Received: 2 February 2018 | Revised: 17 May 2018 | Accepted: 27 June 2018

DOI: 10.1111/cdoe.12407

ORIGINAL ARTICLE

WILEY COMMUNITY DENTISTRY AND ORAL EPIDEMIOLOGY

The impact of a reduction in fluoride concentration in the Malaysian water supply on the prevalence of fluorosis and dental caries

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Abstract

Objective: To assess the prevalence and severity of dental fluorosis and caries among Malaysian children following the reduction in fluoride concentration from 0.7 to 0.5 parts per million (ppm) in the public water supply.

Methods: This study involved lifelong residents aged 9- and 12-year-olds in fluoridated and nonfluoridated areas in Malaysia (n = 1155). In the fluoridated area, children aged 12 years and 9 years were exposed to 0.7 and 0.5 ppm, respectively, at the times when maxillary central incisors developed. Standardized photographs of maxillary central incisors were blind scored for fluorosis using Dean's criteria. Dental caries was examined using ICDAS-II criteria.

Results: The prevalence of fluorosis (Dean's score ≥ 2) among children in the fluoridated area (35.7%, 95% CI: 31.9%-39.6%) was significantly higher ($P < 0.001$) than children in the nonfluoridated area (5.5%, 95% CI: 3.6%-7.4%). Of those in the fluoridated area, the prevalence of fluorosis decreased from 38.4% (95% CI: 33.1%-44.3%) for 12-year-olds to 31.9% (95% CI: 27.6%-38.2%) for 9-year-olds, although this difference was not statistically significant ($P = 0.139$). The mean caries experience in the permanent dentition was significantly lower in the fluoridated area than in the nonfluoridated area for both age groups ($P < 0.05$). In the multivariate models, the difference in the differences of caries experience between fluoridated and nonfluoridated areas remained statistically significant. This suggests that caries-preventive effect is still maintained at 0.5 ppm.

Conclusion: Findings indicate that the change in fluoride level from 0.7 to 0.5 ppm has reduced fluorosis and maintains a caries-preventive effect. Although there is a reduction in fluorosis prevalence, the difference was not statistically significant.

KEYWORDS

dental caries, dental fluorosis, public health, reduction in fluoride level

1 | INTRODUCTION

In Malaysia, as a public health measure to prevent dental caries, the public water supply was artificially fluoridated in 1972 at a concentration of 0.7 parts per million fluoride (ppmF).[1] However, concern arose that a fluoride concentration at 0.7 ppm may be too high given increasing exposure to other sources of fluoride such as fluoridated toothpaste, leading to an increased prevalence of dental fluorosis.[2-4] In addition, there was concern over higher water intake in Malaysian due to warmer climatic conditions, with average temperatures of 27-30°C.[4] This prompted a downward adjustment of fluoride concentration from 0.7 to 0.5 ppm in December 2005.[1]

Malaysia is not the only country to review their fluoridation policy in the light of alternative modes of fluoride delivery. The United States Public Health Services have recommended lowering the concentration of fluoride in public water supplies from a range of 0.7 to 1.2 ppm to a level of 0.7 ppm.[5] In Europe, Ireland has lowered the fluoride concentration in the water from 1.0 ppm to a new range of 0.6-0.8 ppm, with a target concentration of 0.7 ppm in 2007.[6] In Asia, authorities in Hong Kong have reduced the fluoride concentration in their public water supply twice, from 1 ppm to 0.7 ppm in 1978 with a further reduction to 0.5 ppm in 1988.[7] In South-East Asia, Singapore has taken similar action by reducing the concentration of fluoride in drinking water twice from 0.7 to 0.6 ppm in 1992 and further to 0.5 ppm in 2008.[8] However, despite the substantial evidence of the effectiveness of water fluoridation, evidence relating the impact of minor changes of fluoride concentration of public water supply has seldom been investigated.

