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A comparison of the prevalence of fluorosis in 8-year-old children from seven European study sites using a standardized methodology

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Abstract – *Objectives:* The objectives of this study were to report on the prevalence of enamel opacities from seven European study sites using a standardized photographic method, and to investigate the importance of variables responsible for enamel fluorosis. *Methods:* The sample comprised a randomly selected group of 300 8-year-old children in each of the study areas. One examiner from each area was trained and calibrated in the use of a standardized photographic technique. Two transparencies were taken of each child's permanent maxillary central incisor teeth; one to represent the teeth 'wet' and one when the teeth had been allowed to dry out naturally for 105 s. The transparencies were viewed 'blind' by the author (JAC) and scored using the DDE and TF indices. Data relating to variables considered to be associated with enamel fluorosis were also collected. *Results:* The prevalence of diffuse opacities ranged from 61% in fluoridated Cork (Ireland) to 28% in Athens (Greece). The percentage of subjects with a TF score of three or more ranged from 4% in Cork and nonfluoridated Haarlem (the Netherlands) to zero in Oulu (Finland) and Athens. Fluoridated water and the prolonged use of fluoride tablets were found to be significant contributory factors to fluorosis. *Conclusions:* The prevalence of fluorosis was found to be highest in fluoridated Cork. The prolonged use of fluoride supplements was also found to be a significant risk indicator associated with fluorosis.

Key words: children; comparison; dental fluorosis; photographic method; prevalence; standardization

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Photography has been used as a method to assist in diagnosing or assessing plaque and gingivitis (1–5). Standardized photographic methods have been favoured, particularly when it has been recognized that the investigations may be at high risk of bias. A number of studies investigating the prevalence of developmental defects of enamel or enamel fluorosis have also adopted a photographic approach (6–15).

The main advantages of using transparencies for recording enamel opacities are that they provide a permanent record of the appearance of the tooth and allow the examiner to grade the teeth 'blind' without reference to subject detail. The permanent record is particularly useful for measuring changes in enamel over time, and several sets of transparencies from one or more studies may be read or re-read by one examiner. This approach helps to reduce the

likelihood of examiner drift affecting the grades and the reported prevalence. The strength of these advantages is particularly important, as the debate regarding the alleged increase in the prevalence of fluorosis has gained momentum in the last 10 years (16, 17). On a large scale a standardized and robust intraoral photographic technique would allow more than one photographer to record developmental defects of enamel without giving rise to unacceptable variation in the quality of the pictures, which may affect the reliability of the grading at a later stage.

The aim of this study was to report on the prevalence of enamel opacities in 8-year-old children using a robust and standardized photographic method (18), as part of a multicentre epidemiological study involving seven European study sites (Project FLINT) (19). A secondary aim was to investigate the importance of variables responsible for enamel fluorosis.

Materials and methods

Study sites

The study sites were selected on the basis of convenience. They were Cork, the second city in Ireland, which was also the co-ordinating centre for the study; Knowsley, a suburb of Liverpool in England; a suburb of Athens in Greece; Haarlem, a town close to Amsterdam in the Netherlands; Oulu in the north of Finland; Reykjavik, the capital of Iceland; and Almada and Setúbal, suburbs of Lisbon in Portugal. Ethical approval to conduct the studies was obtained at a local level.

Sampling procedure

Sampling was conducted in two stages. Initially a number of schools were selected to represent a wide socioeconomic spread of children in the study area, based on local knowledge. In the selected schools all children in the school year in which the majority of children were 8 years old were invited to participate in the study and were sent information sheets and consent forms. In each study area the final sample comprised approximately 300 8-year-old school children.

Photographic technique

Following training and calibration in the standardized methodology as described in an earlier paper (18) one photographer in each study site photographed the children. The detail on the photographic equipment used by each photographer was also described previously, as are the data on the level of standardization of the drying periods and reproducibility of the photographic method. After cleaning with a dry toothbrush, two transparencies were taken at standardized drying periods, one to represent the tooth enamel 'wet' taken 8 s after placement of the cheek retractor and the other to represent the tooth enamel 'dry' taken after 105 s. Each research team took repeat photographs for 15% of the sample to measure intraexaminer repeatability. Additionally the 'Gold Standard' photographer visited each study site and took repeat photographs for a further 15% of each sample to measure interexaminer repeatability.

