Impact of reducing water fluoride on dental caries and fluorosis

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A supplemetal appendix to this article is available.

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Abstract:

Introduction: Guidance intended to reduce fluoride toothpaste ingestion in early childhood was introduced in Ireland in 2002. In 2007, water fluoride concentration was adjusted from 0.8-1.0 to 0.6-0.8ppm.

Objective: To determine the difference in caries and fluorosis levels following introduction of these two policy measures.

Methods: A before-and-after study compared caries and fluorosis in random samples of 8-year-olds in Dublin (n=707) and Cork-Kerry (n=1148) in 2017 with 8-year-olds in Dublin (n=679) and Cork-Kerry (n=565) in 2002. Dentinal caries experience (primary teeth, d_{3vc}mft(cde)) and fluorosis (permanent teeth, Dean's ≥very mild) were clinically measured. Lifetime exposure to community water fluoridation (CWF) was classified as 'Full-CWF'/'No-CWF'. Effect of examination year on caries prevalence and severity and fluorosis prevalence was assessed using multivariate regression adjusting for other explanatory variables.

Results: There was little change in commencement of fluoride toothpaste use at ≤24 months following introduction of toothbrushing guidance. Among children with Full-CWF, there was no statistically significant difference in caries prevalence or severity between 2017 and 2002. In 2017, caries prevalence was 55% in Dublin (Full-CWF) and 56% in Cork-Kerry (Full-CWF) and mean d_{3vc}mft(cde) among children with caries was 3.4 and 3.7, respectively. Caries severity was less in 2017 (mean 4.2) than 2002 (mean 4.9) among children with No-CWF (P=0.039). The difference in caries severity between children with Full-CWF and No-CWF was less in 2017 than 2002 (Interaction P = 0.013), suggesting a reduced benefit for CWF in 2017. In 2017, fluorosis prevalence was 18% in Dublin (Full-CWF) and 12% in Cork-Kerry (Full-CWF). Fluorosis was predominantly 'very mild' with no statistically significant difference between 2017 and 2002.

Conclusion: CWF at 0.6-0.8ppm is an effective caries-preventive measure. Results suggested low uptake of toothbrushing guidance, a reduced caries-preventive effect for CWF in primary teeth and no reduction in fluorosis following introduction of the policy measures.

Introduction:

Dental caries presents a major public health challenge especially for lower socio-economic groups (Bernabe et al. 2020) for which community water fluoridation (CWF) is a safe and effective strategy (Jack et al. 2016). CWF reaches all socio-economic groups without active participation of individuals (O'Mullane et al. 2016). Fluoride toothpaste provides caries prevention additional to CWF (Marinho et al. 2003). The benefits of fluoride for preventing caries must be balanced against the risk of developing dental fluorosis from fluoride ingestion during amelogenesis. Moderate and severe fluorosis may adversely affect aesthetics and oral health-related quality of life (OHRQoL) (Chankanka et al. 2010).

Following introduction of CWF at 0.8–1.0ppm fluoride (Government of Ireland 1960) and increasing use of fluoride toothpaste, there was a substantial decline in caries in Irish children (O'Mullane et al. 1986). However, by 2002, with 71% of the population supplied by CWF and fluoride toothpaste widely used, dental fluorosis had increased, particularly among children with lifetime exposure to CWF (Whelton et al. 2006). This prompted two new policy measures aimed at minimising the occurrence of dental fluorosis while maintaining reductions in caries. Firstly, with fluoride toothpastes holding over 95% of the market in Ireland, guidance was introduced in 2002 to reduce ingestion of fluoride toothpaste in early childhood (Department of Health and Children 2002). Parents were advised to delay commencing toothpaste use until after age 24 months and to supervise toothbrushing using a small pea-sized amount of toothpaste up to age 7. The majority of children's toothpastes used in Ireland contained at least 1000ppm fluoride. Although low fluoride toothpastes (500ppm or less) were available, the guidance did not recommend their use as their effectiveness was deemed uncertain. This toothbrushing guidance remains in place following recent review of the evidence underpinning it (O'Mullane et al. 2018). Secondly, in 2007, the fluoride concentration of public water supplies was adjusted downwards to a range of 0.6-0.8ppm fluoride with a target of 0.7ppm.

