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The prevalence of enamel and dentine caries lesions and their determinant factors among children living in fluoridated and non-fluoridated areas

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Objective: To determine the prevalence and severity of dental caries (at dentine and enamel levels of diagnosis) amongst Malaysian children and to investigate determinant factors associated with caries detection at these different thresholds. ***Methods:*** This study involved life-long residents aged 12 years-old in fluoridated and non-fluoridated areas in Malaysia (n=595). The survey was carried out in 16 public schools by a calibrated examiner, using ICDAS-II criteria. A questionnaire on socio-demographic and oral hygiene practices was self-administered by parents/guardians. Data were analysed using Mann-Whitney U tests and logistic regression. ***Results:*** The overall response rate was 74.4%. Caries prevalence at the dentine level or at the dentine and enamel level was significantly ($p<0.001$) higher among children in the non-fluoridated area ($D_{1\text{-}6}MFT>0 = 82.4\%$, $D_{4\text{-}6}MFT>0 = 53.5\%$) than in the fluoridated area ($D_{1\text{-}6}MFT>0 = 68.7\%$, $D_{4\text{-}6}MFT>0 = 25.5\%$). Considering only the decayed component of the index, no significant differences were observed between the two areas when the detection threshold was set at enamel caries ($D_{1\text{-}3}$) ($p=0.506$). However, when the detection criteria were elevated to the level of caries into dentine ($D_{4\text{-}6}$) there were clear differences between the fluoridated and non-fluoridated areas ($p=0.006$). Exposure to fluoridated water proved a significant predictor for lower caries prevalence in the statistical model. Children whose father and mother had a low monthly income had a significantly higher dentine caries prevalence. ***Conclusion:*** Results confirmed existing evidence of the benefit of water fluoridation in caries prevention. Detection criteria set at caries into dentine shows clear differences between fluoridated and non-fluoridated areas. Exposure to fluoridated water and socio-economic status were associated with caries prevalence.

Keywords: *dental caries , epidemiology, ICDAS II, water fluoridation*

Introduction

Three systematic reviews have acknowledged the benefits of fluoridation in terms of dental caries prevention (McDonagh *et al*., 2000; Australian National Health and Medical Research Council, 2007; Iheozor-Ejiofor *et al*., 2015). However, most studies included in these reviews were conducted pre-1975 and measured caries at the 'dentine level' or as 'cavitated lesions' (i.e. $D_{4\text{-}6}$) using the DMF (Decay, Missing and Filled Teeth) index (Klein *et al*., 1938). More recent fluoridation studies conducted post-2000 have also been reported using the conventional (i.e. into dentine) DMF index (Rugg-Gun and Do 2012; Slade *et al*., 2018; Spencer *et al*., 2018). One of the major disadvantages of the DMF index at the dentine threshold is its failure to record caries in its early stages, when still confined to dental enamel. Recording only dentinal lesions as an outcome measure is becoming outmoded (Pitts and Stamm, 2004). Subsequently, caries classification systems have been developed that aim to overcome the limitations of the DMF Index. This includes new caries assessment systems such as that described by Nyvad *et al*., (1999) and the International Caries Detection Assessment System in 2001 (ICDAS) (Pitts, 2004). Unlike DMF, the Nyvad and ICDAS record stages of caries lesion development that include cavitated and non-cavitated lesions and active or inactive lesions.

The prevalence of early caries lesions is often under reported in epidemiology studies. Findings from previous studies (Dirks, 1961a; Dirks *et al*., 1961b; Groeneveld, 1985; Marthaler, 1981) reported a smaller effect of fluoride on caries prevalence when overall caries lesions (enamel + dentine lesions) were considered. Groeneveld examined the longitudinal effect of water fluoridation in Tiel (1 mg/L) and Culemborg (0.1 mg/L) and reported that at the initial caries stage, only a small caries preventive effect was observed. However, caries progression beyond enamel caries was significantly reduced in the fluoridated area. Nevertheless, these earlier studies were conducted in an era when fluoridated toothpaste was not yet widely available. One relatively recent English study reported on the prevalence of early caries lesions in fluoridated (Newcastle, 1mg/l) and non-fluoridated (Manchester) communities using ICDAS (McGrady *et al*., 2012). The dentine caries experience ($D_{4\text{-}6}MFT$) was 1.07 in the non-fluoridated and 0.65 in the fluoridated community whereas caries experience with early caries lesion ($D_{1\text{-}6}MFT$) was 4.48 and 2.94 in the two communities respectively. When early caries lesions were included, the mean DMFT score increased by four times more than when only dentine caries lesions were included for both communities. Whether the same findings pertain in other communities with lower water fluoride levels remains unexplored. Previous studies have

