Community Dent Oral Epidemiol 2005; 33: 298–306

COMMUNITY DENTISTRY AND ORAL EPIDEMIOLOGY

An assessment of teenagers' perceptions of dental fluorosis using digital simulation and web-based testing

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Edwards M, Macpherson LMD, Simmons DR, Gilmour WH, Stephen KW. An assessment of teenagers' perceptions of dental fluorosis using digital simulation and web-based testing. Community Dent Oral Epidemiol 2005; 33: 298–306.

Abstract – *Objectives:* To develop a new model to establish teenagers' perceptions of the aesthetic impact of fluorosis, in the context of overall facial appearance. This web-based model was used to compare different degrees of fluorosis at any one distance, while also comparing the same level of fluorosis at different 'distances'. *Methods:* A 14-year-old subject was used as the model face. Different degrees of fluorosis were 'built-up' on this subject's teeth using digital simulation. A web-based questionnaire showed 30 photographs, displaying four levels of fluorosis, in addition to fluorosis-free, at five different 'distances'. The closest images were shown with and without retractors, while the more distant pictures showed more of the subject's face. Teenage pupils ($n = 217$) were then asked to grade the acceptability of the appearances and indicate if they would wish treatment for each such appearance. *Results:* At any one distance, acceptability fell as fluorosis level increased. When the same degree of fluorosis was compared at different distances, acceptability improved as the teeth were viewed from further away. Pictures taken without retractors had higher acceptability than those taken with retractors in place. *Conclusions:* Teenagers can discriminate between various degrees of fluorosis. However, more distant viewing of fluorosed teeth, within the overall context of the face, improves acceptability of the appearance.

Key words: aesthetics; computer simulation; dental fluorosis; perception; World Wide Web

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Submitted 18 November 2004;
accepted 4 March 2005

Introduction

In 1986, Leverett (1) published data indicating an apparent increase in fluorosis, even in nonfluoridated areas of the US. Since then, there has been debate concerning the most appropriate exposure to fluoride in order to obtain optimal cariostatic and caries preventive effects, without increasing the prevalence of fluorosis of aesthetic concern. The UK 'York Review' (2), commissioned to investigate the efficacy and safety of water fluoridation, calculated a prevalence of 12% for fluorosis of aesthetic concern in water-fluoridated areas. However, one of the main conclusions of the review was the low quality of research, generally, concerning water fluoridation. In addition, in 2001, further research in the area of public perceptions of fluorosis was highlighted as a priority by a Centers for Disease Control and Prevention report from the USA (3). This was followed in 2002 by a similar recommendation from the UK Medical Research Council (4).

Many previous fluorosis studies have concentrated mainly on its professional assessment and have used a variety of different clinical indices, e.g. some (5, 6) have used the Developmental Defects of Enamel Index (7), others (8) the Tooth Surface Index of Fluorosis (9), while others (10, 11) the Thylstrup & Fejerskov Index (12). However, since the early 1990s, the views of the common man have also been obtained. This has involved panels of

individuals rating photographs of teeth (13–18) and patients/parents being asked to assess the appearance of their own/their child's teeth (19–25). With regard to the former method of assessment, standard clinical photographs, which are taken close-up and often magnified, have normally been used with lip retractors in place to show the teeth more clearly. However, this prevents the teeth from being viewed naturally, i.e. surrounded by lips and within the overall context of a face. Although some investigators have used 'live' subjects to simulate more natural conditions (26, 27), variations in tooth colour, shape and alignment, as well as overall facial attractiveness, can confound the results. Nonetheless, with the advent of computer technology, image manipulation has been employed to a limited extent using close-up pictures (17, 18). However, the effect of viewing distance has yet to be explored.

Aims

This study aimed to develop a web-based model, using digitally simulated images, to investigate the public's perceptions of fluorosis. In addition to comparing different levels of fluorosis, further aims were to investigate the effect of viewing distance on perceptions of fluorosis severity, and to compare pictures where lips were retracted with images where lips were nonretracted.

Methods

A 14-year-old, fluorosis-free female subject, was enrolled to act as the model face. Ethical approval was granted by the University of Glasgow Medical Faculty Ethics Committee and full written consent was obtained from both the subject and her parents.