Several other countries with CWF such as Hong Kong, Singapore, Malaysia, Canada and the United States (U.S.) have also lowered water fluoride concentration. The adjustment in the U.S. from a range of 0.7-1.2 to 0.7ppm fluoride (U.S.H.H.S. 2015) is similar to that in Ireland. Reports from Hong Kong and Malaysia indicate a downward trend in dental fluorosis without an increase in caries (Evans and Stamm 1991; Wong et al. 2014; Lee et al. 2016; Mohd Nor et al. 2018). However, it is difficult to generalise the results of these studies due to cultural and contextual differences.

This paper reports on the Fluoride and Caring for Children's Teeth (FACCT) study, which aimed to evaluate the impact of downward adjustment of water fluoride concentration and introduction of toothbrushing guidance on caries and fluorosis in Ireland. The objectives were to determine if there was a difference in 1) the prevalence and severity of caries in primary teeth and 2) the prevalence of fluorosis in permanent teeth of children born after introduction of the policy measures compared with children examined in the same regions in 2002 in the North South Survey of Children's Oral Health (Whelton et al. 2006), prior to introduction of the policy measures.

Methods

Ethical approval (Clinical Research Ethics Committee of the Cork Teaching Hospitals, ECM 5 (2) 07/05/13), written informed consent from parents/guardians, and child assent were obtained. This manuscript follows STROBE guidelines (von Elm et al. 2008).

Study setting and design:

In 2017, 71% of the Irish population had access to CWF, the remainder supplied by non-fluoridated water schemes or private wells. This study was conducted in Counties Dublin, Cork and Kerry. One quarter of the population of Ireland reside in Dublin (Central Statistics Office 2017) with CWF, while Counties Cork and Kerry have a mix of areas with and without CWF.

Using a before-and-after study design (Figure), caries in primary teeth and fluorosis in permanent teeth of 8-year-olds 2017 were compared with 8-year-olds 2002. At both time points, children were aged 7-9 (fourth year of primary school). Eight-year-olds in 2017 were participants in a longitudinal study that commenced in 2014 (FACCT phase 1) when they were 5-year-olds (first year of primary school). The methods of the FACCT study and the 2002 survey were previously reported (Whelton et al. 2006; James et al. 2018). As domestic water supplies throughout urban Dublin are fluoridated, no concurrent control group was available in Dublin. However, concurrent control groups with no exposure to CWF were available in 2002 and 2017 in Cork-Kerry, facilitating a controlled before-and–after study in this region. Eight-year-olds examined in 2017 were born after introduction of toothbrushing guidance (2002) and downward adjustment of water fluoride concentration (2007) and thus had lifelong exposure to both policy measures. Conversely, 8-year-olds in 2002 had exposure to neither policy measure.

Study sample:

Samples were selected in 2002 and 2014 using the same method of multistage stratified cluster random sampling with school as the primary sampling unit. For children with CWF in 2017, the target sample size of 424 8-year-olds in Cork-Kerry and 497 8-year-olds in Dublin had in excess of 80% power, at a 5% level of significance, to demonstrate that the proportion of children with Dean's Index scores 'normal' in each region had increased by at least 5% since 2002. This sample size had 80% power to demonstrate a difference in d_{3vc}mft(cde) of 20% in Dublin and Cork-Kerry for children with CWF in 2017 relative to 2002.

Measurement of exposure to CWF

Data from mandatory monitoring of fluoride levels in public water supplies in Ireland confirmed that the downward adjustment was implemented from mid-2007 (Appendix Figure 1). Parents detailed their child's full residential history. Exposure to CWF in 2002 and 2017 was classified individually based on the fluoride concentration of water supplying the child's

current and previous addresses. Participants were classified as having lifetime exposure (Full-CWF), no exposure (No-CWF), sporadic exposure (Part-CWF), or 'unknown' exposure to CWF. Analyses reported here relate to children with Full-CWF and No-CWF.

In 2002, following a defined protocol, examining teams classified the fluoridation status of children in their area, whereas in FACCT, this classification was completed after clinical examination by researchers not involved in clinical fieldwork. In principle, classification of exposure to CWF was the same in FACCT and 2002 surveys. However, with the passage of time, access to new resources including the Irish Water website (https://www.water.ie/water-supply/water-quality/) facilitated use of more sophisticated methods for classifying fluoridation status in the FACCT study.

