicates very good agreement. The scores for decay into dentine ($D_{3cv}$), filled teeth, missing teeth and obvious decay experience ($D_{3cv}MFT$) were calculated.

Fieldwork was carried out between January and May 2006. The principal of each school was contacted first in writing and later by telephone to invite participation in the study. With the exception of two schools in the North and one in the Republic, all schools agreed to participate. Each school was asked to provide a list of 16 year-olds from which a random sample of students would be drawn. Sampled pupils were then forwarded a consent form inviting their participation in the survey as well as their consent to undergo a dental examination. Consent forms were mailed to each school two weeks in advance of the school visit and were collected on the day of the examination.

Recording of social indicators was complicated by the fact that the survey included two different jurisdictions, and thus common indicators may not exist. Questionnaire responses for parental occupation were coded into three categories: non-manual (e.g. management), manual (e.g. farmer) and unemployed

Two methods of assigning individuals to fluoride exposure were used. These were the 'traditional' method of assigning persons to categories based on residential history, as used in previous studies of child dental health in Ireland (the Estimated Fluoridation Status method). The second is a more detailed estimation to derive a percentage lifetime exposure to optimally fluoridated drinking water (Percentage Lifetime Exposure method).

Information on fluoridation status was gathered by the examining team on the day of the examination, which took place at the school. The students completed a questionnaire in which their lifetime residency was listed and which could be linked to monthly water fluoride analysis tests carried out by the Environmental Health Officers in the Republic. Subjects with 3 or more years of unknown exposure were excluded. An estimate was made in the Sligo-Leitrim area for three years of missing data, from 1990-1992, where records were unavailable but where fluoridation is known to have continued. To provide estimates, fluoridation levels for 1990 and 1992 were imputed to be the same as for 1989 and 1993 respectively, while the value applied to 1991 was an average of the years 1989 and 1993. The validity of these estimates was based on the consistency of the results before and after the lacunae in the records. Note that if fluoridation had been interrupted in this period, the effect of this error would be to reduce the estimate of effectiveness of fluoridation rather than exaggerate it.

The first method, Estimated Fluoridation Status, saw children assigned to one of three possible categories based on residential history. The categories were non-, partial- and full-fluoridation assigned in the manner used in previous child surveys in Ireland. "Full fluoridation" indicates that a child has experienced a fluoridated domestic water supply since birth, "partial fluoridation" indicates that the supply was fluoridated, but not continuously, and "non-fluoridated" indicates that the child has no experience of domestic fluoridated water supplies. This simple classification does not take any account of monthly variation in the level of fluoride in water supplies.

In the second method, Percentage Lifetime Exposure to Water Fluoridation, the calculation of the percentage exposure to optimally fluoridated public water supplies was modelled on methods used by Slade *et al*. (1995). The method calculates lifetime exposure using the history of residency since birth. The monthly fluoride values were categorised as follows for each fluoride treatment plant: 1, <0.3ppm (imputed as 0ppm); 2, 0.3-0.7ppm (imputed as 0.5ppm); 3, 0.7 and above (imputed as 1.0ppm); 4, Unknown. Any period during which well water was consumed or where the person was resident in the North was categorised as 0ppm. The variable Percentage Lifetime Exposure was then calculated as the number of known monthly water analysis results multiplied by imputed fluoride concentration divided by the total number of months with known fluoride levels. As an example of the calculation, consider a water supply that was measured monthly over a 15 year period (180 months) which had 75 readings at 0.5mg/l, 45 readings at 0.3mg/l and 60 readings at 1.0mg/l. The calculation would be: $[(75 \times 0.5)+(45 \times 0.3)+(60 \times 1.0)] \div 180 \times 100 = 62\%$. This figure was expressed as a percentage which was subsequently cat-

egorised into four bands: no exposure (0%), low exposure (1-50%), medium exposure (51-80%) and high exposure (81-100%). This arbitrary categorisation was applied to ensure a sufficient number of subjects in each category to allow statistical analysis. The smaller sample size in this study rendered it problematic to replicate the original categorisations suggested by Slade *et al.* (1995).

## Results

Overall 2,000 adolescents were approached and 70.2%, 1,403, participated, these values were 719/1,000, 71.9%, in the Republic and 684/1,000, 68.4%, in the North. Those data discount the 10 subjects excluded on grounds of uncertain residency history. The sample of 1,403 across the total region was achieved, giving a confidence interval of ±2.6% and a balanced gender profile with 54% of respondents being female (NWHB 52%, WHSSB 56%). Overall, 97% of children examined were aged 16 at the time of examination. The mean age was 16.41 (95% CI 16.39, 16.43) in the North and 16.51 (95% CI 16.49, 16.53) in the Republic samples. The mean scores for decay into dentine ($D_{3cv}$), filled teeth, missing teeth and obvious decay experience ($D_{3cv}$MFT) were 0.91. 0.96. 1.00 and 0.94 respectively.

Stated parental occupation was carefully examined and coded into three categories. These were non-manual occupations (e.g. management), manual (e.g. farmer) and unemployed. A significantly larger proportion of Northern Ireland adolescents (20%) stated that they had parents who were unemployed compared with the Republic of Ireland adolescents (13%) (X2[2]=12.49: p=0.002). However, there was no significant difference between the children of unemployed parents, with a mean score of 3.59 (95% CI 3.14, 4.03) and the children of those in manual occupations, at a mean score of 3.58 (3.23,

3.94) and non-manual occupations, at mean value of 3.00 (2.78, 3.23). Note that parental employment status was used as an indicator of social deprivation, and it is acknowledged that there are difficulties in developing harmonised indicators to cover both jurisdictions.