The situation in Malaysia offers a unique opportunity to evaluate the outcome of the 0.2 ppm adjustment of fluoride concentration in the public water supply on both dental caries and fluorosis. Apart from generating evidence on the effectiveness of the policy initiative, information about fluoride exposure is useful for policymakers, public health planners and healthcare professionals when planning effective community-based fluoride therapy for the prevention of dental caries, while limiting dental fluorosis.

The aim of the study reported here was therefore to assess the prevalence and severity of dental fluorosis and caries among Malaysian children following the reduction in fluoride concentration from 0.7 to 0.5 parts per million (ppm).

2 | METHODS

This study was reviewed and approved by Cardiff University Dental School Research Ethics Committee (DSREC 14/17a). In addition, permission to conduct the study was obtained from the relevant Ministries in Malaysia namely the Ministry of Health, the Ministry of Education and the State Education Department.

2.1 | Study design

This is a single point cross-sectional study that compared children from different age groups that were exposed to different fluoride levels. Altogether the study sample consisted of four subgroups that were divided by age (9 and 12 years) and area of residence (fluoridated and nonfluoridated).

Fluorosis outcome was assessed by comparing children who were likely to be affected by the change in fluoridation policy and children whose teeth developed before the adjustment in fluoride level. At the time of the clinical examination in this study, children born after the policy change were 9 years of age and children born before the policy change were 12 years of age. The 9-year-old children were born between 1 January and 31 December 2006 and the 12-year-old children were born between 1 January and 31 December 2003. Years of fluoride exposure was calculated based on the date of birth and the commencement of Malaysian school term in January. The period between the samples had been chosen taking into account, critical fluoride exposure from water fluoridation during maxillary central incisor development, which is between 16 and 36 months of age.[9,10] In this study, the 9-year-old children in the test sample had been exposed to 0.5 ppm fluoridated water throughout their life. Children in the comparison sample have had mixed exposure to fluoridated water (0.7 ppm in the first 2 years of life followed by 0.5 ppm thereafter) during the development of their permanent teeth.

Caries prevalence was measured to determine whether a caries-preventive effect is still maintained following the reduction in fluoride level to 0.5 ppm. This was done by comparing the difference in the differences of caries experience between fluoridated and nonfluoridated areas.

2.2 | Research site and study sample

The study was conducted in two states in Peninsular Malaysia to represent fluoridated (Negeri Sembilan) and nonfluoridated (Kelantan) areas. A sample size calculation with a statistical significance level of 0.05, a confidence interval level of 95%, a power of 90%, and the prevalence of mild fluorosis at 17.8%, suggested the minimum sample size was 227 per subgroup. The sample size was inflated and rounded to 400 children per subgroup after taking into account nonrespondents (30%), nonconsenting parents/children (15%) and mobility rate (15%). A total of 1600 children aged 9- and 12-year-olds were estimated for this study. Sampling of the participants was conducted according to a two-stage sampling method.[11] The first stage involved the selection of public schools under coverage of School Dental Services, Ministry of Health. Schools were divided according to school size (small schools ≤50 children/large schools >50 children). A random number generator used to select the survey schools. In total 16 schools were selected. The second sampling stage involved selection of children within the 16 selected schools. For small schools, every child was selected. For large schools, systematic sampling was used, when every second child on the class list was selected. All the class lists from a school were collated and treated as a single list.

2.3 | Data collection

A set of survey forms (including consent form, patient information sheet, parental questionnaire that asked about fluoride history, infant feeding and oral hygiene practices) was delivered by hand to the head teacher or representative teacher of the school. The pupils selected to participate in the study were given a copy of the questionnaire by their teachers. Pupils were asked to deliver the survey forms to their parents for completion and return to school on the following day. Those pupils whose parents failed to return the survey forms were given a reminder one week after the initial distribution. The completed questionnaires and consent form were then collected by the teachers and passed to the investigator during visits to each school. Upon receiving all the survey forms from the teachers, the investigator identified consented children and their lifelong residency status in the locality. Children who were not lifelong residents were excluded from the study.