Using a high-quality digital camera (Fujifilm FinePix F601 Zoom, Fuji Photo Film Co. Ltd, Tokyo, Japan), three images of the subject's face were taken. The first showed a standard view of the labial surfaces of the anterior teeth, with lips retracted ('teeth' view, or D0), with a second nonretracted picture taken at the same distance, in order to place the teeth in their natural context ('lips' view, or D1). The third was a full-face 'master' photograph (D5) which was later altered in size to simulate different 'distances' (D2–D4), as shown in Table 1. The resultant '.jpeg' files were imported into the Matlab data-processing package. Examples of existing clinical cases of fluorosis, showing Thylstrup & Fejerskov (12) fluorosis levels TF1 to TF4, were then used to create 'stencils' of fluorotic markings. These stencils were overlaid on to the model's teeth, preserving both their size and arrangement, and allowing the base colour and highlights of the teeth to be retained. Digitally simulated images were prepared, showing four levels of fluorosis plus fluorosis-free (i.e. five different 'levels'), at five different 'distances', with the closest 'distance' shown both with and without retractors (i.e. six different 'views'). This resulted in an overall total of 30 images. Examples of the 'lips' view, showing TF levels TF0–TF4 are displayed in Fig. 1.

Table 1. The photographic details shown in each of the five 'distance' views used in the study, with the size of the upper incisor progressively decreasing to simulate increasing viewing distance

Image name	Features	On-screen size of upper central incisor
D0 ('teeth' view)	Teeth (retracted)	17 mm
D1 ('lips' view)	Teeth and lips (nonretracted)	17 mm
D2	Nose and lips	14 mm
D3	Eyes and chin	11 mm
D4	A smaller view of eyes to chin	8 mm
D5 (master)	The full face	5 mm

The images were loaded on to a website, designed to present the photographs in a different random order to each participant. Basic demographics, i.e. age and gender, were collected on the first webpage. Subsequently, for each separate-paged image, the viewer was asked to complete two questions, as used previously (15). The first involved rating the appearance of the teeth as 'highly acceptable', 'acceptable', 'unacceptable' or 'highly unacceptable'. In the second question, viewers were asked to indicate whether or not they would request treatment if their teeth had such an appearance. For each question, participants had to click on the chosen response and were unable to move on to the next image until both answers were complete.

The study participants were third-year pupils ($n = 239$) from a Glasgow secondary school. They were aged between 14 and 15 years, thereby allowing comparison with the Manchester-based study by Hawley et al. (15). The pupils completed the survey during their technology classes, over the course of 1 week. A tutorial was given by the