The films from all seven study sites were processed in one central professional laboratory in London. The transparencies were then returned to their respective sites to be labelled and placed in random order in plastic storage pages containing 16 transparencies per page. The pages from all seven countries were then randomized and viewed by one examiner (JAC). Those of 'wet' enamel were used to grade the maxillary central incisor teeth using the Developmental Defects of Enamel (DDE) index (20) and those of the 'dry' enamel were used to grade the maxillary incisor teeth using the Thylstrup and Fejerskov (TF) index (21). Technically poor transparencies were removed prior to reporting on the data. A spreadsheet was designed for direct data entry. The details pertaining to the transparencies to be graded were checked for accuracy and entered into the spreadsheet before the transparencies were graded. As the transparencies were graded the data were entered directly into the spreadsheet without reference to study area. A small percentage of transparencies was re-graded.

To obtain information on the factors which may result in fluorosis the parents of the children participating in the study were given a questionnaire. This was designed to obtain information about use of fluoride supplements, history of living in a fluoridated area, the age at which toothpaste was first used and the amount and type of toothpaste used. The questionnaire was translated into the national languages of the participating centres. Group discussions were held to ensure that the sentiments of the questions were understood to facilitate comparability between the ways the questions were phrased in five different languages.

In addition, records of the level of fluoride in the local drinking water were obtained for a period of 10 years between 1988 and 1998 which covered the lifespan of any child sampled in the study.

Statistical analysis

Statistical analysis was confined to descriptive statistics of subject prevalence of enamel defects. In the case of the DDE index, prevalence was recorded at the subject level if at least one permanent maxillary central incisor tooth was affected by either a diffuse opacity, a demarcated opacity or hypoplasia. In the case of the TF index the highest grade of fluorosis on either tooth was used in the analysis.

To investigate the importance of variables responsible for enamel fluorosis logistic regression analysis was carried out using information obtained from the questionnaires completed by the parents. For this purpose subjects were categorized into one of two categories: TF grade 0 or 1, and TF grade 2 and above.

Results

Characteristics of the study sites

Data collection began in the autumn of 1997 and was completed by February 1998. Technical difficulties were experienced in Almada/Setúbal, which were easily resolved upon consultation with the 'Gold Standard' photographer. Consequently, there was a reduction of the sample size and no intraexaminer reproducibility measures, as there was neither funding nor time to repeat the film exposures of 100 children who had been photographed using inappropriate camera settings.

Cork was the only site to receive an artificially fluoridated water supply. The water, supplied from two treatment plants, was fluoridated to a concentration between 0.8 and 1.0 ppm. The fluoride in the water occurring naturally at the other study sites was considerably lower. Haarlem reported fluoride levels that fluctuated between 0.1 and 0.15 ppm for the 10-year period. In Knowsley the fluoride levels were reported as being less than 0.1 ppm fluoride annually. In Almada and Setúbal the fluoride levels were reported as 0.08 ppm annually and in Reykjavik fluoride levels were reported as 0.05 ppm annually. The levels of fluoride for Athens and Oulu were reported as being less than 0.01 ppm annually.

Sampling procedures

The total population of 8-year-olds varied from 1343 in Oulu to 2002 in Cork (figures for Knowsley, Haarlem and Athens were not available.) Approximately 20% of the primary schools in a study site were visited to achieve a final sample of approximately 300 in each site. This ranged from four schools in Knowsley to 18 schools in Athens. Consent ranged from 66% to 96% (figures for Knowsley, Haarlem and Athens were not available.) The number of children photographed as a percentage of the total population of children in the age group studied ranged from 12% to 23% (figures for Knowsley, Haarlem and Athens were not available).

Variations in method

A total of 5250 transparencies was taken, of which 114 (2.2%) were not suitable for analysis. Four transparencies had a substantial part of the image missing; a poor 1 : 1 reproduction ratio was identified in the case of six transparencies; 34 transparencies were affected by grade 2 lip shadow; 70 transparencies were affected by grade 2 specular reflection. Transparencies arrived from three sites in an order that did not appear to be random; it was therefore necessary to rearrange the position of the transparencies to ensure that all were in a random order.