Measurement of dental caries and fluorosis:

Dental examiners assisted by dental nurses conducted clinical examinations in schools January-June 2002 and November 2016-May 2017. The same experienced benchmark examiner (HW) supported by assistant benchmark examiners, trained and calibrated different groups of examiners in 2002 and 2017 (Appendix Table 1). Methods for measuring caries and fluorosis were identical in 2002 and 2017 as described previously (James et al. 2018). Teeth were not dried for either examination. Caries in primary teeth was measured using WHO criteria (World Health Organisation 2013) modified to include visible non-cavitated dentinal caries (d_{3vc}mft, 'v' indicating 'visual caries') (Whelton et al. 2006). Caries experience was reported as the proportion of children with decayed, missing or filled primary canines, first or second primary molars (prevalence, d_{3vc}mft(cde)>0) and mean d_{3vc}mft(cde) among children with caries experience (severity). For fluorosis, a person-level Dean's Index score was assigned following assessment of all permanent teeth present (Dean 1942). Case definition for fluorosis was a Dean's Index score 'very mild' or higher.

Measurement of other explanatory variables:

Socio-demographic and oral health behaviours data were collected in 2002, 2014 (at age 5, FACCT phase 1) and 2017 (at age 8, FACCT phase 2) via a parent-completed questionnaire. Relevant explanatory variables common to the 2002 and FACCT data sets were identified and categorical responses grouped for analysis (Table 1).

Statistical Analysis:

Repeat examinations during fieldwork yielded intra-examiner kappa scores for caries ranging from 0.86 to 1.00 (median 0.97) in 2002 and 0.77 to 1.00 (median 0.92) in 2017 and for fluorosis from 0.40 to 1.00 (median 0.67) in 2002 and 0.57 to 1.00 (median 0.92) in 2017. Although inter-examiner reliability with benchmark examiners was monitored in 2002, kappa scores are unavailable. In 2017, kappa scores for inter-examiner reliability for caries ranged from 0.55 to 0.92 (median 0.81) and for fluorosis from 0.43 to 1.00 (median 0.74).

Multivariate regression with a negative binomial Hurdle Model (HNB) assessed the association between year of examination and prevalence and severity of caries, adjusted for the effect of other relevant explanatory variables. The HNB is a two-part model which assesses 1) the association between year of examination and caries prevalence and 2) the association between year of examination and caries severity among children with caries experience. Differences between children with Full-CWF and No-CWF in Cork-Kerry were compared (2017 vs 2002) by testing the interaction between fluoridation (Full-CWF vs No-CWF) and year of examination.

Multivariate logistic regression assessed the association between year of examination and prevalence of fluorosis, adjusted for the effect of other relevant explanatory variables. Differences in severity were not assessed because numbers with ‘mild’ and ‘moderate’ fluorosis were too low to be considered separately.

Interactions between year of examination and all other explanatory variables were tested but none were statistically significant. The lower proportion of children examined in 2017 with

Full-CWF (25%) compared with 2002 (51%) (Appendix Figures 2 and 3), reflected improvements in access to electronic data for classification of lifetime exposure to CWF. Thus, a proportion of children classified as Full-CWF in Cork-Kerry 2002 may have had Part-CWF. A sensitivity analysis indicated that re-classifying Part-CWF 2002 as Full-CWF or No-CWF did not change the overall findings (Appendix Table 2). Thus, any potential misclassification of exposure to CWF in 2002 was considered unlikely to have had an important impact on the results. Data were analysed using STATA (IC Version 14.2) and SAS (Version 9.4) software.

Results

The flow of participants through FACCT and 2002 surveys are outlined in Appendix Figures 2 and 3. The response rate was 68% in 2002 and 72% for phase 1 of FACCT (2014). Of 4215 children invited to participate in phase 1 of FACCT, 2308 (55%) were examined for caries and 2304 (55%) for fluorosis in phase 2 (2017). Characteristics of children whose parents consented to participate in 2014 and of children who were followed up and examined in 2017 were similar (Appendix Table 3). Of children examined in Dublin, 94% in 2002 and 89% in 2017 had Full-CWF. Of those examined in Cork-Kerry 51% in 2002 and 25% in 2017 had Full-CWF, whereas 36% in 2002 and 51% in 2017 had No-CWF.