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noted a similar increase in caries values with the inclusion of early caries lesions using different indices (Goswami and Rajwar, 2015; Ismail *et al*., 1992; Nyvad *et al.,* 1999; Pitts and Fyffe, 1988). However, these studies were not designed to evaluate water fluoridation.

There is a lack of contemporary evidence that assesses the impact of water fluoridation on the early stages of lesion development and hence a need to report additional evidence to fill this gap. In addition, data from a community exposed to relatively low Fluoride concentrations (0.5 mg/L fluoride) would be a valuable addition to the literature on water fluoridation study. Much existing literature has reported data from areas where fluoride concentrations ranged from 0.7 to 1 mg/L. Therefore the objectives of this study were, firstly to determine the prevalence and severity of dental caries amongst Malaysian children in fluoridated and non-fluoridated areas using the ICDAS-II criteria. Secondly, to investigate determinant factors (in particular in relation to demographics and oral hygiene practices) associated with caries detection at different thresholds.

The ICDAS system was chosen over other caries assessment systems as it has been selected for national caries data surveillance by the Ministry of Health in Malaysia, commencing 2019. Data from the present study will serve as a baseline and allow comparison of the relative contribution of enamel and dentine caries to overall caries experience.

Methods

This study received ethical approval from the Research Ethics Committee, School of Dentistry, Cardiff University (DSREC 14/17a). Permission to conduct the study was obtained from the Malaysian Ministry of Education, Ministry of Health and State Education Department. Informed signed consent was obtained from the children's parents or guardians.

This study is part of a larger study of the impact of a change in the level of fluoride in the Malaysian water supply (Mohd Nor, 2017). This paper presents data on caries experience in fluoridated and non-fluoridated communities using ICDAS-II criteria among 12 year-old Malaysian schoolchildren. Data were collected in two states: Negeri Sembilan (fluoridated at 0.5-0.7 mg/L) and Kelantan (non-fluoridated). Children in the fluoridated area were exposed to 0.7 mg/L in the first 2 years of life followed by 0.5 mg/L. Sample size calculation was based on caries experience (DMFT) in 12 year-old children from a National Survey of School Children in Malaysia, which was 39.0% and the mean DMFT was 2.6 (S.D: 4.1) (Oral Health Division Ministry of Health Malaysia, 2010). The sample size required to detect a 25% difference in population mean decayed, missing and filled permanent teeth with 90% power and significance level of 0.05 was calculated as a minimum of 232 people per area. The total sample was inflated by an additional 30% to account for non-respondents, 15% non-consenting and 15% mobility rate yields and then rounded to 400 per area.

Data were collected from sixteen public schools using a two stage stratified sampling method. The inclusion criteria for this study included; self-reported lifelong residents, no medical contraindication to undergoing a clinical dental examination, not wearing fixed orthodontic appliances and provision of informed written consent by the child's parent/guardian.

A parental questionnaire that asked about demographic characteristics, fluoride history and oral hygiene practices was distributed to the participants with help from school teachers.

Clinical examinations were performed by a single calibrated examiner (NAMN) in a school setting. The examiner completed the ICDAS online training module, followed by a six-hour ICDAS workshop at the Dental School, Cardiff University. The training workshop involved theoretical explanation and clinical photograph case scenarios. In a subsequent calibration exercise using 40 clinical slides, the kappa score for inter-examiner reliability was 0.61, representing substantial agreement (Landis and Koch, 1977). In order to test the consistency of the examiner in the field, twenty children were re-examined during clinical examination at random, two weeks after the first examination with an excellent kappa score of 0.81.

Dental caries was diagnosed by visual examination with the aid of a portable light (Halogen bulb, Daray light x100, 12 Volt and 20 Watt) disposable mouth mirror and a WHO periodontal probe (if necessary) using ICDAS-II criteria. This study used the epidemiology modification for caries code D1, that the teeth were dried and cleaned with gauze and cotton roll.