As a token of appreciation for participation in the study, children were provided with a toothbrush and toothpaste. Parents were offered an incentive of entry to a prize draw for 1 of 20 MYR100 (USD 23) shopping vouchers.

2.4 | Clinical and photographic examination

Clinical examinations were conducted by a trained and calibrated examiner (NAMN). Clinical recording of fluorosis was conducted on maxillary central incisors under natural light with the subject sitting on a chair in the upright position using a disposable mirror, CPITN probe and gauze for plaque removal (if necessary) using Dean's Index. Immediately after fluorosis examination, children were examined for caries on a mobile dental chair in a supine position. Dental caries was diagnosed by visual examination with the aid of a portable light (Halogen bulb, Daray light ×100, 12 V and 20 W) disposable mouth mirror using and a WHO periodontal probe (if necessary) using ICDAS-II criteria. This study used the epidemiology modification for caries code 2, that the teeth were dried and cleaned with gauze. Twenty children were re-examined after a two-week interval.

Following clinical examination, digital images of the maxillary incisors were taken to enable blind scoring of dental fluorosis. Intraoral photographs were taken using standardized methods described in previous studies.[12] Standardized images were taken using a digital SLR camera, Nikon D3300 body, Sigma 105 mm f/2.8 macrolense, Sigma ring flash EM 140DG. Intraoral photographs were taken while teeth are still wet. None of the images contained any identifying aspects of the subject's face.

To minimize bias from clinical scoring, the primary outcome measure for fluorosis was the consensus score from the digital photographs. The final score used was based on agreement from three examiners. All images were scored using Dean's Index. Two trained examiners (IGC, BLC) who were not involved in the clinical examination, scored these photographs together with the clinical examiner (NAMN). All images (n = 1155) were included in the assessment and projected onto a screen (69 cm length × 38 cm width) using Microsoft PowerPoint in standardized conditions. All examiners were blinded to the subject fluoride exposure and each photographic slide was assigned a unique code number. Following individual assessment, all examiners re-examined all photographs and discussed thoroughly for consensus agreement of final photographic score. A calibration exercise was carried out using 111 images following the pilot study. Findings of examiner reliability in fluorosis scoring between clinical and photographic methods have been previously published.[13]

2.5 | Statistical analysis

Descriptive, bivariate and multivariate statistics were analysed using SPSS version 21 (IBM Corp, Armonk, NY) and STATA version 13 (StataCorp, College Station, TX) software. Examiner reliability for caries and fluorosis scores were analysed using the Kappa statistic. The cases for fluorosis were defined as any fluorosis by Dean's score > 0, which include questionable or greater and fluorosis at Dean's score ≥ 2 which indicates very mild or greater. Chi-square test was used to compare fluorosis prevalence of the subgroups. The association between the prevalence of fluorosis and different levels of fluoride exposure in the water were analysed using binary logistic regression and odds ratios.

To establish how the decay component using ICDAS-II correlated with the DMF caries classification scores, the DMFT was calculated at three cut-off points: scores D_{1-3} classified as enamel caries, score D_{4-6} classified as dentine caries and D_{1-6} classified as caries at all levels. In terms of caries prevalence, the dentine caries prevalence ($D_{4-6}MFT > 0$) was dichotomized into absence and presence of the disease. Mann-Whitney U test was used to compare the mean caries scores of the subgroups. In contrast to fluorosis analysis, direct comparison across birth samples was not possible for caries prevalence because of the different dentition present in different age groups. Therefore, two types of multivariate analyses namely zero-inflated negative binomial (STATA) and generalized linear model (SPSS) were performed to explore the relationship between a change in fluoride level of the public water supply and dental caries at dentine level.