The sample's distribution by estimated fluoride category was 58% from non-, 21% partial- and 21% full-fluoridation areas. By fluoridation exposure categories the distribution was 59% with no exposure (<1%), 13% low exposure (1-50%), 10% medium exposure (51-80%) and 18% high exposure (81-100%).

The results using Estimated Fluoridation Status showed a difference in caries experience ($D_{3cv}$MFT) between the groups (Table 1). The mean for the non-fluoridation group was 3.63, which showed a significantly higher caries experience than for the full fluoridation group at 2.54 and the partial fluoridation group at 3.01. However, for untreated current active caries and for missing teeth there was no difference. There was a significant difference between all the groups in terms of restorations (FT), with the full fluoridation group having the lowest mean number of restorations at 2.01 and the non-fluoridation group having the highest, 3.11.

Turning to results for the Percentage Lifetime Exposure method (Table 2), again there was a difference in caries experience ($D_{3cv}$MFT) between the groups with the only statistically significant difference in DMFT being between the means of the high exposure group, 2.42 and the no exposure group, 3.61. For untreated current active caries there was no difference between these categories.

There are significantly fewer restorations (FT) in both the high exposure group (mean 1.98) and medium exposure group (2.33) compared to the no exposure group (3.10). There is also significantly lower value for past restorations in the high exposure group than in the low exposure group, 1.98 vs. 2.07.

**Table 1.** Caries experience ($D_{3cv}$MFT), active caries $D_{3cv}$ (teeth) and filled teeth (FT) means and confidence intervals by Estimated Fluoridation Status

| | Estimated Fluoridation Status category | | |
| --- | --- | --- | --- |
| | *None* | *Partial* | *Full* |
| | *mean (95%CI)* | *mean (95%CI)* | *mean (95%CI)* |
| Obvious decay experience, $D_{3cv}$MFT | 3.63 (3.38, 3.88) | 3.01 (2.66, 3.36) | 2.54 (2.23, 2.85) |
| Decay into dentine, $D_{3cv}$ | 0.23 (0.18, 0.27) | 0.20 (0.14, 0.26) | 0.23 (0.14, 0.32) |
| Filled Teeth,, FT | 3.11 (2.88, 3.33) | 2.58 (2.25. 2.91) | 2.01 (1.75, 2.26) |

**Table 2.** Caries experience ($D_{3cv}$MFT), active caries $D_{3cv}$ (teeth) and filled teeth (FT) means and confidence intervals by Percentage Lifetime Exposure category

| | Percentage Lifetime Exposure category | | | |
| --- | --- | --- | --- | --- |
| | *None* | *Low* | *Medium* | *High* |
| | *mean (95%CI)* | *mean (95%CI)* | *mean (95%CI)* | *mean (95%CI)* |
| Obvious decay experience, $D_{3cv}$MFT | 3.61 (3.36, 3.86) | 3.16 (2.70, 3.62) | 2.93 (2.41, 3.45) | 2.42 (2.12, 2.73) |
| Decay into dentine, $D_{3cv}$ | 0.22 (0.18, 0.26) | 0.26 (0.16, 0.36) | 0.29 (0.13, 0.45) | 0.16 (0.10, 0.22) |
| Filled Teeth, FT | 3.10 (2.87, 3.32) | 2.70 (2.27, 3.13) | 2.33 (1.88, 2.78) | 1.98 (1.72, 2.24) |

## Discussion

The response rate of 70% is considered appropriate for epidemiological investigations (Locker, 1993). The observed lack of difference in untreated caries might be expected as this variable is more likely to be related to access to dental care than to fluoridation status. With regard to the observed fewer restorations in higher exposure groups, it is important to note that this is not a result of a greater number of alternative treatments (extractions due to caries) due to dentist behaviour or access to treatment in any area as the mean number of extracted teeth is the same in the no exposure (virtually all from the North), and the two higher exposure groups (virtually all from the Republic) at 0.29 and 0.31/0.28 respectively.

The subjects' mean age was 16.41 (95% CI 16.39, 16.43) in the North and 16.51 (16.49, 16.53) in the Republic samples. While the difference is *statistically* significant, it is probably of no *clinical* significance, amounting to a mean difference of some 37 days in age. If it had clinical significance it would lead one to expect a bias towards marginally lower scores for decay in the North. In fact, decay scores were lower in the Republic.

Differences in dental caries experience relating to fluoridation status were found using both methods described. Adolescents with a greater degree of exposure to fluoridated water have lower caries experience (as measured by DMFT) than those with the lowest degree of exposure. These findings evidence the continued effectiveness of water fluoridation. Previous studies have noted such differences up to 15 years of age. In the 2002 All-Ireland study, 15-year-olds in fluoridated areas of the Republic had a mean DMFT of 2.1 while those in the North had a score of 3.6; in the current study the 16 year olds in this study scored 2.5 and 3.6 respectively.

## Conclusions

In this study, the dental caries levels of 16-year olds in a border area in Ireland have been shown to be lower in those exposed to higher degrees of water fluoridation. This difference in caries experience was demonstrated in terms of Percentage Lifetime Exposure to water fluoridation and by Estimated Fluoridation Status.

Two methods for comparing exposure to fluoridated drinking water were used. The authors found the only practical disadvantage of the Percentage Lifetime Exposure method was that it is more complex than the Estimated Fluoridation Status procedure. However, while the authors found there was little extra information gained in this study if compared with the more traditional method, this observation may not hold true in other societies where there are more complex residential histories with families moving house more often.

The results of this study provide evidence of the continuing effectiveness of community water fluoridation as a public health policy measure.

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