Approximately one-third of the population are eligible for a medical card (PCRS). The proportion of the samples in 2002 and FACCT surveys who were dependants of medical card holders was 21% and 26%, respectively (Table 1). Compared with 2002, a higher proportion of children in 2017 brushed at least twice a day and used a pea-sized amount of toothpaste or less. However, despite advice to delay commencing fluoride toothpaste use until after 24 months, 80% of parents in 2017 with Full-CWF and No-CWF indicated that they first used toothpaste with their child at ≤24 months compared with 76%-86% in 2002.

In Dublin (Full-CWF), caries prevalence was 55% in 2017 compared with 54% in 2002. Among children with caries experience, mean d_{3vc}mft(cde) was 3.4 (SD 2.3) in 2017

compared with 3.3 (SD 2.1) in 2002 (Table 2). Multivariate regression revealed no statistically significant difference in either the prevalence or severity of caries in Dublin children (Full-CWF) in 2017 relative to 2002 (Table 3). Results were similar among children with Full-CWF in Cork-Kerry. Among children with No-CWF in Cork-Kerry, caries prevalence and mean d_{3vc}mft(cde) were higher at both time points compared with their Full-CWF counterparts. The difference in caries prevalence among children with No-CWF in Cork-Kerry in 2017 (65%) relative to 2002 (73%) was not statistically significant. However, among children with caries, the reduction in mean d_{3vc}mft(cde) from 4.9 (SD 2.6) in 2002 to 4.2 (SD 2.5) in 2017 was statistically significant (reduction in mean 13%, CI 1 to 24) (Table 3). The difference in caries prevalence between children with Full-CWF and No-CWF in Cork-Kerry was similar in 2002 and 2017 (Interaction *P*=0.098). However, among children with caries experience, the difference in caries severity between children with Full-CWF and No-CWF was less in 2017 than 2002 (Interaction *P*=0.013).

Among children with Full-CWF in Dublin, fluorosis prevalence was 18% in 2017 and 15% in 2002 and in Cork-Kerry it was 12% in 2017 and 13% in 2002 (Table 4). Fluorosis prevalence among children with No-CWF in Cork-Kerry was 5% in 2017 and 3% in 2002. None of the differences were statistically significant (Table 3).

Other explanatory variables associated with increased prevalence and/or severity of caries in 2002/2017 were medical card ownership, brushing once/day or less (vs twice/day or more), having sweet foods/drinks more than once a day between meals, and visiting the dentist (vs never) (Appendix Tables 4-6). In Dublin (Full-CWF), first using toothpaste at ≤24 months was associated with reduced prevalence of caries (Appendix Table 4). In Dublin (Full-CWF), being female (vs male) was associated with increased prevalence of fluorosis (Appendix Table 7).

Discussion

Following introduction of the policy measures, there was no increase in caries but the expected reduction in dental fluorosis was not observed. Although fluorosis prevalence was low with little or no impact on OHRQoL (Chankanka et al. 2010), the latter findings suggest that reduction in fluoride absorption in early childhood was not achieved.

As compliance with reducing fluoride levels in water was excellent, the findings could be explained by increased ingestion of fluoride from discretionary sources. As fluoride supplements and infant formula reconstituted with fluoridated water are not considered important risk factors for fluorosis in Ireland (Department of Health and Children 2002; Anderson et al. 2004; FSAI 2018), the most important source of discretionary fluoride is fluoride toothpaste. Knowledge about certain desirable oral health behaviours such as brushing twice a day, using a pea-sized amount of toothpaste and not to use a glass to rinse after toothbrushing increased since 2002. However, acknowledging the risk of recall bias, there was low uptake of advice in relation to age of commencing fluoride toothpaste use. The Dental Health Foundation Ireland (dental health.ie), promotes official oral health messages using different strategies to engage with the public and the dental profession. As dental visiting was low in Ireland among infants and young children (Whelton et al. 2006; Parnell et al. 2007), advice from dental health professionals regarding use of fluoride toothpaste in early childhood was unlikely to be timely. Children under age 30 months ingest much of the toothpaste (Cochran et al. 2004), thus increased toothbrushing frequency could have compensated for reduced exposure to water fluoride, offsetting a reduction in dental fluorosis.