3 | RESULTS

Results of the intraexaminer repeated clinical examination for caries (κ: 0.81) and fluorosis (κ: 0.89) score indicate excellent agreement. Results of intra and interexaminer reliability in fluorosis scoring between clinical and photographic methods ranged between (κ: 0.72-0.90). This indicates substantial to excellent agreement.[14]

A total of 1600 children were approached to participate in this study. Following questionnaire distribution, 1298 returned the questionnaire giving an 81.1% overall response rate. Of those who responded, 1291 provided signed parental consent. All consented participants were further assessed for their residency status and 50 children were excluded as nonlifelong residents. Lifelong resident children with parental consent were further assessed for additional inclusion criteria. In total 57 children were absent on the day of the clinical examination. Of those who attended the examination, 21 children were excluded because of unerupted upper central incisor/s, followed by fractured incisor(s) (n = 4), partially erupted incisor(s) (n = 3) and the presence of a fixed orthodontic appliance (n = 1). The number of children excluded across age groups and in fluoridated and nonfluoridated areas was broadly similar.

In total (n = 1155) were clinically examined and photographed. Out of 1155 photographs available for scoring, 12 photographs were not able to be scored because of poor quality photographs. This resulted in 1143 children for whom both a valid photograph and questionnaire data were available for analysis. In terms of caries analysis, all clinical and questionnaire data (n = 1155) were analysed.

3.1 | Fluorosis prevalence

Table 1 shows the distribution of dental fluorosis in fluoridated and nonfluoridated areas. A clear difference in the proportion of children affected between the fluoridated and nonfluoridated communities is apparent. The fluorosis experience in the studied population was mostly very mild to mild. The prevalence of fluorosis (Dean's score ≥ 2) among children in the fluoridated area was significantly higher ($P < 0.001$) than children in the nonfluoridated area for both fluorosis case definitions (Dean's > 0 and Dean's ≥ 2).

Table 2 shows the bivariate analysis between the prevalence of fluorosis and different fluoride exposures from the water in the study participants. For both fluorosis outcome measures, children who were exposed to 0.7 ppmF in the first two years of life and then 0.5 ppmF thereafter were 8-11 times more likely to develop fluorosis than those who did not have any exposure. Those who had been exposed to 0.5 ppmF in the local water supply throughout life were 6-8 times more likely to have fluorosis compared to the nonfluoridated reference group. Among those living in the fluoridated area, children who had been exposed to 0.7 ppmF in the first 2 years of life and then 0.5 ppmF thereafter had a higher fluorosis prevalence than those exposed to 0.5 ppmF throughout life but the difference was not statistically significant.

Table 3 shows that reducing fluoride level in the water has resulted in a narrowing of the fluorosis prevalence between fluoridated and control areas. This implies that the decrease in fluorosis prevalence corresponds with the reduction (0.2 ppm) of fluoride in the drinking water during the time of enamel development.

3.2 | Caries experience

Regardless of which threshold of diagnosis is used, the mean caries experience in the permanent dentition was significantly lower in the fluoridated area than the nonfluoridated area for both age groups ($P < 0.05$) (Table 4). The enamel caries prevalence was higher than the dentine caries prevalence for both age groups and area of residence. When enamel caries lesions were included, the mean DMFT score increased by 2-4 times more than when only dentine caries lesions were included among all study participants. The prevalence of filled teeth was three times higher in nonfluoridated areas for both age groups and the differences were significant ($P < 0.001$). Missing teeth due to extraction was also higher among children in the nonfluoridated area and the difference was significant in 12-year-old children.