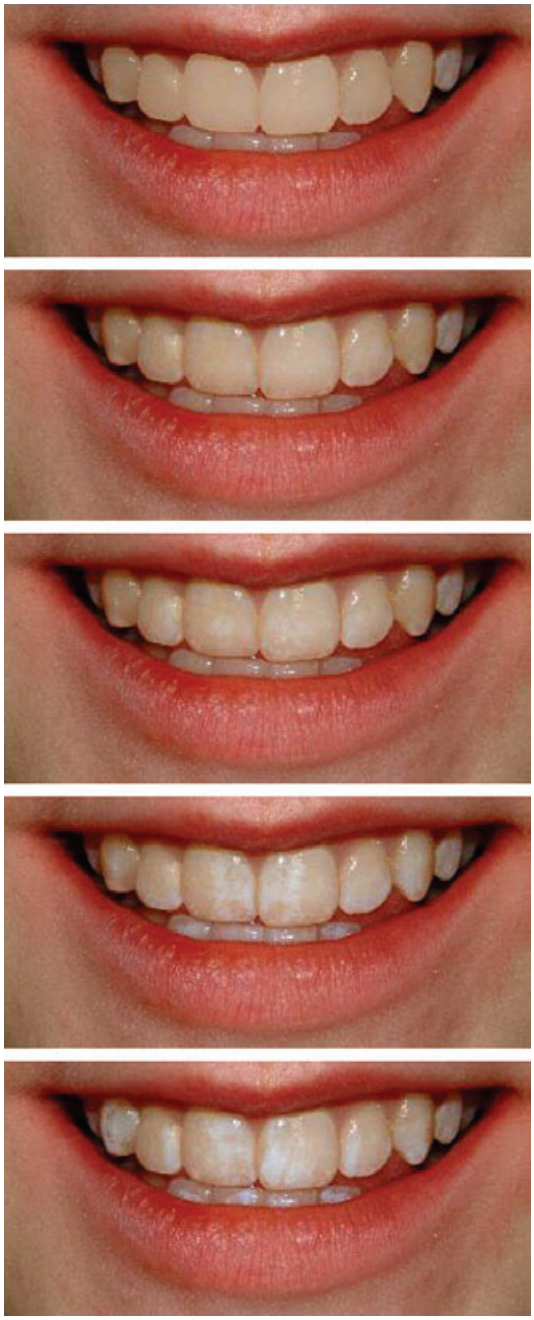

Fig. 1. Examples of the 'lips' images, showing fluorosis levels TF0 to TF4.

principal investigator, explaining that the same face had been used throughout the study, and that the 'marks' seen on the teeth 'could not be rubbed or brushed off'. Pupils were then asked to log-on to the website, displaying the photographs of normal and fluorotic teeth. Each monitor was of the same standard size, and pupils were requested to sit a constant distance from the monitor during the exercise. In order to check the reproducibility of this new methodology, six images (20% of the total) were chosen at random to be incorporated twice within the survey. This brought the total number of images to 36, which were then viewed by 5% of the study population. The responses were sent automatically by e-mail to the investigator, before being transferred to a spreadsheet (Microsoft Excel) for analysis.

To obtain a mean acceptability score for each image, each of the four acceptability response categories was allocated a mid-quartile numerical value, from a 'highly acceptable' value of 0.875 to a 'highly unacceptable' value of 0.125. For each image, within each acceptability category, the mid-quartile value was multiplied by the number of responses. The resulting four category scores were then summed and divided by the overall total number of responses, to give a mean score for each image.

Data analyses

Graphs and tables of the data were plotted using Microsoft Excel. Initial comparisons of the 'lips' and 'teeth' views, which represented the same 'distance', were undertaken at each TF level using paired *t*-tests, with a Bonferroni correction applied to take account of multiple significance testing.

Then, repeated-measures ANOVA was employed, initially to investigate the effect of the two factors of fluorosis severity and 'distance', and any interaction between them. Subsequent ANOVA calculations were then carried out on the factors separately, first to compare different TF levels at the same 'distance', and then to compare the same TF level at different 'distances'. Follow-up Bonferroni comparisons were used to show the statistically significant differences. The relationship between acceptability and treatment need was investigated by cross-tabulating the data, with one table for each TF level/'distance'.

Results

A total of 217 of 239 pupils responded (90%; 99 males and 118 females). The average age was 14 years 10 months, with a range from 14 years 4 months to 15 years 5 months.

For the reproducibility exercise, 11 pupils (5% of the study population) viewed six duplicate images randomly among the other 30 images. Of the 66 duplicate responses, 44 (67%) showed total agreement, in terms of both choice of acceptability categories and desire for treatment (Table 2), with only 10 responses (15%) having no agreement in

Table 2. Comparisons of the first and second viewings of the same image to show reproducibility

	'HU'		'U'		'A'		'HA'		
Category	Y	N	Y	N	Y	N	Y	N	Totals
'HU'									
Y	**8**		4				2*		14
N									
'U'									
Y	4		**26**		2*				32
N			1						1
'A'									
Y			2*		**2**	1			5
N			4*		1	**8**		1	14
'HA'									
Y									
N									
Totals									**66**

The four response categories of highly unacceptable (HU), unacceptable (U), acceptable (A) and highly acceptable (HA) are shown, along with an indication of desire for treatment, yes (Y) or no (N).
The responses in total agreement are highlighted in bold on the diagonal.
*Responses showing no agreement in terms of acceptability.

terms of acceptability, although six of these agreed on the need for treatment.

Concerning the responses to the first question, when appearance was rated, the results were dichotomized into 'acceptable' and 'unacceptable', as shown in Table 3. For the initial comparisons between the 'teeth' and 'lips' views, the 'lips' pictures showed a higher acceptability than the 'teeth' views, even when no fluorosis was present. Only 62% of pupils found the TF0 'teeth' acceptable, compared with 80% when viewing the TF0 'lips' image ($P < 0.001$).

