Development of a Standardisation Device for Photographic Assessment of Dental Fluorosis in Field Studies

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Purpose: This study evaluated the agreement between clinical and photographic assessment of dental fluorosis (DF) in 73 children during a field study, using portable equipment and a standardising device.

Materials and Methods: A dental exam was performed using the Tooth Surface Index of Fluorosis (TSIF). Photographs of the facial aspects of front teeth and from the occlusal aspect of the mandibular posterior teeth were taken. All photographs were taken following a standard operating procedure. Photographs of anterior and posterior teeth were coded and assigned a random study number. Examiners scored photographs as fluorosis cases or non-cases.

Results: Agreement among the clinical examiners ranged from good to excellent. Agreement was also good for the repeated photographic evaluations. In total, 22% of the children were diagnosed with DF during a clinical exam, and 19% were diagnosed with DF using the photographs.

Conclusions: Development of this method aided in the photographic assessment of DF. The photographs obtained were a useful tool for documenting DF, to re-train examiners, and to determine intra- and inter-examiner agreement.

Key words: dental fluorosis, fluoride, photography, TFI, TSIF

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Dental fluorosis (DF) is defined as a hypomineralisation of the enamel caused by the excess of fluoride in the environment surrounding the enamel during tooth formation. The first clinical signs of DF appear as thin white lines across tooth surfaces. In moderate cases, the white lines are more pronounced and may fuse, resulting in areas that appear cloudy and are spread over the enamel surface. With increasing severity, the entire tooth surface exhibits opaque cloudy areas that may mix with areas of brownish discoloration. In the most severe cases, pitting of the enamel surface occurs (Dean, 1934; Cutress and Suckling, 1990; Rozier, 1994).

Since the early 1930s, several indices have been developed to diagnose, qualify and quantify the clinical features of DF (Dean, 1934; Thylstrup and Fejerskov, 1978; Horowitz et al, 1984; Rozier, 1994). To date, most published indices base their diagnosis on the clinicians' interpretation of the clinical signs of enamel defects, while the classification is based solely on the clinical appearance or the correlation of the clinical appearance with histological features. The indices are primarily used for research and epidemiological purposes, and require special training and calibration.

Because interpretation is needed for the diagnosis of DF when an examiner is checking tooth surfaces,

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subjective differences may be found. In order to eliminate any observer's bias, the use of objective screening methods such as photography have been proposed (Fleming et al, 1989; Levine et al, 1989; Nunn et al, 1993; Sabieha and Rock, 1998). Photographs, either in print or slides, have been employed by several investigations to determine the prevalence of DF, used in a method to calibrate and train examiners, and to validate the indices (Fleming et al, 1989; Levine et al, 1989; Stephen et al, 1991; Nunn et al, 1993; Ellwood et al, 1994; Clark, 1995; Ellwood et al, 1996; Sabieha and Rock, 1998; Stephen et al, 2002). A few of these studies have used photographs to assess examiners reliability while diagnosing DF. However, some differences have been reported between clinical and photographic assessments (Ellwood et al, 1996; Levy et al, 2002; Stephen et al, 2002).

The use of photographs to score DF may present some distinct advantages in comparison to a clinical examination. Photographic images are a valuable aid in visualising cases, they allow repeated objective assessments and they may be used to eliminate possible biases (Ellwood et al, 1996; Levy, et al, 2002; Stephen et al, 2002). The use of photographs would also offer a clear advantage while conducting multisite epidemiological field studies. It would provide a tool to maintain standardisation when multiple examiners are performing exams under different field conditions. However, some disadvantages of dental photography to assess DF may exist. There may be difficulties in photographing teeth due to a lack of accessibility. This has resulted in assessments being made using only the child's front teeth (Nunn et al, 1993; Ellwood et al, 1994; Tabari et al, 2000), which could result in an under reporting of the prevalence of DF. In addition, because DF is often detected by line of sight tangential to the teeth, the use of photographs that provide a single line of sight (usually perpendicular) may lead to over- or under-grading of teeth, and therefore to over- or under-detection and reporting. It has been suggested that cross-polarisation would be an appropriate method to avoid unwanted reflections. However, for the specific assessment of DF, this technique may not be suitable because the surface detail of enamel is lost. Cross-polarisation also produces an airbrushed effect, a frosty appearance and loss of colour balance (Robertson and Toumba, 1999). It has been reported that this technique may create unnatural images in dental photography (Bengel, 2002).

