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Prevalence and severity of dental fluorosis in four English cities

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Objective: To assess the prevalence and severity of dental fluorosis in four city-based populations using a robust photographic method with TF index reporting; and to record the aesthetic satisfaction scores of children in all four cities. ***Basic research design:*** Cross sectional epidemiological survey (surveillance). ***Participants:*** 1,904 children aged 11-14 years, in four English cities. ***Interventions:*** Two cities were served by community water fluoridation schemes supplying water at 1mg/l F. The other two cities did not have water fluoridation schemes and had low levels of fluoride naturally present. ***Main outcome measures:*** The prevalence and severity of dental fluorosis. Scoring was undertaken using high quality digital images by a single calibrated examiner. ***Results:*** Data suggest that the prevalence of fluorosis at levels greater than TF2 are broadly similar to previous studies (F 10%, NF 2%), with an apparent increase in the total number of TF1 cases across both fluoridated (41%) and non-fluoridated cities (32%) with a commensurate decrease in TF0 (F 39%, NF 63%). Data suggest that the proportion of children expressing dissatisfaction with the appearance of their teeth is the same in fluoridated and non-fluoridated communities although the reasons for this may differ. ***Conclusions:*** The levels of fluorosis that might be considered of aesthetic concern are low and stable while the increase in TF1 may be due to an increase in self- and professionally-applied fluoride products or the increased sensitivity afforded by the digital imaging system. It is not however a public health problem or concern. Further monitoring appears justified.

Key words: *dental fluorosis, TF index, water fluoridation, dental health survey, England*

Introduction

Section 90A of the Water Industry Act (1991, as amended) requires the relevant authority (currently the Secretary of State for England) to monitor the health effects of water fluoridation and report at no more than four year intervals. Enamel fluorosis is the only widely accepted risk associated with the consumption of fluoride. The assessment of fluorosis has not typically been part of the regular National Dental Epidemiology programme in England. The methods used in this survey to assess fluorosis were employed to overcome the potential problems of inter- and intra-examiner variation and assessment bias associated with visual "on the spot" assessment and scoring (McGrady *et al.*, 2012a);(Tabari *et al.*, 2000).

There has been a concerted effort to improve the assessment of enamel fluorosis in studies over recent years with the assessment and introduction of camera systems into epidemiological programs (Boye *et al.*, 2012; Davies *et al.*, 2012; McGrady *al., N=957 et al.*, 2000) to reduce bias and increase the utilization of experienced, but geographically remote, examiners. The use of high quality image capture systems confers a number of benefits: images can be viewed and scored for analysis, training, calibration, verification, etc. in any place and at any time by any number of scorers; scorers can be blinded to the status of the subject; archived images can be assessed later for longitudinal assessments; collection of epidemiological data no longer requires a trained clinician reducing the cost of such surveys.

Camera based systems have been used in previous assessments of fluorosis in English as well as Thai populations (McGrady *et al.*, 2012a,b) and were found to be reliable and valid when the Thylstrup and Fejerskov (TF) index (1978) was used and also following assessment with the Dean's Index (Dean *et al.*, 1950). Photographic images (typically 35mm slides) have been used since the late 1980s and have since been replaced with digital images. Previous works (Levine *et al.*, 1989; Nunn *et al.*, 1992) have also shown that viewing high quality images of teeth will generally enhance minor enamel defects making them easier to record and therefore prevalence estimates using such systems will generally be higher than those using clinical field measurements. The use of polarised images, reducing or eliminating the presence of flash artefacts, the ability to resize images and the time available for viewing all contribute to the increased reporting rate (Nunn *et al.*, 1992).

The reporting of fluorosis prevalence is complex. The use of two main indices (TF and Dean's) complicates comparisons between areas; Ireland and the United States favouring Dean's index and the rest of Europe and the UK generally reporting TF (Whelton *et al.*, 2004). The use of the Developmental Defects of Enamel Index (DDE) has also been reported but this does not specifically score for fluorosis but rather all enamel opacities (Commission on Oral Health, 1982). A review of fluorosis in Europe (Whelton *et al.*, 2004) found a range of reported prevalence values that depended on the index used, the presence of any supplemental fluoridation (water, salt, tablets, drops, etc.) and the conditions under which the examination was undertaken.

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The recent Cochrane Review of water fluoridation (Iheozor-Ejiofor *et al.*, 2015) concluded that there was an association between fluorosis and fluoride level but the evidence was weak due to the between-study variations identified.

The most recent prevalence studies undertaken in England using a photographic technique found that the prevalence of fluorosis at TF1 was 39% in fluoridated Newcastle upon Tyne and 24% in non-fluoridated Manchester. These figures were broadly similar to earlier studies in Newcastle and Northumbria (Tabari *et al.*, 2000).