Caries data were recorded and stored by using a graphical user interface (GUI) written in Visual Basic for Windows shown in Figure 1. Data were entered into the ICDAS-II table as two single digits for all tooth surfaces (D, O, M, B, L) as per ICDAS-II scoring criteria.

To relate the decay component using ICDAS-II to the DMF classification, DMFT scores were 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. The Mann-Whitney U test was used to compare caries scores between the two different areas. The association between the dichotomous dependent variables (D_{4-6}MFT>0 and D_{1-6}MFT>0) was modelled using binary logistic regression analysis. All independent variables were entered into the model at the same time. The statistical significance level was set at $p<0.05$. Statistical analysis was carried out using the Statistical Package for Social Sciences (SPSS) version 21 (IBM Corp, Armonk, NY).

Results

Out of 800 questionnaires distributed, 664 (83%) were returned. Of those returned, only 595 children were consented for clinical examination and also met the inclusion criteria, with 294 in the fluoridated area (Negeri Sembilan) and 301 in the non-fluoridated area (Kelantan).

Caries prevalence at the dentine level or at all levels was significantly ($p<0.001$) higher among children in the non-fluoridated area (D_{4-6}MFT>0 = 53.5%: D_{1-6}MFT>0 = 82.4%) than in the fluoridated area (D_{4-6}MFT>0 = 25.5%: D_{1-6}MFT>0 = 68.7%).

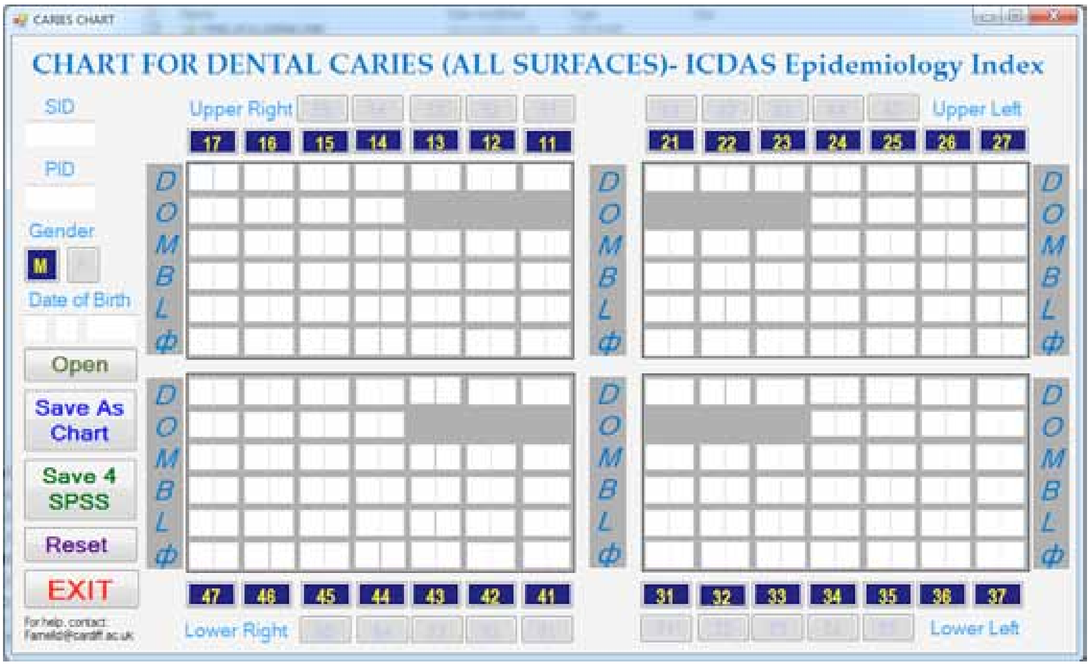

Figure 1. *Bespoke graphical user interface (GUI) written in Visual Basic for efficient ICDAS-II data entry*

Table 1 describes the tooth level caries experience at different thresholds. Regardless of the diagnostic threshold used, the mean caries experience (DMFT) in the permanent dentition was lower in the fluoridated than the non-fluoridated area (p<0.05). When measuring caries at the different thresholds, the mean enamel caries was high and the prevalence rate was similar for both areas. The caries experience was similar in the two areas for enamel caries lesions ($D_{1\text{-}3}$) (p=0.506). However, when the detection criteria were set at the level of caries into dentine ($D_{4\text{-}6}$) there were significant differences between the fluoridated and non-fluoridated areas (p=0.006). When enamel caries lesions were included (i.e. $D_{1\text{-}6}$), the mean DMFT score increased by two to four times more than when only dentine caries lesions were included among all study participants. The prevalence of filled teeth was three times higher in non-fluoridated areas and the difference was significant (p<0.001). Missing teeth due to extraction was also higher among children in the non-fluoridated area and the difference was also statistically significant. A similar caries pattern was observed for caries experience at tooth surface level.