Previous studies have used a methodology developed by Ellwood and co-workers (Ellwood et al, 1996) to diagnose DF using photographs, which has been reported to be reproducible and precise. Tabari et al (2000) scored two labial surfaces viewed on a graphics light box without magnification. Good agreement was reported when comparing the clinical and photographic assessment of DF (Kappa = 0.70). Intra-examiner agreement was reported as 73%. In total, 38% of the teeth were defined clinically as cases of DF and 37% were defined photographically. Ellwood and collaborators (1994 and 1996), using the same methodology, similarly reported substantial agreement between the clinical and photographic assessments of DF. However, in both investigations, higher scores were found when using photographs, which suggests some limitations for this method. Only upper incisor assessments were used, which may have limited the applicability of the method. Although colour spectrum cards were used to assess consistency of the developing and processing of films, no analytical or quantifiable assessment was reported, which suggests that subjectivity could still exist. No further studies by this group or others using the same methodology have been reported to date.

Reports concerning an increase in the prevalence of DF (Driscoll et al, 1983; Szpunar and Burt 1987; Clark, 1994; Stephen et al, 1999; Soto-Rojas et al, 2004) have raised interest in investigating new methods for diagnosing DF. The lack of reproducible objective diagnostic methods has made it difficult to determine if these reported increases in prevalence are partly or completely the result of differences in diagnostic criteria, study design or examination conditions. Therefore, objective and reproducible methods for the assessment of fluorosis would be valuable. The aim of the present investigation was to evaluate the use of photographs for the diagnosis of dental fluorosis. This was done by evaluating the agreement between clinical and photographic assessment of the presence of dental fluorosis in a group of children with and without dental fluorosis, using portable equipment for both clinical diagnosis and image acquisition in field studies.

MATERIALS AND METHODS

Training procedures

Three dentists underwent an initial training and calibration session for DF examinations. This involved a period of training and both inter- and intra-examiner calibrations, which were performed until reliable Kappa values were obtained. For the initial calibra-

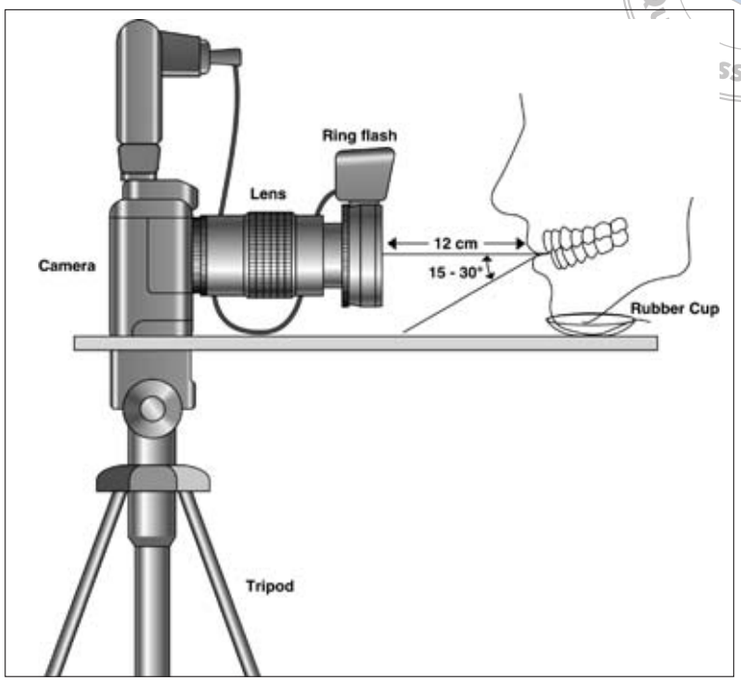

Fig 1 Drawing of photographic equipment and technique used.