Fluorosis, at the severity seen in England, is an almost exclusively aesthetic issue with mildly fluorosed enamel remaining fully functional and rarely visible but more severe fluorosis presenting with pitted and stained enamel (Whelton *et al.*, 2004). A recent study (Davies *et al.*, 2012) incorporated into the English National Health Service (NHS) Dental Epidemiological survey attempted to assess the impact of dental opacities on children's self-perception of their teeth and found that the professionally assessed and self-assessed metrics did not always agree. The aesthetic assessment of teeth is influenced by numerous factors, including orthodontic condition, the presence of caries, results of trauma and tooth colour. It should also be recognised that non-dental, psychosocial factors, will also influence this metric. Determining which of these elements contributes to the overall assessment is complex and, within epidemiological work, very challenging to measure.

The two purposes of this surveillance work were: to assess the prevalence and severity of dental fluorosis in four city-based populations using a robust photographic method with TF index reporting; and to examine differences in children's dental aesthetic satisfaction scores in relation to water fluoridation.

Method

A surveillance approach was adopted across four English cities. Two, Newcastle upon Tyne and Birmingham, were fluoridated while Manchester and Liverpool were non-fluoridated. The survey was school-based involving children aged 11 to 14 years who self-reported life time residency in the city. No further checks on residency were undertaken. Schools were pragmatically selected based on prior participation in dental surveys, likely lifetime residency of students and class size. The examinations were carried out during school terms from September 2014 through to August 2015. Children consented to take part and parents were given the opportunity to opt out via postal forms supplied on two occasions. The eight inclusion criteria were therefore: aged 11 to 14 years old, i.e. in the first three years of secondary school; self-reported life time residency in the fluoridated or non-fluoridated area; in good general health; have at least both permanent maxillary central incisors fully erupted; parents have not opted to exclude their child from the survey (see online-only Appendix 1); be cooperative and able to be examined; not have fixed orthodontic appliances; able to provide their own assent to take part.

A sample size calculation using a two-group continuity corrected Chi squared test with a 0.05 two-sided significance level was conducted. Using 80% power to detect the difference between a Group 1 proportion of 20% and a Group 2 proportion 40% (odds ratio of 2.7) would require a sample size in each group of 249. We oversampled the populations to gain broader insight and to allow for non-scorable images.

Assented participants were provided with lip retractors to place, teeth were dried using cotton wool rolls (10 seconds) and digital images taken using a camera system designed for this work. The drying time and imaging time were standardised as far as possible, but given variances in moisture the objective was to achieve dry teeth as per the TF index method. A polarised white light image demonstrating the anterior maxillary teeth was taken using a stabilisation frame enabling the subject to be positioned in a consistent manner for optimal imaging. The image system utilised a single, high-resolution camera with rotating filter wheels and LED arrays to provide flat field illumination without specular reflection. Images were saved as high resolution PNG files for later analysis.

Subjects were asked to rate their satisfaction with the aesthetic appearance of their teeth using a pictorial scale with a narrative description: 0, Very happy with my teeth, I wouldn't change anything about them; 1, Happy with my teeth; 2, I think my teeth are fine I don't worry about their appearance; 3, I am a little bit worried about how my teeth look; 4, I am worried about how my teeth look and I might think about speaking to a dentist about it; 5, I don't like how my teeth look and I will try and get treatment to change them.

Anonymised white light images were uploaded to a secure website for scoring by a single trained and calibrated examiner using both the TF and Dean's index. Images were presented to the examiner ordered randomly and the four maxillary incisors scored when present, with at least two scores for each subject. Data were exported from the website to SPSS for analysis. Descriptive analyses were undertaken for both indices providing the proportion of each index level at the highest score when two or more teeth scored at that level, statistical differences were detected, where present, using Mann-Whitney U tests. Scores for aesthetic perception were assessed for statistical significance between fluoridated and non-fluoridated cities using Mann-Whitney U tests. Socio-economic status was not considered within the analysis due to subject anonymisation requirements characteristic of the surveillance approach used.

Results

A total of 1,904 children participated in the survey, with 467 in Manchester, 474 in Liverpool, 513 in Newcastle upon Tyne and 450 in Birmingham. In total twelve schools were utilised, four in the non-fluoridated cities and eight in the fluoridated cities. Some 1,89 images were scorable for TF index, and 1,903 for Dean's. A response to the aesthetic question was provided by 1,898 children. Just 1,465 had all teeth scored (77.2%), 347 had one tooth un-scorable (or non-fluoridated opacity) 18.3%, 86 had two teeth un-scorable (or non-fluoridated opacity) 4.5%.