Toothpaste use in early childhood and increased frequency of toothbrushing could also help to explain the reduced severity of caries in children with No-CWF. A similar trend in caries was not apparent in children with Full-CWF despite similar reported toothbrushing behaviours in children with Full-CWF and No-CWF in 2017. These trends indicate that the

caries-preventive effect of CWF may have reduced following adjustment of water fluoride concentration.

The majority of children at both time points had experienced caries in their primary dentition. The first opportunity for these children to avail of free routine dental care was at age 7-9. Attending the dentist was associated with increased caries levels in primary teeth reflecting a pattern of dental attendance for caries-related problems. The recent Irish Oral Health Policy aims to reduce caries in the primary dentition through early access to preventive services (Department of Health 2019).

Randomised controlled trials are often not feasible when evaluating complex public health interventions (Jack et al. 2016). A major strength of this pragmatic study was the thorough individual classification of exposure to CWF. A further strength was assessment of caries and fluorosis using identical protocols at both time points with training led by the same experienced benchmark examiner. Also, control groups at both time points facilitated assessment of temporal trends in caries and fluorosis in children with No-CWF. Multivariate regression controlled for any differences in demographics or oral health behaviours between the groups being compared.

However, the study has some limitations. Firstly, examiners were not blind to participants' fluoridation status because transporting children to a neutral venue was not logistically feasible. In FACCT, although examiners likely knew whether the child's school was in a fluoridated or non-fluoridated area, risk of bias was mitigated by ensuring that examiners were not aware of the child's exposure to CWF throughout their lives. Secondly, a shortcoming of Dean's Index as applied in this study is that the teeth that were the basis for the whole mouth score were not recorded. Therefore, fluorosis affecting the aesthetically important maxillary incisors could not be quantified. The impact of the policy measures on fluorosis measured from photographs is underway, focussing on maxillary permanent incisor

teeth. This will facilitate blind scoring and allow assessment of the impact of the policy measures on fluorosis in aesthetically important teeth.

Although a downward trend in dental fluorosis without a corresponding increase in caries was reported in Hong Kong and Malaysia following downward adjustment of water fluoride concentration (Evans and Stamm 1991; Wong et al. 2014; Lee et al. 2016; Mohd Nor et al. 2018), comparison with our results is hampered by the adjustments involving different concentrations of fluoride, different climates, methodological differences between the studies and cultural and contextual differences between the populations. An alternative approach adopted in Australia in the early 1990s to maintain the water fluoride concentration while targeting reductions in exposure to discretionary sources of fluoride, was successful in achieving a reduction in fluorosis prevalence (Riordan 2002; Do and Spencer 2007), with increased use of low-concentration fluoride toothpaste shown to be largely responsible for the reduction (Do and Spencer 2007). Studies of the caries-preventive effect of low-concentration fluoride toothpastes in primary teeth have produced conflicting results (Walsh et al. 2019) and further research is warranted.

Lowering the fluoride level of CWF has been questioned on the basis that it reduces the benefit for caries prevention across the life course in order to reduce the risk of dental fluorosis in early childhood (Spencer and Do 2016). Caries development in the primary dentition sets children on a steep trajectory towards further disease experience in the permanent dentition (Hall-Scullin et al. 2017). Dental fluorosis, on the other hand, does not progress and may decline in severity over time (Do et al. 2016; Curtis et al. 2020). The trend of increasing fluorosis that prompted introduction of the policy measures has stabilised. CWF at 0.6-0.8ppm fluoride is an effective caries-preventive measure. However, there are indications that downward adjustment of water fluoride concentration has reduced the caries-preventive effect of CWF. Evaluating the impact of the downward adjustment on caries in permanent teeth of children and adults with CWF is a priority for further research.

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Author Contributions:

P James contributed to conception, design, data acquisition, analysis and interpretation, drafted and critically revised the manuscript. M Harding contributed to conception, design, data acquisition, analysis and interpretation, drafted and critically revised the manuscript. T Beecher contributed to conception, design, data acquisition and critically revised the manuscript. D Browne contributed to conception, design and critically revised the manuscript. M Cronin contributed to conception, design, analysis and interpretation and critically revised the manuscript. H Guiney contributed to analysis and interpretation and critically revised the manuscript. D O'Mullane contributed to conception, design, analysis and interpretation, drafted and critically revised the manuscript. H Whelton contributed to conception, design, data acquisition, analysis and interpretation and critically revised the manuscript. All authors gave their final approval and agree to be accountable for all aspects of the work.