tion, each examiner assessed 55 children. The same examiner examined 2% of the children twice and all the dentists examined every fifth child twice to obtain the Kappa value for this calibration session. The same procedure was subsequently followed during the implementation of this study. A second calibration session was undertaken prior to the start of the clinical study by two researchers who performed the clinical investigation. Finally, both examiners underwent a third calibration exercise during the clinical stage of the study.

Clinical procedures

Prior to the initiation of the study, approval was obtained from the Scientific Committee and the Ethics and Safety Committee. Written consent to have an oral exam and pictures taken was obtained from the parent or legal guardian of each child. To participate in this study, children had to be between 7 and 10 years of age, have at least two central incisors and two molars which were fully erupted, have no orthodontic brackets or any other appliances or conditions that prevented the assessment of DF, and have no medical conditions that would contraindicate a dental examination.

Before the dental examination each child was asked to brush his/her teeth using water and a manual toothbrush provided by the investigators. The Tooth Surface Index of Fluorosis (TSIF) (Horowitz et al, 1984) was used to score DF. The examiners observed the buccal, lingual and occlusal aspects of posterior permanent teeth and the labial and lingual aspects of anterior permanent teeth. A score was given for each graded surface. The entire surface being evaluated had to be visible in order to be scored. To differentiate fluorosis from non-fluorosis opacities, a flowchart for differential diagnosis, adapted from the one developed by Cutress and Suckling (1990), was used.

Strict infection control guidelines were followed for all clinical examinations. The dental examinations were performed using a portable dental light and dental chair. Examinations were conducted in the field. Examination rooms were set up in either classrooms or nurses offices in schools or orphanages. Data were recorded in a spreadsheet and entered in a computer database.

Photographic procedures

Once the dental exam was finished, one of the examiners took photographs of the facial aspects of front

Fig 2 Fluorosis case, front teeth.

Fig 3 Non-fluorosis case, front teeth.

teeth and from the occlusal aspect of the mandibular posterior teeth. To obtain reproducible photographic conditions and to minimise differences, all photographs were taken following a standard operating procedure. Photographs were taken using a 35mm Nikkormat camera with a Macro lens (AF Micro Nikkor 60 mm, Nikkor, Japan) to give a reproduction ratio of half life-size (1:2) with a grey polarising filter to minimise extraneous reflections. A standard portable light and a ring flash mounted on the lens (Soligor AR-40 AF, Soligor, Germany) were also used to standardise lighting conditions. All photographs were taken with an aperture setting of f/32, to maximize depth of field and minimise light defects and reflections. The exposure and distance remained constant for all photographs.

A headrest and an adjustable tripod specially designed for children were used to standardise head position (15 degrees above the horizontal plane for anterior teeth, and up to 30 degrees for posterior teeth, to diminish reflections) and distance from the camera (~12 cm) using a rubber cup (Fig 1). Professional film (Fuji Chrome Provia, Fuji Photo Film, Japan) from one batch was used and all photographs were developed at the same professional photographic laboratory on the same day. Each child had his/her teeth brushed without toothpaste using a new toothbrush before the clinical examination. Photographs were taken within the first minute of the oral exam. If this was not possible, children were asked to moisten their teeth again prior to taking the photograph. Children were asked to retract their cheeks using their hand-washed fingers and to close incisors edge to edge.

Colour prints were obtained (14.8 x 10.0 cm) from the same laboratory that processed the film. A number was assigned to each print. Prints were randomly filed in a picture album to blind the examiners. In a separate exercise, the clinician assigned scores to the photographs after viewing them under direct standard light. Photographs were scored as DF cases or non-cases, and no attempt was made to score individual surfaces in the photographs. A third examiner, who did not participate in the clinical examinations but did participate at the initial calibration session, also scored photographs on repeated occasions. All the examiners scored the photographs under similar lighting conditions.