The results of the TF and Dean's index scores are shown in Tables 1 and 2 respectively. These tables present the highest score of two or more teeth from the maximum of four scored, e.g. scores of 1, 4, 3, 3 would result in a score of 3. There were no statistically significant differences in TF ($p=0.351$) or Dean's scores ($p=0.12$) between the two fluoridated cities or between the two non-fluoridated cities (TF, $p=0.85$, Dean's $p=0.35$). There was a statistically significant difference in overall fluorosis prevalence between the fluoridated and non-fluoridated cities when considering fluorosis to be TF>0 ($p<0.0001$) and when TF>2 ($p<0.0001$).

Table 1. TF index scores (highest score when 2 or more teeth scored at this level), n and %

TF	*Manchester (NF)*				*Liverpool (NF)*		*Newcastle (F)*						*Birmingham(F)*		*All four cities*	
Index	*2015**		*2012*		*2015*		*2015**		*2012*		*2000†*		*2015**		*2015*	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
TF0	286	61	638	73	304	64	195	38	410	45	202	46	175	39	960	51
TF1	154	33	209	24	143	30	212	42	355	39	182	42	176	39	685	36
TF2	15	3	16	2	16	3	54	11	79	9	40	9	49	11	134	7
TF3	11	2	4	1	10	2	43	8	53	6	14	3	37	8	101	5
TF4	0	0	0	0	0	0	6	1	8	1	0	0	9	2	15	1
TF5	0	0	2	0.2	0	0	0	0	1	0.1	0	0	2	0.4	2	0.1
TF6	0	0	0	0	0	0	0	0	0	0	0	0	1	0.2	1	0.1
TF8	0	0	0	0	0	0	0	0	0	0	0	0	1	0.2	1	0.1
Total	466		869		473		510		906		438		450		1,899	

NF, non-fluoridated; F, fluoridated; person level scores; *indicates use of polarised light images; † indicates clinical rather than photographic examination; 2012 Manchester and 2012 Newcastle data from McGrady *et al*., 2012 and 2000 Newcastle data from Tabari *et al.*, 2000

Table 2. Dean's index scores (highest score when 2 or more teeth scored at this level), n and %

Dean's Index	*Manchester (NF)*		*Liverpool (NF)*		*Newcastle (F)*		*Birmingham (F)*		*All four cities*	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
0 Normal	293	63	321	68	186	36	161	36	961	50
½ Questionable	145	31	129	27	249	49	196	44	719	38
1 Very Mild	21	5	13	3	40	8	51	11	125	7
2 Mild	7	2	11	2	31	6	28	6	77	4
3 Moderate	0	0	0	0	7	1	13	3	20	1
4 Severe	1	0.2	0	0	0	0	1	0.2	2	0.1
Total	467	100	474	100	513	100	450	100	1904	100

NF, non-fluoridated; F, fluoridated;

Data from the aesthetic survey's 1,888 responses (99% response rate in both groups) are summarised in Figure 1. There was no significant difference in the mean aesthetic score between respondents from fluoridated cities and non-fluoridated cities (p=0.572). The median rank from the scale this was 2 (not worried) in each city, for each TF with the exception of TF3 in non-fluoridated areas where the median was 3 (a little bit worried).

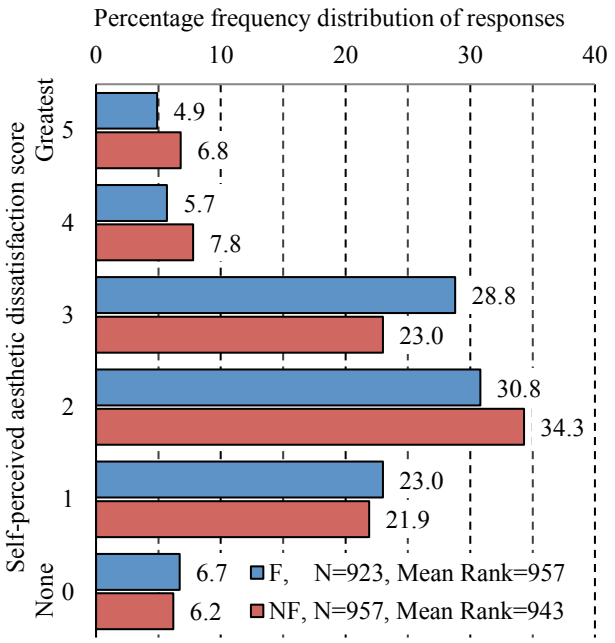

Figure 1. *Self-perceived aesthetic score across fluoridated (F) and non-fluoridated (NF) cities*

Discussion

While we have presented both TF Index and Dean's Index data it is important to recognise that the survey was designed to report TF as a primary outcome. The TF index is histologically validated and represents the biological presentation and development of fluorosis (Thylstrup and Fejerskov, 1978). Prior to photographic examination the teeth were dried, as per the TF protocol, but the Dean's examination calls for wet teeth (Dean *et al.*, 1950). As such the Dean's Index data should be treated with caution and are included for completeness.