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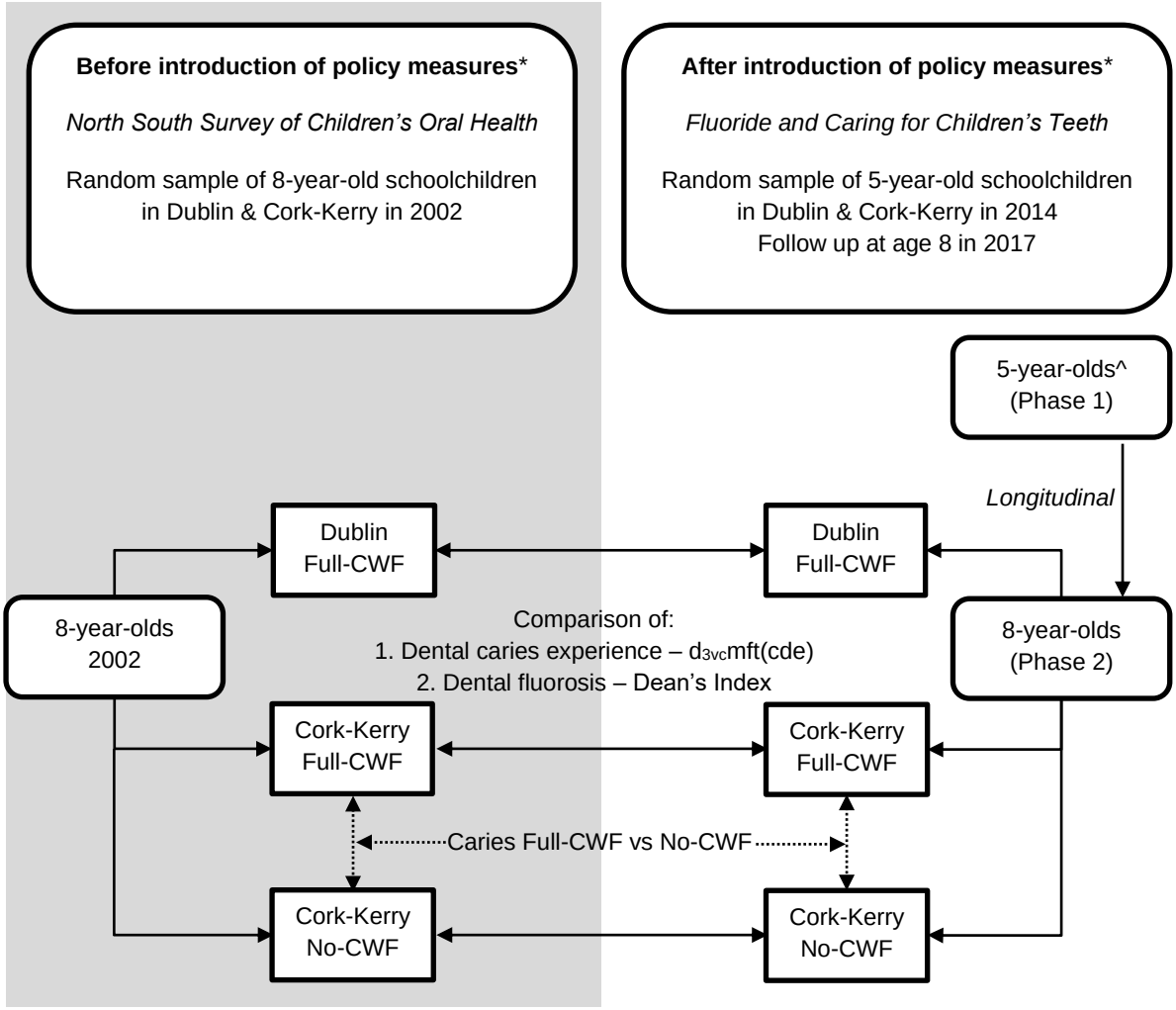

Figure: Overview of study design

*****Toothbrushing guidance in 2002 & downward adjustment of CWF concentration in 2007

^Information about age first used toothpaste collected via parent-completed questionnaire at age 5 (2014) used in analysis at age 8 (2017)