Table 5 shows the zero-inflated negative binomial for mean caries experience ($D_{4\text{-}6}$MFT) and generalized linear model regression for percentage caries prevalence ($D_{4\text{-}6}$MFT > 0) with different fluoridation status and age groups. Model 1 shows that although mean $D_{4\text{-}6}$MFT is lower in the fluoridated than the nonfluoridated area, no significant association was found between the fluoridated and nonfluoridated area when both age groups were considered together in the analysis. Similarly, no significant association observed between the two age groups when both areas were considered together in the analysis. After allowing for interaction between age group and fluoridation status, the results show that children who were exposed

TABLE 1 Fluorosis distribution among study participants based on the consensus score on maxillary central incisors in 9- and 12-year-olds in fluoridated and nonfluoridated communities

Fluorosis Dean's Score	Fluoridated no. (%)			Nonfluoridated no. (%)		
	12 y	9 y	Total	12 y	9 y	Total
(0) Normal	161 (54.8)	181 (57.8)	342 (56.3)	271 (89.7)	224 (90.7)	494 (90.1)
(1) Questionable	18 (6.1)	23 (7.3)	41 (6.8)	17 (5.6)	6 (2.4)	23 (4.2)
(2) Very mild	48 (16.3)	47 (15.0)	95 (15.7)	10 (3.3)	13 (5.3)	23 (4.2)
(3) Mild	33 (11.2)	32 (10.2)	65 (10.7)	3 (1.0)	2 (0.8)	5 (0.9)
(4) Moderate	32 (10.9)	21 (6.7)	53 (8.7)	1 (0.3)	1 (0.4)	2 (0.4)
(5) Severe	0	0	0	0	0	0
Not able to score[a]	2 (0.7)	9 (2.9)	11 (1.8)	0	1 (0.4)	1 (0.2)
Total	294 (100.0)	313 (100.0)	607 (100.0)	301 (100.0)	247 (100.0)	548 (100.0)
Fluorosis prevalence (Deans > 0)	131 (44.6)	123 (39.3)	254 (42.6)*	30 (10.3)	22 (8.9)	53 (9.7)
Fluorosis prevalence (Deans ≥ 2)	113 (38.4)	100 (31.9)	213 (35.7)*	14 (4.7)	16 (6.5)	30 (5.5)

[a]"Not able to score" photographs were excluded from further analysis.
*Chi-square, $P < 0.001$ (statistically significant between fluoridated and nonfluoridated areas).

TABLE 2 Bivariate analysis of fluorosis prevalence with different fluoride exposures in the public water supply

Exposure to fluoride in the water supply	Fluorosis Deans ≥ 2 n (%)		Unadjusted Odds ratio 95% CI	*P* value	Any fluorosis Deans > 0 n (%)		Unadjusted Odds ratio 95% CI	*P* value
	Yes	No			Yes	No		
0 lifetime	30 (12.30)	517 (57.4)	Reference		53 (9.7)	494 (90.3)	Reference	
0.5 ppmF lifetime	100 (41.2)	204 (22.7)	8.45 (5.45-13.10)	0.001	123 (40.5)	181 (59.5)	6.33 (4.40-9.12)	0.001
0.7 ppmF for first 2 years and then 0.5 ppmF	113 (46.5)	179 (19.9)	10.88 (7.03-16.84)	0.001	131 (44.9)	161 (55.1)	7.58 (5.26-10.93)	0.001

TABLE 3 Proportion of fluorosis prevalence after fluoride concentration in the water supply was reduced

	% Prevalence 12-year-old (PreReduction)	% Prevalence 9-year-old (PostReduction)	% Difference (post-pre)[a]	% Difference (pre)	% Difference (post)
Outcome: any fluorosis (deans > 0)					
Fluoridated	44.6	39.3	−5.3	34.3	30.4
Nonfluoridated (control)	10.3	8.9	−1.4		
Outcome: fluorosis (deans ≥ 2)					
Fluoridated	38.4	31.9	−6.5	33.7	25.4
Nonfluoridated (control)	4.7	6.5	1.8		

[a]Percentage (%) difference = (PostReduction − PreReduction). A negative difference shows that the % fluorosis prevalence decreased after reduction in fluoride level in the water.
Percentage (%) difference (pre) = $\text{PreReduction}_{\text{Intervention}} - \text{PreReduction}_{\text{Control.}}$
Percentage (%) difference (post) = $\text{PostReduction}_{\text{Intervention}} - \text{PostReduction}_{\text{Control.}}$