Table 2 shows the prevalence and mean scores of the severity of caries lesions among the study population. In general, the number of lesions at dentine level (D_4 to D_6) was low in comparison to lesions at enamel level (D_1 to D_3) for both areas. For enamel lesions, decay at D_1 was highest followed by decay recorded at the D_2 and D_3 levels. For dentine lesions, the highest number of lesions was at the D_4 level for children in the non-fluoridated area.

Table 3 shows the prevalence of fissure sealants among participants. The frequency of sealants was analysed for sound sealants (ICDAS codes: 10, 20) and a combination of sound sealants and sealants with enamel caries (ICDAS codes: 10, 11, 12, 13, 20, 21, 22, 23). More children in the non-fluoridated area had received sealants than in the fluoridated area. The proportion of partial sealants with enamel caries was higher than the proportion of complete sealants with enamel caries in both areas.

When the association between the presence of dental caries at the dentine level and independent variables was modelled in logistic regression (Table 4), father's and mother's monthly income and exposure to fluoride from the water supply were the significant predictors. Children whose parents reported a low monthly income had high dentine caries. Children exposed to fluoridated water had low dentine caries.

Table 5 shows the binary logistic regression model for the prevalence of caries at all levels (enamel and dentine caries). Exposure to fluoride from the water was the only predictor (B coefficient = 0.71, odds ratio = 2.03 (95% CI = 1.307, 3.166). Children exposed to water fluoridation had lower caries scores at all levels.

Discussion

The results from this study confirmed existing evidence of the benefit of water fluoridation in caries prevention reported in other countries (Iheozor-Ejiofor *et al*., 2015; McDonagh *et al*., 2000; Rugg-Gunn and Do, 2012). 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, most participants reported using fluoridated toothpaste. In addition, about 37% off children in the non-fluoridated area had received fissure sealants and this proportion was found to be significantly higher than children compared to only 8% in the fluoridated area. Although this preventive strategy was in place alongside fluoridated toothpaste, children who had no exposure to fluoride in the water still had a higher caries score than those that had exposure to fluoridation.

Table 1. Mean caries experience and severity at tooth and surface levels of 12 year-old Malaysian children living in fluoridated and non-fluoridated areas

	$D_{1\text{-}3}$ Mean (SD)	$D_{4\text{-}6}$ Mean (SD)	$D_{1\text{-}6}$ Mean (SD)	M Mean (SD)	F Mean (SD)	$D_{1\text{-}3}MF$ Mean (SD)	$D_{4\text{-}6}MF$ Mean (SD)	$D_{1\text{-}6}MF$ Mean (SD)
F (n=294)								
Tooth	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)
Surface	1.90 (2.37)	0.22 (0.98)	2.12 (2.67)	0	0.38 (0.95)	2.28 (2.63)	0.61 (1.46)	2.50 (2.95)
NF (n=301)								
Tooth	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)
Surface	1.92 (2.17)	0.31 (0.87)	2.23 (2.52)	0.10 (0.81)	1.37 (2.27)	3.40 (3.73)	1.78 (2.91)	3.70 (4.12)
p value[a]	0.506	0.006*	0.175	0.027*	<0.001*	<0.001*	<0.001*	<0.001*
p value[b]	0.416	0.007*	0.159	0.027*	<0.001*	<0.001*	<0.001*	<0.001*

[a]Mann-Whitney test, association between mean caries at tooth level by residency area.
[b]Mann-Whitney test, association between mean caries at surface level by residency area.
F: fluoridated area, NF: non-fluoridated area.
$D_{1\text{-}3=}$enamel caries; $D_{4\text{-}6=}$dentine caries; $D_{1\text{-}6=}$ caries at all levels of severity.
*Statistically significant