Prevalence of opacities

Table 1 gives a summary of the results for the DDE index as graded on the permanent maxillary central incisors using the transparencies taken to represent

Table 1. Percentage of subjects with at least one permanent maxillary central incisor affected by diffuse or demarcated opacities or hypoplasia and overall prevalence of enamel defects as graded by one examiner from transparencies taken of 'wet' teeth measured using the DDE index

Site	F in water (ppm)	*n*	Diffuse (%)	Demarcated (%)	Hypoplasia(%)	Overall prevalence (%)
Cork	1.0	324	61	16	1	69
Knowsley	<0.1	315	32	19	2	48
Oulu	<0.01	314	48	18	2	59
Athens	<0.01	287	28	18	0	43
Reykjavik	0.05	298	37	24	2	54
Haarlem	0.13	303	56	25	3	70
Almada/Setúbal	0.08	210	34	20	1	49

Table 2. Percentage of subjects with each grade of the TF index (highest grade of 2 teeth) as graded by one examiner from transparencies taken of 'dry' teeth

Site	F in water (ppm)	*n*	TF grade (highest of two teeth; %)			
			0	1	2	≥3
Cork	1.0	325	11	59	26	4
Knowsley	<0.1	314	34	54	11	1
Oulu	<0.01	315	18	61	21	0
Athens	<0.01	283	47	48	5	0
Reykjavik	0.05	296	32	51	16	1
Haarlem	0.13	303	21	54	22	4
Almada/Setúbal	0.08	210	49	43	7	1

Table 3. Logistic regression of water fluoridation and prolonged use of fluoride tablets as risk indicators associated with fluorosis

Variable	Parameter estimate	SE	*P*-value	Odds ratio and 95% CI
Intercept	−2.0472	0.1103	0.0001	
Water fluoridation	1.2599	0.1715	0.0001	3.53 (2, 52 4, 93)
Use of fluoride tablets >2 years	0.7750	0.1555	0.0001	2.17 (1, 60 2, 95)

the tooth enamel as 'wet'. The level of diffuse opacities ranged from 61% in Cork to 28% in Athens. The level of demarcated opacities ranged from 25% in Haarlem to 16% in Cork. There were very few hypoplastic opacities recorded.

Table 2 shows the prevalence of fluorosis as measured on transparencies of dry teeth by the TF index. The highest grade of either tooth was used in the analysis. The prevalence of enamel opacities for grades 0, 1, 2 and 3 is given but as there were so few opacities of grades 3–9 recorded these are presented as grades 3 and above. The percentage of teeth where no fluorosis was recorded was lowest in Cork (11%), which is the only city with a fluoridated water supply, and highest in Almada and Setúbal (49%).

Comparing the data obtained from both indices, Cork had the highest percentage of subjects with a TF grade greater than 0 (indicating some level of fluorosis) at 89%, followed by Oulu (82%) and Haarlem (79%). Similarly Cork, Oulu and Haarlem had the highest overall prevalence of developmental defects of enamel. The lowest levels of TF prevalence were seen in Almada and Setúbal (51%) and Athens (53%), compared with the lowest overall prevalence of developmental enamel defects for Almada and Setúbal (49%), Knowsley (48%) and Athens (43%).

Fluorosis represented by a TF grade of 1 can be described as extremely mild fluorosis and in all study areas this formed the majority of fluorosis reported, ranging from 61% in Oulu to 43% in Almada and Setúbal. Fluorosis represented by a TF grade of 2 was highest in Cork (26%) and lowest in Athens (5%). There were very few subjects with a TF grade of 3 or more.

Variables associated with enamel fluorosis

Logistic regression was carried out to determine which variables were most important in relation to the prevalence of fluorosis (Table 3). The first variable to enter the model was water fluoridation, with a fluoridated water supply of 0.8–1.0 ppm yielding an odds ratio of 3.53. For a fluoridated water supply fluorosis of TF index grade 2 or more was approximately 3.5 times more likely than when the water supply was not fluoridated. The next variable to enter the model was the use of fluoride tablets, with an odds ratio of 2.17. If fluoride tablets were used for more than 2 years prior to the eruption of the first permanent maxillary incisors, this appeared to increase the chance of enamel fluorosis by a factor of approximately two. No other variables entered the model. Therefore, from the data set compiled, the most influential variables with respect to levels of fluorosis would appear to be water fluoridation and the prolonged use of fluoride tablets.

Discussion

Since the mid-1970s a decline in dental caries among children and adolescents from industrialized western countries has been widely reported. Not only has the prevalence of caries in children declined, but

also the distribution of caries within the population now shows that 20% of the child population experiences most of the disease (22). Recent evidence would suggest that there may be a change in the pattern of dental caries. Caries in the primary dentition of children in England and Wales is reported to have stabilised since 1983, and may even have increased slightly since 1993 (23). The issue of whether enamel fluorosis is increasing in prevalence, and whether it is an aesthetic issue that affects, for example, acceptance of the use of fluoride toothpaste by the public, needs to be determined.