TABLE 4 Mean caries experience in the permanent dentition at different severity of caries for 9- and 12-year-old Malaysian children in fluoridated and nonfluoridated areas

Age/area	$D_{1\text{-}3}$ Mean (SD)	$D_{4\text{-}6}$ Mean (SD)	$D_{1\text{-}6}$ Mean (SD)	M Mean (SD)	F Mean (SD)	$D_{1\text{-}3}$MFT Mean (SD)	$D_{4\text{-}6}$MFT Mean (SD)	$D_{1\text{-}6}$MFT Mean (SD)
9-year-old sample								
9 F [n = 313]	0.75 (1.08)	0.22 (0.75)	0.97 (1.42)	0.01 (0.08)	0.17 (0.57)	0.93 (1.24)	0.40 (0.96)	1.15 (1.55)
9 NF [n = 247]	0.71 (1.10)	0.24 (0.63)	0.96 (1.37)	0.03 (0.25)	0.45 (0.88)	1.20 (1.46)	0.73 (1.17)	1.44 (1.70)
P value	0.646	0.319	0.980	0.142	<0.001	0.043	<0.001	0.021
12-year-old sample								
12 F [n = 294]	1.54 (1.92)	0.13 (0.47)	1.67 (2.04)	0	0.34 (0.80)	1.88 (2.07)	0.47 (0.97)	2.01 (2.19)
12 NF [n = 301]	1.52 (1.62)	0.26 (0.70)	1.78 (1.90)	0.02 (0.16)	1.03 (1.52)	2.57 (2.47)	1.31 (1.81)	2.83 (2.74)
P value	0.506	0.006	0.175	0.027	<0.001	<0.001	<0.001	<0.001

F, fluoridated; NF, nonfluoridated; SD, standard deviation.
ICDAS criteria, $D_{1\text{-}3,}$ enamel caries, $D_{4\text{-}6}$, dentine caries, $D_{1\text{-}6}$, caries at all levels.

to fluoride at 0.5 ppm remained significantly associated with lower caries experience than those who did not have any exposure.

Model 2 shows that caries prevalence ($D_{4\text{-}6}$MFT > 0) is lower in the fluoridated than nonfluoridated area. Results remained statistically significant between fluoridated and nonfluoridated areas when both age groups were considered together in the analysis. In terms of age, caries prevalence was significantly lower in the 9-year-old children when both areas were considered together in the analysis. Similar to model 1, after allowing for interaction between age group and fluoridation status, the results show that children who were exposed to the fluoride level (0.5 ppm throughout life) remained significantly associated with lower caries experience than those who did not have any exposure.

4 | DISCUSSION

In the present study, fluorosis prevalence was significantly higher in fluoridated (35.7%-42.6%) than nonfluoridated (5.5%-9.7%) areas. The findings confirm findings from various studies that fluorosis

TABLE 5 Multivariate regression models for mean caries experience and caries prevalence following reduction in fluoride concentration from 0.7 ppm to 0.5 ppm in the public water supply

Age group	Outcome measure	Fluoridation status		P value (Wald test)
		Fluoridated[a]	Nonfluoridated	
Zero-inflated negative binomial (Model 1)				
9	D_{4-6}MFT Mean (SD) [Median]	0.40 (0.96) [0.00]	0.73 (1.17) [0.00]	*P*(area) = 0.339[b] *P*(age) = 0.348[b] *P*(age × area) = <0.001[b]
12		0.47 (0.97) [0.00]	1.31 (1.81) [1.00]	
Generalized linear model (Model 2)				
9	D_{4-6}MFT > 0 % caries prevalence	24.6%	40.2%	*P*(area)=<0.001[c] *P*(age)=0.021[c] *P*(age × area) = 0.054[c]
12		25.5%	53.5%	