Data analyses

A minimal sample size of 72 subjects was determined to be necessary to detect a difference of 20% in fluorosis cases with a p value of 0.05 and a power of 80%. A subject was classified as a fluorosis case in this study if his or her maximum TSIF score was greater than or equal to one (case definition, TSIF). A Kappa statistic, using a linear weighting scheme, and a 95 % Confidence Interval were calculated to assess the intra- and inter-examiner's reliability for the three calibration sessions. Reliability was assessed by classifying a subject as a fluorosis case (yes/no) for clinical and photographic exams as well as on a surface-to-surface basis for the clinical examinations. Inter-examiner's reliability was assessed among the three examiners for the initial training session, and between examiners 1 and 2 for the other two sessions. Intra-examiner reliability was assessed for examiners 1 and 2 for all three sessions. In addition, clinical and photographic assessments of DF were compared, and reliability values were calculated for these exercises. Kappa values were ob-

Table 1 Results of initial training and calibration exercises conducted prior to initiation of the study

Examiners	Number of subjects	Surfaces analysed	Kappa value	Confidence Interval (95%)
examiner 1 vs. examiner 1	27	1944	0.91	0.89, 0.92
examiner 1 vs. examiner 2	28	2016	0.81	0.79, 0.84
examiner 1 vs. examiner 3	13	936	0.81	0.78, 0.84

Table 2 Results of clinical assessment of dental fluorosis

Examiners	Clinical exams	Repeated clinical exams	Surfaces analysed	Kappa	Confidence Interval (95%)
examiner 1 vs. examiner 1	77	14	970	0.90	0.88, 0.93
examiner 1 vs. examiner 2	N/A	16	1236	0.79	0.77, 0.85
examiner 2 vs. examiner 2	61	14	990	0.91	0.88, 0.94

N/A: not applicable

Table 3 Agreement of photographic vs. clinical assessment of dental fluorosis

Examiners	Number of subjects	Kappa	Confidence Interval (95%)
examiner 1 vs. examiner 1	73	0.92	0.91, 0.93
examiner 1 vs. examiner 2	20	0.87	0.85, 0.89
examiner 2 vs. examiner 2	61	0.90	0.88, 0.92
examiner 1 vs. examiner 3*	40	0.80	0.79, 0.83
examiner 2 vs. examiner 3*	33	0.79	0.76, 0.82

* Photographic assessment of examiner 3 was compared to the clinical assessments of examiner 1 and examiner 2.

tained for the agreement between the photographic assessment of examiner 3 and the clinical assessment of examiners 1 and 2, and also for the repeated photographic assessment of examiner 3.

RESULTS

Results of the training and calibration exercises conducted prior to the initiation of this study are shown in Table 1. Results of the clinical study calibration session are shown in Table 2. Agreement, as calculated by Kappa values, ranged from what was considered good to excellent for all these sessions.

A total of 138 children were examined clinically. Of these, 73 children were randomly selected for a photograph. Figures 2 and 3 show representative photographs of a fluorosis case and a non-case. In four cases (5.47%), the photographs taken could not be used for the photographic diagnosis, because they were unfocused. During the study, both examiners 1 and 2 examined twenty subjects each time, examiner 1 examined seven subjects twice, and examiner 2 examined three subjects twice. The Kappa value for the repeated examinations of examiner 1 was 0.92, and for examiner 2 it was 0.97 (Kappa value for prevalence was 1.0 for both examiners). The Kappa value for examinations conducted by both ex-

aminers was 0.83. The Kappa value for the repeated photographic evaluations of examiner 3 was 0.83.