When first comparing different TF levels at any one 'distance', by and large, as fluorosis increased, acceptability of the appearance fell, e.g. for the 'lips' images, the proportion falling into the 'acceptable' category fell from 80% at TF0 to 11% at TF4 (Table 3). Overall, this trend was noted at the different 'distances' except the furthest (D5), when the teeth formed only a small proportion of the image viewed.

Table 3. Percentage of responses deemed 'acceptable' for each TF level at every distance

	% 'Acceptable'				
Image	TF0	TF1	TF2	TF3	TF4
'Teeth'	62	52	22	9	9
'Lips'/D1	80	56	28	13	11
D2	57	48	28	15	16
D3	53	51	28	21	21
D4	55	37	29	30	22
D5	56	36	42	36	41

The distances range from close-up ('teeth' and 'lips') to further away (D5), while the fluorosis levels extend from TF0 (normal) to TF4 (moderate fluorosis).

The second aspect of the analysis, looking at the impact of simulated 'distance' at any one TF level, used the 'lips' view to represent distance D1. At TF0 and TF1, acceptability decreased as distance increased. However, for more obvious fluorosis (levels TF2, TF3 and TF4), acceptability rose as the viewing 'distance' increased, e.g. only 28% found the TF2 image acceptable at D1, but 42% found the TF2 acceptable at D5 (Table 3).

Mean acceptability scores derived from the mid-quartile values were used in the repeated-measures ANOVA. This found a highly significant interaction between TF and 'distance' ($P < 0.001$), indicating that the differences in mean scores across TF levels were not the same at all distances. Subsequent ANOVA comparisons were then carried out on the factors of TF level and 'distance' separately.

Comparisons, first of different TF levels at each 'distance', are displayed in Fig. 2, with higher values indicating greater acceptability. Again, there was a trend at all 'distances' except D5 for the acceptability score to fall as the TF level increased. Where mean values were compared using ANOVA, all the results were highly significant ($P < 0.001$). Data in Table 4 give the 95% confidence intervals for the pairwise comparisons. Although acceptability decreased as fluorosis increased, the differences in discernment became less marked as the viewing distance increased. While differences were seen at 'distances' D4 and D5, these became significant only in comparisons of more extreme levels of fluorosis.

For the second aspect of comparing different 'distances' (D1–D5) at each TF level, the mean acceptability scores for each image were again used. Figure 3 summarizes the impact of viewing distance and shows that, at the closest 'distance' (D1), there was wide divergence of the data points at each of the TF levels. However, the lines converged as 'distance' increased. Once fluorosis became more marked (TF2–TF4), the trend was such that more distant pictures had a higher acceptability than closer photographs. At the highest TF level (TF4), the closest picture (D1) had a significantly lower score than any of the other 'distances', and the farthest picture (D5) had a significantly higher score than any other. All the ANOVA values were again found to be highly

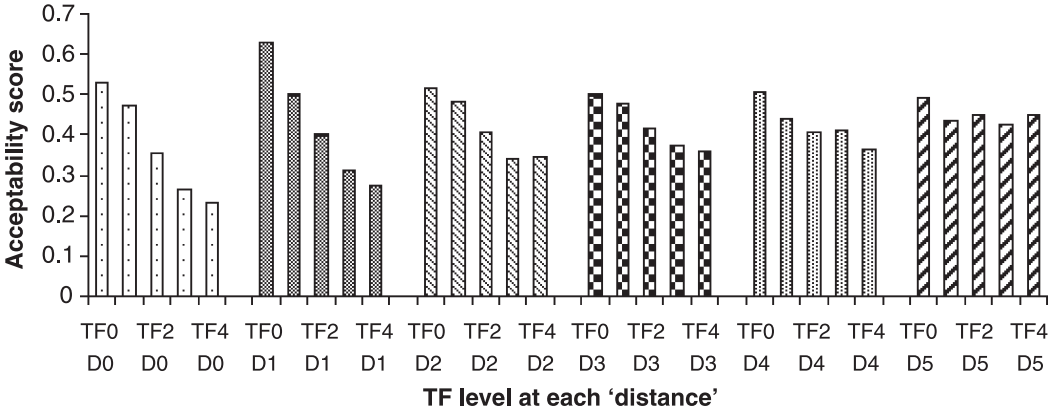

Fig. 2. Comparisons of the mean image acceptability score for the different TF levels at each of the 'distances'. The fluorosis levels extend from TF0 (normal) to TF4 (moderate fluorosis). The different TF levels are shown at each of the 'distances', ranging from close-up (D0, 'teeth'; D1, 'lips') to further away (D5).