Table 2. Severity of dental caries lesions of the permanent dentition in fluoridated and non-fluoridated areas at tooth level

	D_1 Mean (SD)	D_2 Mean (SD)	D_3 Mean (SD)	D_4 Mean (SD)	D_5 Mean (SD)	D_6 Mean (SD)
Fluoridated (n=294)	0.94 (1.31)	0.43 (0.87)	0.17 (0.56)	0.04 (0.24)	0.05 (0.25)	0.04 (0.22)
Non-fluoridated (n=301)	1.02 (1.26)	0.29 (0.58)	0.20 (0.54)	0.17 (0.58)	0.05 (0.21)	0.04 (0.20)

$D_{1\text{-}3=}$enamel caries; $D_{4\text{-}6=}$dentine caries

Table 3. Mean score and percentage of sealed permanent teeth in 12 year-old Malaysian children, in fluoridated and non-fluoridated areas

	Sound Sealant (ICDAS code: 10,20)				*Sound sealant & sealant with enamel caries (ICDAS code: 10, 11, 12, 13, 20, 21, 22, 23)*			
	Complete		Partial		Complete		Partial	
	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%
Fluoridated (n=294)	0.03 (0.18)	2.4	0.06 (0.27)	5.8	0.03 (0.19)	2.7	0.09 (0.33)	7.5
Non-fluoridated (n=301)	0.11 (0.38)	9.3	0.28 (0.58)	22.3	0.12 (0.39)	9.6	0.37 (0.68)	27.6
p value[a]	<0.001*		<0.001*		<0.001*		<0.001*	

[a]Mann-Whitney test, association between mean sealant score by residency area.
*Statistically significant

Findings from this study support previous evidence of an inverse relationship between socio-economic status and caries prevalence. Previous studies have reported higher caries prevalence was found among the children of lower social groups (McGrady *et al.,* 2012; Ostberg *et al.,* 2017; Reisine and Psoter, 2001). These trends are similar to the findings from the present study that indicated children whose father had a low monthly income had a higher caries prevalence (at different threshold) than those whose father had a high monthly income. However, the differences were only statistically significant for caries at the dentine level.

More enamel caries was diagnosed than dentine caries in both areas of residence. When enamel caries were included, the mean DMFT and DMFS score increased by two to four times more than when only dentine caries lesions were included. For example for mean caries experience among 12 year-olds in the fluoridated area was 0.47 at ($D_{4\text{-}6}$MFT) and increased to 2.01 at ($D_{1\text{-}6}$MFT). The inclusion of early caries lesion contributed to the higher overall caries score diagnosed using ICDAS II in comparison to the traditional DMF score. This resulted in underestimation of the actual caries experience in the population using only 'dentine caries' diagnosis indices. Similar trends have been observed in other studies that have used ICDAS II criteria when assessing caries prevalence (Almerich-Silla *et al.,* 2014; Cadavid *et al.,* 2010; de Amorim *et al*., 2012; McGrady *et al.,* 2012). For instance in a study conducted in Spain, the mean $D_{4\text{-}6}$MFT was 0.83 and 3.46 ($D_{1\text{-}6}$MFT) according to ICDAS II criteria (Almerich-Silla *et al.,* 2014) among 12 year-old children. Similarly in a national survey in Iceland, caries prevalence at age 12 years was 1.43 at $D_{3\text{-}6}$MFT and 3.93 at $D_{1\text{-}6}$MFT (Agustsdottir *et al*., 2010).

Table 4. Binary logistic regression analysis model for dentine caries, $D_{4-6}MFT>0$ (Yes/No) in the permanent dentition of 12 year-olds