The data presented in Table 1 which, for the cities of Manchester and Newcastle contain fluorosis data from 2012, and Newcastle for 2000 demonstrate broadly consistent fluorosis prevalence especially at the levels of TF2 or above. There does appear to be an increase in TF1 compared to the previous studies, and this seems to be related to a decrease in TF0. Caution must be drawn when considering the Newcastle data from 2000 as, while photographic techniques were used, the reported data for prevalence were from clinical, not photographic assessments. TF scores higher than three were seen, especially in Birmingham, although they were few in number and likely to be a result of failure to disclose past residency status (where water fluoride levels may be >1ppm), perhaps as a wish to conform or not to be excluded from participation. It is also impossible to exclude causes such as excessive or inappropriate use of supplemental fluorides.

The increase from TF0 to TF1 might be attributable to the increased exposure to fluorides, such as from fluoride toothpaste or professional fluoride applications. The children in this survey were aged between 11 to 14 and would have been 4 and 7 years old when the first edition of Delivering Better Oral Health was published in 2007 (DH, 2007) that advocated for increased use of professional applied fluorides and risk based recommendations for higher concentration toothpastes (2800ppm). The risk period for fluorosis of the anterior maxillary teeth is generally agreed to be from birth to the age of three (Evans and Darvell, 1995), so the increase is unlikely to be associated with the introduction of new guidance on other forms of fluoride. In considering any possible trend in the prevalence of fluorosis, it should be noted that previous photographic studies have employed conventional or digital 35mm cameras. The images obtained from the current system, due to the stabilisation frame and illumination array are of higher quality and hence the ability to detect the small changes associated with TF1 is increased; therefore the change we observed might be due to changes in method and not a true increase. The images are also polarised to remove specular reflection – the impact of polarisation on overall detection is not known – anecdotally it would appear to have little impact on scoring but does reduce the number of un-scorable images within datasets. In addition to the caution that is needed regarding any possible trend, it is important to bear in mind that the teeth in this survey will, through drying, appear to have more fluorosis than they would normally display in social circumstances. However the drying method and timings for the studies were the same as utilised in the current survey.

The consistencies in reported fluorosis free subjects between the two fluoridated and two non-fluoridated cities suggest external validity of the survey and there were no statistical differences at either TF>0 or TF>2 between the cities in each cohort.

The results from the evaluation of aesthetic impact suggest that the presence of fluorosis in the two cities benefiting from optimally fluoridated water may not affect children's self-perception of their teeth. The presence of other factors contributing to aesthetic loss, such as trauma and orthodontic condition should be similar across the populations, although data from earlier studies suggest that caries will be lower in the fluoridated communities (McGrady *et al.*, 2012a;b). Aesthetic assessment is complex, and oral health has been shown to be a significant factor in physical attractiveness (Ament and Ament, 1970). While data suggest that appearance (as opposed to functional deficit) is a major driver for those seeking orthodontic care the data concerning fluorosis is less clear (Albino *et al.*, 1981).

TF scores of 3 and above are generally considered to be aesthetically objectionable (Hawley *et al.*, 1996; Riordan, 1993). Given the apparent increase in TF1 (although the cautionary notes regarding image sensitivity should be considered) it is useful to note that these are not considered by children or their parents as an aesthetic issue (Clark *et al.*, 1993). The results from the current survey suggest that, in this age group, the presence of fluorosis (on a population level) does not appear to cause aesthetic concern or, where it does cause concern there is an equal level of dissatisfaction due to other factors, such as caries.

Conclusion

This surveillance work provides further cross-sectional epidemiological data on the prevalence and severity of dental fluorosis in English adolescents in fluoridated and non-fluoridated communities. There is a possible increase in the mildest forms of fluorosis that appear to shift from cases of non-fluorosis although this may be related to the superior image quality and assessment undertaken in this work.

If the increase in very mild fluorosis from TF0 to TF1 in both fluoridated and non-fluoridated communities is real and not artefact, the increase is unlikely to be related to water fluoridation as the schemes continued to operate across the time periods when the children were at risk. The proportion of aesthetically objectionable fluorosis, between 9% and 10.5% within the fluoridated communities, is unlikely to represent a public health issue. We must recognise that the use of TF3 or greater is a professional measure of fluorosis, one that is scored following tooth drying and assessed from clinical images taken with polarised light. The use of increased self-reported outcomes in relation to aesthetic impact is to be recommended Chankanka *et al*. (2010). There is no evidence from this survey of an increase in levels of fluorosis that might be of aesthetic concern. Future surveillance and epidemiological studies should employ high quality image capture and assessment to enable meaningful comparators with these data.

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