P(area): main effect by area (fluoridated and nonfluoridated), that is, was there a difference in results by area alone.
P(age): main effect by age (9 or 12), that is, was there a difference in results by age alone.
P(age × area): interaction between age and fluoridation status, that is, did fluoridation reduction affect results for the two ages (9 and 12) in the same way (null) or differently (alternative).
[a]9-year-old children in fluoridated area were exposed to 0.5 ppmF throughout life, and 12-year-old children in fluoridated area were exposed to 0.7 ppmF in the first 2 years of life and 0.5 ppmF thereafter.
[b]Zero-inflated negative binomial.
[c]Generalized linear model.

prevalence is strongly associated with fluoridated water.[15,16] Furthermore, some authorities have reported that it may not be possible to achieve effective fluoride-based caries prevention without some degree of enamel fluorosis.[17] Using Deans score ≥ 2 as the case definition, the present study indicated a lower fluorosis prevalence (35.7%) than a previous national survey, which fluorosis prevalence as 62.3% in fluoridated areas.[2] When comparing with the another local study reported the prevalence of fluorosis in the fluoridated state of Selangor as 58.7%.[3] These earlier studies were conducted among children that were exposed to 0.7 ppm fluoride in the water throughout life before the change in the fluoridation policy took place and results were reported using full mouth fluorosis score.

Little is known about the effect of reducing fluoride level to a fluoride concentration as low as 0.5 ppm. This limits direct comparison of the present data with other studies. Findings from this study can only be compared with a series of Hong Kong studies that examined fluorosis prevalence on maxillary central incisors after downward adjustment of fluoride in Hong Kong water supply. The earlier Hong Kong studies by Evans and Stamm reported that fluorosis prevalence with Dean's Index declined from 64% to 47% (Deans ≥ 2) after the reduction in fluoridation level from 1.0 ppm to 0.7 ppm.[9,18] Recent data from Hong Kong reported four cross-sectional surveys on fluorosis prevalence.[7] The fluorosis was blind scored using photographs of maxillary incisors with the Developmental Defects of Enamel (DDE) index. A similar trend was reported following reduction in fluoride level in the water from 1.0 ppm (1967) to 0.7 ppm (1978) to 0.5 ppm (1988).[7] Fluorosis decreased from 89.3% in 1983 to 48.5% in 1991 and 32.4% in 2001 surveys. However, the follow-up survey in 2010 reported fluorosis prevalence has increased to 42.1% while the fluoride level remained the same at 0.5 ppm as in 2001. The authors suggested the increase in prevalence of fluorosis might be contributed to by other sources of fluoride such as fluoridated toothpaste, infant formula and fluoride content in food.[7] In 2013, the authors conducted another follow-up study and re-examined the same participants that had participated in 2010 survey.[19] The follow-up dropout rate was 35%. Findings indicated a significant decrease in fluorosis prevalence from 2010 to 2013. The authors concluded that the fluorosis diminished over time. Possible explanations given were the possibility of tooth wear and the effect of remineralization. Constant exposure to saliva, which is supersaturated with calcium and phosphate, findings in continued enamel mineralization that in turn can lead to reduced opacity in affected areas.[19] However, findings should be treated with caution because the main aim of the later study by was to look at overall enamel defects not just fluorosis. Significant findings were only observed for “diffuse opacities” but not on other enamel defects such demarcated and hypoplastic enamel. Although the DDE index classifies enamel defects in a descriptive way and does not assume aetiology, one of its main types, diffuse opacities has been used synonymously as dental fluorosis.