Table 4. Results of the 10 pairwise comparisons carried out at each of the six distances, showing the lower and upper levels of the confidence intervals (CI)

	Teeth		Lips (D1) ($P < 0.001$)		D2 ($P < 0.001$)		D3 ($P < 0.001$)		D4 ($P < 0.001$)		D5 ($P < 0.001$)	
Comparisons	CI lower	CI upper	CI lower	CI upper	CI lower	CI upper	CI lower	CI upper	CI lower	CI upper	CI lower	CI upper
TF0 vs.												
TF1	−0.09	−0.01	−0.17	−0.09	−0.07*	0.00*	−0.05*	0.00*	−0.10	−0.03	−0.09	−0.02
TF2	−0.21	−0.13	−0.27	−0.19	−0.15	−0.07	−0.12	−0.05	−0.13	−0.06	−0.08	0.00
TF3	−0.30	−0.22	−0.36	−0.27	−0.21	−0.14	−0.16	−0.09	−0.13	−0.06	−0.10	−0.03
TF4	−0.34	−0.25	−0.39	−0.31	−0.21	−0.13	−0.18	−0.10	−0.18	−0.11	−0.08	−0.01
TF1 vs.												
TF2	−0.16	−0.08	−0.14	−0.06	−0.12	−0.04	−0.10	−0.03	−0.07*	0.00*	−0.02*	0.06*
TF3	−0.25	−0.17	−0.22	−0.14	−0.18	−0.11	−0.14	−0.07	−0.07*	0.00*	−0.05*	0.03*
TF4	−0.29	−0.20	−0.26	−0.18	−0.18	−0.10	−0.16	−0.08	−0.11	−0.04	−0.03*	0.05*
TF2 vs.												
TF3	−0.13	−0.05	−0.12	−0.04	−0.10	−0.03	−0.08	0.00	−0.03*	0.03*	−0.06*	0.01*
TF4	−0.17	−0.08	−0.16	−0.08	−0.10	−0.02	−0.09	−0.02	−0.08	−0.01	−0.04*	0.03*
TF3 vs.												
TF4	−0.08*	0.01*	−0.08*	0.00*	−0.03*	0.04*	−0.05*	0.03*	−0.08	−0.01	−0.02*	0.06*

*Nonsignificant values; all the other values are significant.
The fluorosis levels extend from TF0 (normal) to TF4 (moderate fluorosis), while the distances range from close-up ('teeth' and 'lips') to further away (D5). Some of the confidence intervals, when given to two decimal places, now round to zero, although they remain significant (TF2/TF3 at D3, TF0/TF2 at D5).

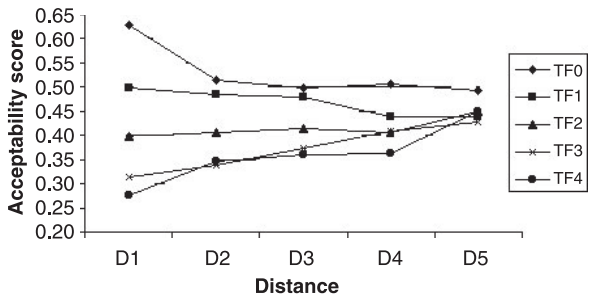

Fig. 3. The mean acceptability score for each image, plotted against 'distance', for each TF series, ranging from TF0 (normal) to TF4 (moderate fluorosis). The 'distances' extend from close-up (D1) to further away (D5).

significant ($P < 0.001$), and the 95% confidence intervals for the pairwise comparisons are tabulated in Table 5.

The desire for treatment closely matched acceptability of the appearance. Those who thought the appearance 'acceptable' tended to respond that they needed no treatment, while those who found the appearance 'unacceptable' mostly indicated they wanted treatment. As shown in Table 6, the level of agreement between the two questions was between 73% and 90% (average 82%).