Table 1: Characteristics of 8-year-olds examined in Dublin (Full-CWF) and Cork-Kerry (Full-CWF and No-CWF) in 2002 and 2017

	Dublin Full-CWF		Cork-Kerry Full-CWF		Cork-Kerry No-CWF	
	2002	2017	2002	2017	2002	2017
Characteristic	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Total examined	679	707	332	376	233	772
Gender						
Female	319 (47)	383 (54)	183 (55)	198 (53)	130 (56)	392 (51)
Male	360 (53)	324 (46)	149 (45)	178 (47)	103 (44)	380 (49)
Age*	8.3 (0.4)	8.2 (0.3)	8.4 (0.5)	8.3 (0.4)	8.5 (0.4)	8.4 (0.4)
Economic disadvantage‡						
Medical card	139 (20)	206 (29)	80 (24)	111 (30)	39 (17)	158 (20)
No Medical card	532 (78)	486 (69)	251 (76)	257 (68)	193 (83)	603 (78)
Missing	8 (1)	15 (2)	1 (<1)	8 (2)	1 (<1)	11 (1)
Age first used toothpaste∞						
≤ 24 months	547 (81)	568 (80)	284 (86)	303 (81)	177 (76)	618 (80)
> 24 months^	123 (18)	133 (19)	43 (13)	68 (18)	54 (23)	145 (19)
Missing	9 (1)	6 (<1)	5 (2)	5 (1)	2 (<1)	9 (1)
Age at first visit to the dentist						
≤ 4 years old	165 (24)	166 (23)	94 (28)	92 (24)	67 (29)	238 (31)
5-6 years old	189 (28)	222 (31)	115 (35)	119 (32)	87 (37)	244 (32)
≥7 years old	182 (27)	102 (14)	87 (26)	84 (22)	58 (25)	148 (19)
Never	122 (18)	186 (26)	30 (9)	67 (18)	17 (7)	122 (16)
Missing	21 (3)	31 (4)	6 (2)	14 (4)	4 (2)	20 (3)
Frequency of toothbrushing (age 8)						
Once a day or less	286 (42)	195 (28)	128 (39)	97 (26)	103 (44)	204 (26)
Twice a day or more	387 (57)	498 (70)	202 (61)	271 (72)	127 (55)	561 (73)
Missing	6 (<1)	14 (2)	2 (<1)	8 (2)	3 (1)	7 (<1)
Amount of toothpaste (age 8)						
Pea-sized^ or less	289 (43)	600 (85)	161 (48)	305 (81)	92 (39)	642 (83)
> Pea-sized	381 (56)	88 (12)	170 (51)	60 (16)	138 (59)	114 (15)
Missing	9 (1)	19 (3)	1 (<1)	11 (3)	3 (1)	16 (2)
Rinse method after toothbrushing (age 8)						
Glass	181 (27)	147 (21)	99 (30)	84 (22)	91 (39)	209 (27)
Other◊ or no rinse	483 (71)	547 (77)	232 (70)	284 (76)	137 (59)	555 (72)
Missing	15 (2)	13 (2)	1 (<1)	8 (2)	5 (2)	8 (1)
Sweet foods/drinks between meals (age 8)						
≥ 4 times per day	74 (11)	68 (10)	19 (6)	32 (9)	13 (6)	48 (6)
2-3 times per day	321 (47)	308 (44)	163 (49)	165 (44)	90 (39)	296 (38)
Once a day or less	275 (41)	312 (44)	148 (45)	164 (44)	127 (55)	411 (53)
Missing	9 (1)	19 (3)	2 (<1)	15 (4)	3 (1)	17 (2)

Data are for children who had a caries and/or fluorosis examination in 2002 (n=1244) or 2017 (n=1855). Sample size in Cork-Kerry No-CWF is larger in 2017 than 2002 because the FACCT study was powered to demonstrate differences (Full-CWF vs No-CWF) within Cork-Kerry, whereas the No-CWF sample in Cork-Kerry 2002 contributed to a national No-CWF sample. Percentages may not sum to 100 due to rounding.

*mean (SD), no missing data

‡Medical card ownership indicates socio-economic disadvantage. A medical card is a means-tested benefit provided by the Irish state to applicants who meet criteria based on income, expenses, marital status, dependants and other circumstances.