In terms of caries data, regardless of which threshold of diagnosis was used, the mean caries experience in the permanent dentition was significantly lower in the fluoridated than nonfluoridated areas for both age groups. A higher number of teeth, missing due to caries was observed among children in the nonfluoridated area in both dentitions. The prevalence of filled surfaces was also significantly higher in the nonfluoridated area. The findings in relation to caries prevalence into dentine are in agreement with findings from the Malaysian national survey.[20] and school dental service data.[21] Additionally, findings confirmed existing evidence of the benefit of water fluoridation in caries prevention reported in other countries.[22,23] As highlighted in many studies, it has become difficult to investigate the impact of water fluoridation alone in the community where fluoridated toothpaste use is widespread. For example, in the present study, the majority of the respondents in both areas reported using fluoridated toothpaste when brushing. Findings from this study also confirm findings from the York Review that the caries-preventive effect is still apparent in the fluoridated community that used fluoridated toothpaste.[22]

This study is a single point cross-sectional survey that evaluated the effect of a change in fluoride level in the water supply on dental fluorosis and caries. Dental fluorosis status was directly comparable between two birth samples. The comparison is possible because the main effect on fluorosis development was during the pre-eruptive period. In contrast to the fluorosis analysis, the caries status of different birth samples was not directly comparable because of the different stages of development of the dentition in the different age groups involved. Permanent caries experience increased with age. This pattern reflects the biological change in the process of ageing, which impacts on caries prevalence, namely the number of teeth present and the accumulation of caries over time. The ageing effect was controlled using zero-inflated negative binomial and generalized linear model regressions when estimating the difference in the differences of caries experience between fluoridated and nonfluoridated areas. Interaction between age and fluoridation status were tested and adjusted in the model when performing the analyses. Comparison of mean caries experience (D_{4-6}MFT) and caries prevalence ($D_{4-6}MFT > 0$) between samples exposed to different fluoride levels (after controlling for ageing effect) revealed a significant difference. Both models indicate that the caries-preventive effect is still maintained at 0.5 ppm following the reduction in fluoride level in the water. Children in both age groups in the fluoridated area were mainly exposed to 0.5 ppm fluoride in the water throughout their life and the full fluoridation effect can be seen at this concentration.

In this study, fluorosis prevalence was only measured on maxillary central incisors which may cause underestimation of the true fluorosis prevalence in the study population. However, restricting the analysis to maxillary central incisors helps in minimizing variation in dental fluorosis due to tooth eruption status and variation between tooth types exposed to different fluoride levels during dentition development.[18] In addition, central incisors are the teeth that are likely to be of greatest aesthetic concern. In terms of caries assessment, drying teeth using gauze may not be an ideal condition to reflect early caries lesions using ICDAS criteria (D_1). This may cause an underestimation of the true population caries estimate for D_1. However, the difference in methodology was not expected to have a major impact on the main caries findings and comparison with other studies that use the traditional DMF index where the threshold of caries was analysed at dentine level (D_{4-6}MFT).

In conclusion, the change in water fluoridation policy to 0.5 ppm has resulted in a decrease in fluorosis prevalence without compromising the caries-preventive effect. However, the decrease in fluorosis prevalence was not statistically significant. In addition, it is important to highlight that the optimal fluoride concentration of 0.5 ppm is effective in this study population in which there is widespread use of fluoride toothpaste. The findings provide support for the decision to reduce the fluoride level in the public water supply in Malaysia. These new findings add value to a gap in the literature with regard to the recent trend towards lower levels of fluoride in public water supplies. Further research is still needed to confirm the effectiveness of such a reduction in the longer term, ideally with a longitudinal study or two-point survey.

ACKNOWLEDGEMENT

The authors acknowledge the cooperation of the parents and children who took part in this study and, in addition, the assistance of the school teachers in questionnaire distribution and school visits during clinical examinations. This work was undertaken in part fulfilment of a PhD thesis by NAMN at Cardiff University funded by the Ministry of Education, Malaysia.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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How to cite this article: Mohd Nor NA, Chadwick BL, Farnell DJJ, Chestnutt IG. The impact of a reduction in fluoride concentration in the Malaysian water supply on the prevalence of fluorosis and dental caries. *Community Dent Oral Epidemiol*. 2018;00:1–8. https://doi.org/10.1111/cdoe.12407