During the implementation of this study, examiner 1 clinically examined 77 children, and of these 40 had a picture taken. Examiner 2 clinically examined 61 of children and of these 33 had a picture taken. A total of 16 children were clinically examined by both examiners 1 and 2. Examiner 1 clinically examined seven subjects twice and examiner 2 examined three subjects twice.

A prevalence of 38.6% DF cases was found in the clinical investigation using the TSIF index. Results of the clinical versus photographic agreement are shown in Table 3. Agreement between clinical and photographic assessment of DF was 94% (16/17) for examiner 1, and it was 93.3% (14/15) for examiner 2. Agreement between examiner 1's clinical assessment and examiner 3's photographic assessment of DF was 76.5%.

Of the 23% of children who were scored as fluorosis cases by examiner 1, 15.5% had a maximum score of 1, 2.8% of the children had a maximum score of 2, 1.5% had a maximum score of 3, and 3.2% were assigned the highest score of 5. The clinical fluorosis scores given by the examiners were primarily those for milder forms of fluorosis. Of the 21 % of children who were clinically scored as fluorosis cases by examiner 2, 14.7% had a maximum score of 1, 2.8% of the children had a maximum score of 2, 0.4% had a maximum score of 3, and 3.1% were assigned the highest score of 5. Agreement among all examiners tended to increase in subjects whose clinical score was 2 or higher (99% agreement) as compared to individuals who were scored as non-cases or who had maximum score of 1 (75% agreement).

DISCUSSION

In the present study, the agreement between clinical and photographic assessment of DF using the TSIF index was found to be good. The results of the intra- and inter-examiner calibration for the clinical examination were good to excellent. The examiners who participated in the clinical exams agreed in a large percentage of cases, especially in those with moderate to severe fluorosis. The examiner that did not participate in the clinical examinations was able to accurately detect 76% of the cases using only photographs. Most cases with DF fell into the mild category and the agreement for this category was only fair. The presence of more severe cases of DF would have likely increased the number of agreements.

The methodology developed for this study allowed the investigators to obtain standardised photographs in most cases. The photographs were used to produce training binders that could be used by multiple sites while conducting clinical investigations in the field.

Comparisons of the results of the present study to other investigations were difficult to perform, primarily due to differences in methodologies. Some of the major differences included the index that was used, the methodology used to score the photographs and the photographic technique.

The results of the present study may be compared to three studies that have assessed agreement between the diagnosis of DF using photographs, and visual diagnosis using the TSIF index. The present results are similar to the results of Stephen et al (1999), who reported an agreement of 97.2% between clinical and photographic assessments of DF by a clinical examiner (only two disagreements), and a 100% agreement on repeats (10% of cases). The agreement between all examiners ranged from 92.5% to 97.2%. However, slides were used with the aid of one 'impact' factor imaging tool. An image exhibited symmetrical teeth with different mottling levels, which may have contributed to the high level of agreement reported.

The present results are in disagreement with the other two reports. Levine et al (1989) used the TSIF index and photographs, and reported a slightly higher percentage of opacities than those observed here. The assessments in that study were limited to the maxillary central incisors and the agreement among investigators was not reported. The other report by Clark (1995) measured the highest aesthetically acceptable score of fluorosis using images and assessed a group of people with various backgrounds, which included dentists. However, results of this investigation revealed that correlation coefficients between visual and photographic examination were poor, while the present agreement was good to excellent. The agreement among dentists was not reported in the Clark (1995) study.

It is even more difficult to compare the present results to other studies that used a different index for measuring fluorosis. Some studies have compared clinical and photographic assessments of DF using the Thylstrup-Fejerskov Index (TFI) (Thystrup and Fejerskov, 1978). The TFI requires drying the teeth, and it has been suggested this may lead to over-scoring. The studies that used this index on photographs usually did not specify if teeth were dried prior to the photograph being taken. In the Sabiehah and Rock (1998) study, cal-

ibration exercises were based on the use of slides. A disagreement of 23% was reported between clinical and photographic methods, while agreement in the present study was 94%. However, the correlation coefficient between clinical and projected slides was reported as good (0.78). In another study by Stephen et al (1991) using slides, an inter-examiner agreement ranging from 48% to 86% was reported, while the present results ranged from 76% to 92%. The agreement between clinical and photographic methods was not stated in the Stephen et al (1991) investigation. In a follow-up study, Stephen et al (2002) used slides of dried anterior teeth that were scored when projected on a screen. The reported agreements between dentists ranged from 90% to 97% (Kappa 0.69–0.89), which were higher than the present results. However, more teeth were scored as fluorosis cases using photographs than were in the clinical assessments.