∞Grouped responses for age at first toothbrushing in 2002 (prior to introduction of toothbrushing guidance, collected at age 8) and age of first using toothpaste in 2014 (collected at age 5)^Recommended from 2002 onwards ◊Other = using toothbrush to rinse/cupping hands to rinse/rinsing directly from the tap

Table 2: Dental caries experience in primary teeth of 8-year-olds in Dublin (Full-CWF) and Cork-Kerry (Full-CWF and No-CWF) in 2002 and 2017

	Children with caries experience (d_{3vc}mft(cde) > 0)						Full sample (children with and without caries experience)			
	2002			2017			2002		2017	
	n	%	mean (SD)	n	%	mean (SD)	n	mean (SD)	n	mean (SD)
Dublin										
Full-CWF	368	54	3.3 (2.1)	388	55	3.4 (2.3)	679	1.8 (2.2)	704	1.9 (2.4)
Cork-Kerry										
Full-CWF	182	55	3.5 (2.2)	209	56	3.7 (2.4)	332	1.9 (2.4)	375	2.1 (2.6)
No-CWF	169	73	4.9 (2.6)	497	65	4.2 (2.5)	233	3.5 (3.1)	770	2.7 (2.8)

Table 3: Multivariate (adjusted) regression analyses of the association between year of examination, dental caries in primary teeth and dental fluorosis in permanent teeth of 8-year-olds in Dublin (Full-CWF) and Cork-Kerry (Full-CWF and No-CWF)

		Dublin Full-CWF			Cork-Kerry Full-CWF			Cork-Kerry No-CWF		
Outcome	Year	n	OR% (95%CI)	P value	n	OR% (95%CI)	P value	n	OR% (95%CI)	P value
Caries prevalence[a]	2017 2002	1291	14 (-13, 49) Reference	0.350	663	25 (-12, 78) Reference	0.208	941	-23% (-48, 13) Reference	0.179
Caries severity[ab]	2017 2002	699	5 (-9, 21) Reference	0.487	369	7 (-9, 27) Reference	0.424	622	-13 (-24, -1) Reference	0.039
Fluorosis prevalence[c]	2017 2002	1338	16 (-13,56) Reference	0.312	678	-7 (-41, 48) Reference	0.771	979	97 (-18,373) Reference	0.129

Multivariate models are presented in full in Appendix Tables 4 - 7
OR% = odds ratio percent: the percentage increase/decrease in odds
CI = confidence interval, CWF = Community water fluoridation
[a]Negative binomial Hurdle Model analysis. Adjusted for medical card ownership, age, age first used toothpaste, age at first visit to the dentist, frequency of toothbrushing (age 8), amount of toothpaste (age 8), method of rinsing after toothbrushing (age 8), frequency of intake of sweet foods or drinks between meals (age 8).
[b] Percentage change in mean d_{3vc}mft(cde)
[c]Logistic regression analysis. Adjusted for age, gender, medical card ownership and age first used toothpaste.

Table 4: Prevalence of fluorosis and distribution of clinical Dean's Index scores among 8-year olds in Dublin (Full-CWF) and Cork-Kerry (Full-CWF and No-CWF) in 2002 and 2017

	Dublin Full-CWF		Cork-Kerry Full-CWF		Cork-Kerry No-CWF	
	2002	2017	2002	2017	2002	2017
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Fluorosis Prevalence						
Normal/Questionable	567 (85)	576 (82)	283 (87)	328 (88)	222 (97)	732 (95)
Very mild or higher	104 (15)	127 (18)	42 (13)	43 (12)	6 (3)	40 (5)
Total	**671 (100)**	**703 (100)**	**325 (100)**	**371 (100)**	**228 (100)**	**772 (100)**
Dean's Index score						
Normal	488 (73)	441 (63)	245 (75)	232 (63)	196 (86)	613 (79)
Questionable	79 (12)	135 (19)	38 (12)	96 (26)	26 (11)	119 (15)
Very mild	75 (11)	99 (14)	25 (8)	34 (9)	6 (3)	38 (5)
Mild	24 (4)	26 (4)	17 (5)	8 (2)	0 (0)	2 (<1)
Moderate	5 (<1)	2 (<1)	0 (0)	1 (<1)	0 (0)	0 (0)
Total	**671 (100)**	**703 (100)**	**325 (100)**	**371 (100)**	**228 (100)**	**772 (100)**

No cases of severe fluorosis were recorded