Predictors	*$D_{4-6}MFT>0$ n (%)*	*Dentine Caries, $D_{4-6}MFT>0$ (Yes/No)*				
					95 % CI	
	Yes	*B*	*Sig (p)*	*OR (Exp B)*	*Lower*	*Upper*
Gender		-0.126	0.522	0.882	0.601	1.295
Boys	101 (39.5)					
Girls	135 (39.8)					
Father Education						
Low	28 (47.5)					
Moderate	145 (39.9)	0.124	0.765	1.132	0.501	2.56
High	43 (34.1)	0.164	0.572	1.178	0.667	2.082
Mother Education						
Low	28 (48.3)					
Moderate	152 (40.5)	0.483	0.282	1.621	0.672	3.91
High	45 (33.6)	0.371	0.27	1.449	0.75	2.8
Father monthly income						
Low	8 (57.1)					
Moderate	156 (42.0)	1.677	0.034*	5.349	1.134	25.225
High	52 (32.3)	0.15	0.596	1.162	0.668	2.021
Mother monthly income						
Low	193 (57.8)					
Moderate	85 (63.4)	-0.509	0.156	0.601	0.298	1.215
High	69 (63.3)	-0.896	0.027*	0.408	0.184	0.904
Fluoride level from the water		1.201	<0.001*	3.23	2.23	4.95
Yes	75 (22.5)					
No	161 (53.5)					
Frequency of toothbrushing		-0.056	0.841	0.946	0.55	1.627
≤ Once	31 (34.8)					
> Once	205 (40.7)					
Fluoridated toothpaste		-0.334	0.525	0.716	0.255	2.009
Yes	223 (39.5)					
No	9 (42.9)					
Amount of toothpaste used per brushing		-0.74	0.148	0.477	0.175	1.3
Small	7 (25.0)					
Large	228 (40.4)					

*Statistically significant

Whilst there was more enamel caries in both areas, the difference in the decay component between fluoridated and non-fluoridated was only significant for detection at the dentine level. For example, D_{1-3} was 1.54 in the fluoridated and 1.52 in non-fluoridated areas respectively whereas caries prevalence at D_{4-6} was 0.13 in the fluoridated and 0.26 in non-fluoridated area. Direct comparison with other water fluoridation studies using ICDAS is limited. McGrady and co-workers (2012) assessed the impact of water fluoridation in Newcastle and Manchester using ICDAS and reported that the fluoridated population had a significantly lower caries experience than the non-fluoridated population when assessed by clinical and photographic scoring methods. Mean DMFT among participants in Newcastle was 2.94 (clinical); 2.51 (photo) in comparison to Manchester (4.48 and 3.44 respectively). The scores for caries into dentine ($D_{4-6}MFT$) were lower. In Newcastle the mean DMFT was 0.65 (clinical) and 0.58 (photo) compared to Manchester (1.07 and 0.98 respectively). This raises an important question, whether water fluoridation is effective in preventing early caries lesions? This could be answered by a future longitudinal study. In doing so, ICDAS or Nyvad criteria are potentially useful epidemiological tools to facilitate the longitudinal monitoring of early carious lesions and explore the behaviour of such lesions in an individual over time.

ICDAS is a relatively new index, with only limited epidemiological studies available for comparison. To allow comparison with other studies that have used the traditional DMF index, the ICDAS II codes were collapsed at specific cut-off points for equivalence. There is ongoing debate concerning the equivalence of ICDAS and DMF data. There is less certainty in the literature when considering the traditional definition of caries into dentine about whether codes 3 and 4 should be counted as sound or caries. Some authors consider the cut-off point for caries prevalence (in a binary system / sound or caries) at code 3 (Braga *et al*., 2009; Iranzo-Cortes *et al*., 2013; Mendes *et al.,* 2010). Other authors report the codes 4, 5 and 6 are equivalent to caries score of DMF (i.e. into dentine criteria traditionally used in dental epidemiology (Clara *et al.,* 2012). Depending on the study objectives, some authors have analysed early caries prevalence at $D_{1-2}MFT$ to differentiate cavitated ($D_{3-6}MFT$)

Table 5. Binary logistic regression analysis model for enamel and dentine caries, $D_{1\text{-}6}MFT>0$ (Yes/No) in permanent dentition of 12 year-olds