In terms of using prints, the present results can be compared to a study performed in 1993 by Nunn et al. Although a different index was used, the DDE (Developmental Defects of Enamel) index, the slides in the Nunn et al (1993) study were processed to produce colour prints (14.8 x 10.0 cm), as they were in the present study. However, central incisors were cut to avoid the redness contrast from gingival tissues, and labial surfaces of maxillary incisors were scored against a brown wood background. The results showed that diffuse and demarcated opacities were scored higher than when using photographs. Nunn et al (1993) also reported a higher prevalence of fluorosis when using photographs compared to a clinical examination, while the present study found a lower prevalence of DF using photographs. The Kappa statistics reported in the Nunn et al (1993) study revealed satisfactory levels of inter- and intra-examiner agreements, similar to the present results.

In general, photographs have been reported to be more sensitive than conventional clinical recording (Ellwood et al, 1994), and for this reason it has been suggested the use of photographs may result in over scoring. This is in disagreement with the present results and may be due to the fact that teeth were photographed while they were still wet in the present study. Other differences in methodology may explain the differences in the present results as compared to other studies. For example, a polarised lens was selected to diminish reflections in order not to over-score teeth, although, it has been reported that the use of this polarising filter may affect colour rendition (Bengel, 2002). For the present study, the use of a polarised lens was chosen to avoid unwanted reflections, since the purpose of this study was to investigate enamel defects that in a photograph could be mistaken for a reflection or vice versa. Using a ring flash provides flat images, hinders shadows and provides less brilliant images (Bengel, 2002). Cross–polarisation has been suggested for the study of enamel defects because the technique eliminates all kinds of reflected light (Robertson and Toumba, 1999). However, this technique provides unclear, unnatural and strange looking images in dental photography (Bengel, 2002). Most studies reported using a ring flash, but other technical details were sometimes not specified, including whether the teeth were cleaned before a photograph was taken and the lighting conditions used. This makes it difficult to determine if there were any additional factors that could explain the differences found between the present study and others.

A final methodological difference is that in the majority of studies, the investigators have attempted to assign a score to photographs, not just to detect the presence or absence of the disease. Attempting to score a photograph using an index designed for clinical examinations could lead to over-scoring. In the present study, only ‘cases’ or ‘no cases’ were used and no attempt was made to determine the severity of the disease through the use of the photographs. However, based on the severity determined through clinical examinations, it was observed that if the patient’s score was more severe, the clinical and photographic agreement increased. A TSIF score of one or less was more difficult to compare and to assess using photographs because subtle changes were not easy to spot in a photograph. In spite of this, the percentage agreement between clinical and photographic assessment was still good (75%), highlighting the usefulness of photographs in assessing DF.

Based on the present results, it was concluded that the photographic assessment was a valuable way to evaluate the agreement between the three examiners. For examinations conducted in the field, the development of calibration binders using prints of previously diagnosed cases would be a valuable tool to maintain the standardisation of assessments. Photographs were found to be useful in documenting the clinical prevalence of DF in the studied community. The development of a standardisation device assisted examiners in obtaining reproducible photographs of most cases. Further investigations concerning the use of images as a means of determining levels of DF are needed. In addition, as new imaging technologies (digital and intra-oral) are introduced, the need to develop standardised methods becomes even more critical if the new technologies are to be used effectively and the results of clinical trials are to be compared.

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