This study was the first multicentred study conducted in Europe using a standardized and reproducible photographic method. As such it provides unprecedented data in that direct comparisons on the prevalence of enamel opacities can now be facilitated for both contemporaneous studies and those conducted at two or more points in time.

Although a direct comparison of the results of the current study with those from previous studies where standardization was not as rigorously controlled may appear to defeat the purpose of this paper, several previous studies merit discussion. Milsom and Mitropoulos (24) compared the prevalence of developmental defects of enamel in fluoridated Nantwich (1 ppm) and nonfluoridated Northwich (<0.2 ppm), both in Cheshire, England. The children examined were 8 years old, comparable to the current study; attempts were made to ensure that the examiner was blind to subject detail; and the teeth were described as being examined 'wet' after the removal of debris, albeit clinically as opposed to photographically. The teeth examined included permanent maxillary and mandibular incisors and first molars. The overall prevalence of DDE was 60% in the fluoridated area and 44% in the nonfluoridated area; the significant difference between the two communities was the result of a higher prevalence of diffuse opacities in the children from the fluoridated area. The data reported for hypoplasia (2% and 4%, respectively) and demarcated defects (28% and 31%, respectively) were similar to the prevalence data reported from the current study. The overall prevalence of 60% DDE in fluoridated Nantwich compared with the overall prevalence of 69% DDE in fluoridated Cork.

Nunn et al. (13) studied three areas in the North of England: Hartlepool (water fluoridated to 1.2 ppm), Newcastle (water fluoridated to 1 ppm) and Middlesborough (0.2 ppm fluoride in the water). The maxillary central and lateral incisors were photographed using an elevated camera angle similar to that described in the current study and the same film type was used. No attempt was made to dry the teeth and no attempt was made to standardize this aspect of the method. The study also reported on DDE prevalence data observed clinically. In Hartlepool (1.2 ppmF) the overall DDE prevalence recorded from projected transparencies was 82%, in Newcastle (1 ppmF) it was 84% and in nonfluoridated Middlesborough it was 58%. These figures appear to be slightly higher than those found in the current multicentred European study. It is difficult to comment as to whether the greater prevalence of DDE observed in the North of England is the result of enamel desiccation at the time of photography, examiner drift or other factors.

Other studies have reported that diffuse opacities (DDE index) have been the opacity type to distinguish the difference in prevalence between high and low fluoridated areas (11, 12, 24–27). In the current study the highest level of diffuse opacities was found in Cork, as one would expect because this is the only city with a fluoridated water supply. However, both Haarlem (water fluoride concentration 0.13 pm) and Oulu (water fluoride concentration <0.01 ppm) had levels of diffuse opacities comparable to Cork, and neither of these cities had a fluoridated water supply. Slightly lower levels were seen in Reykjavik and Almada/Setúbal and the lowest levels were seen in Knowsley and Athens. In the light of the above results, it was decided that a further investigation into other factors which may contribute to fluorosis was required. These factors were considered to be water fluoridation, fluoride tablets and fluoride toothpaste, and the extent and duration of their possible influence were determined by questionnaire. Water fluoridation and the use of fluoride tablets for longer than 2 years were found to be the only significant contributory factors.

Reported use of fluoride tablets for more than 2 years did not occur in Ireland and was very low in Athens (1%) and Knowsley (3%). Reported use of fluoride tablets for more than 2 years ranged from 44% in Reykjavik and Haarlem to 58% in Oulu. Fluoride toothpaste was not a significant factor. Milsom and Mitropoulos (24) carried out further analysis of their data, which showed 60% prevalence of DDE in the fluoridated area and 44% in the nonfluoridated area, by looking at the age at which mothers claimed to start brushing with fluoride toothpaste. It was found that mothers of children from fluoridated Nantwich who claimed to start brushing early had more diffuse enamel opacities. Following the same trend as reported by Osuji et al.

(28) the mothers from the higher socioeconomic groups were those to report early toothbrushing.

In conclusion, the prevalence of fluorosis-like enamel lesions measured in seven European study sites using a standardized photographic technique was found to be highest in fluoridated Cork. It was also found that the use of fluoride supplements for longer than 2 years was a significant risk indicator associated with fluorosis.

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