Predictors	*$D_{1\text{-}6}MFT>0$ n (%)*	*Dentine Caries, $D_{1\text{-}6}MFT>0$ (Yes/No)*				
					95 % CI	
	Yes	*B*	*Sig (p)*	*OR (Exp B)*	*Lower*	*Upper*
Gender						
Boys	68 (26.6)					
Girls	262 (77.3)	-0.238	0.266	0.788	0.518	1.199
Father Education						
Low	47 (79.7)					
Moderate	269 (74.1)	-0.32	0.514	0.726	0.278	1.898
High	99 (78.6)	-0.463	0.146	0.63	0.337	1.175
Mother Education						
Low	45 (77.6)					
Moderate	285 (76.0)	0.307	0.54	1.36	0.509	3.631
High	100 (74.6)	0.262	0.459	1.299	0.65	2.599
Father monthly income						
Low	11 (78.6)					
Moderate	285 (76.8)	1.103	0.323	3.014	0.338	26.892
High	118 (73.3)	0.185	0.526	1.203	0.679	2.132
Mother monthly income						
Low	255 (76.3)					
Moderate	99 (73.9)	-0.283	0.445	0.754	0.365	1.556
High	83 (76.1)	-0.322	0.435	0.725	0.323	1.625
Fluoride level from the water						
Yes	202 (68.7)					
No	248 (82.4)	0.71	0.002*	2.034	1.307	3.166
Frequency of toothbrushing						
≤Once	65 (73.0)					
>Once	385 (76.4)	-0.206	0.484	0.814	0.457	1.449
Fluoridated toothpaste						
Yes	427 (75.7)					
No	17 (81.0)	-0.41	0.535	0.664	0.182	2.419
Amount of toothpaste used per brushing						
Small	21 (75.0)					
Large	428 (75.9)	0.104	0.847	1.109	0.388	3.175

*Statistically significant

and non-cavitated caries (Agustsdottir *et al*., 2010). In the present study it was decided to set the ICDAS II cut-off point for comparison with the DMF score at codes 4 to 6. Enamel caries was analysed at codes 1 to 3. This allowed meaningful comparison with local and international studies.

There is a need to strengthen preventive strategies in these communities regardless of their fluoridation status, as caries lesions are reversible at earlier stages. A series of Cochrane reviews on self and professionally applied fluoride agents reported that the use of fluoride toothpaste, fluoride mouthrinses, fluoride gels and fluoride varnishes are able to reduce the incidence of dental caries lesions, irrespective of whether other fluoride vehicles are being used at the same time (Marinho *et al*., 2002; Marinho *et al.,* 2004; Walsh *et al.,* 2010).

These results should be interpreted with some limitations. The primary requirement for applying the ICDAS II system is the examination of clean and dry teeth. This method of examination requires more instruments that incur costs and prolong the examination period. The difference between D_1 and D_2 is only based on whether the detection is viewed while wet (D_2) or dry using compressed air (D_1). One limitation of this study was that air drying of teeth could not be part of the diagnostic process. Drying the teeth using gauze and cotton wool rolls may mask the earliest caries lesions (D_1). This may cause an underestimation of the true population caries estimate for D_1. However, drying the teeth in this way was not expected to have a major impact on comparisons with other studies using the tradition DMF index, where the threshold for a diagnosis of "decay" is into dentine. Secondly, the examiner was not blind to the children's residential status. Ideally, the examination would have been done at a neutral site. However, the location of research sites made this logistically impractical. Remote blind scoring of images of teeth taken during clinical examination could be as an alternative approach. Thirdly, the questionnaire data relied on parents' self-reported answers. Finally, of course this study reports on a cross-sectional examination, which limits conclusions about causation, with the lack of temporality limiting findings to those of association. The data should be treated with caution when comparing with other studies in areas with different water fluoride levels. The population in the present study was exposed to fluoride concentration in the water at 0.7 (first 2 years of life) and 0.5ppm (after 2 years of life). The reduction of the fluoride level from 0.7 to 0.5ppm may have impacted on the caries preventive effect. It is difficult to measure the benefit of water fluoridation alone because of exposure to other fluorides such as fluoridated toothpaste that may impact on caries prevalence. Most participants in this reported using fluoridated toothpaste.

Conclusion

These data confirm existing evidence of the benefit of water fluoridation in caries prevention. Caries levels were significantly lower among children in the fluoridated than the non-fluoridated area. When measuring caries using ICDAS-II, the data suggest no significant differences between the two areas when detection thresholds are at the enamel caries level. However, when detection criteria are set at the level of caries into dentine there are clear differences between the fluoridated and non-fluoridated areas. In logistic regression fluoride exposure was a significant predictor for caries prevalence at the dentine level and the combination of caries at enamel and dentine at all levels. Children whose fathers had low monthly income also had significantly higher dentine caries prevalence than those whose parents had a high monthly income.

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Declarations

Consent for publication

All authors have approved the final version and its publication.

Competing interests

The authors have no potential conflicts of interest to declare.

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