A space was available at the end of the web survey for participants to make any comments

Table 5. Results of the 10 pairwise comparisons carried out at each of the five TF levels, showing the lower and upper levels of the confidence intervals (CI)

	TF0 ($P < 0.001$)		TF1 ($P < 0.001$)		TF2 ($P < 0.001$)		TF3 ($P < 0.001$)		TF4 ($P < 0.001$)	
Comparisons	CI lower	CI upper	CI lower	CI upper	CI lower	CI upper	CI lower	CI upper	CI lower	CI upper
D1 vs.										
D2	−0.15	−0.07	−0.05*	0.03*	−0.03*	0.05*	−0.01*	0.06*	0.03	0.11
D3	−0.17	−0.09	−0.06*	0.02*	−0.02*	0.05*	0.02	0.09	0.05	0.12
D4	−0.16	−0.08	−0.10	−0.02	−0.03*	0.05*	0.06	0.13	0.05	0.13
D5	−0.18	−0.09	−0.10	−0.02	0.02	0.10	0.08	0.15	0.14	0.21
D2 vs.										
D3	−0.06*	0.02*	−0.05*	0.03*	−0.03*	0.05*	0.00*	0.07*	−0.02*	0.05*
D4	−0.05*	0.03*	−0.09	−0.01	−0.04*	0.04*	0.03	0.11	−0.02*	0.06*
D5	−0.06*	0.02*	−0.09	−0.01	0.01	0.09	0.05	0.12	0.06	0.14
D3 vs.										
D4	−0.03*	0.05*	−0.08	0.00	−0.04*	0.03*	0.00	0.07	−0.04*	0.04*
D5	−0.04*	0.04*	−0.08	0.00	0.00	0.08	0.02	0.09	0.05	0.13
D4 vs.										
D5	−0.05*	0.03*	−0.04*	0.04*	0.01	0.08	−0.02*	0.05*	0.05	0.12

*Nonsignificant values; the rest of the values are significant.
The distances range from close-up (D1) to further away (D5), while the fluorosis levels extend from TF0 (normal) to TF4 (moderate fluorosis). Some of the confidence intervals, when given to two decimal places, now round to zero, although they remain significant (D3/D4 and D3/D5 at TF1).

Table 6. Agreement between acceptability of appearance and desire for treatment

	% Agreement					
TF level	'Teeth'	'Lips'	D2	D3	D4	D5
TF0	83.4	73.3	76.5	76.0	76.0	77.0
TF1	81.1	79.3	79.7	74.2	76.0	79.3
TF2	82.0	81.6	79.3	82.0	81.1	81.6
TF3	90.3	87.6	87.1	84.8	81.6	85.3
TF4	87.6	87.1	87.1	82.5	85.7	81.6

The percentage indicating both 'appearance acceptable' and 'did not want treatment' has been added to the percentage indicating 'appearance unacceptable' and 'did want treatment'.

Table 7. Numbers of comments falling into each of the nine broad categories indicated

Category	Description	Frequency
1	Picture always the same	66
2	Staining/poor oral hygiene	32
3	Boring	21
4	Teeth off-putting	20
5	Face off-putting	13
6	Prompted to think of own teeth	11
7	Miscellaneous	9
8	Interesting	5
9	Impact of distance	5
Total		182

concerning the study. Several broad themes recurred, as shown in Table 7. Most comments indicated confusion as to why the same teeth and face had been used throughout the questionnaire. Many pupils felt the teeth could have been brushed more effectively, while there were others who found any pictures of teeth off-putting. Nonetheless, it was apparent that staining and colour changes were noticed by many of the pupils, and some of the comments indicated that participants had realized the impact of viewing distance.

Discussion

The main aim of this study was to develop a new model, for easy assessment of fluorosis perceptions, including placing teeth within the facial context and establishing the influence of viewing distance. To minimize the effect of varying tooth shape, alignment and facial appearance, this model used digital simulation to maintain baseline characteristics, while changing only the degree of fluorosis presented to the viewer.

One benefit of building up fluorosis 'artificially' was that the underlying colour and reflections of the background tooth were preserved under the 'stencil'. However, it remains that the fluorosis pictures used, although having been transported from naturally occurring images, were not necessarily typical representations of these fluorosis levels. Nevertheless, computer-generated techniques have been used elsewhere (17, 18) and have the distinct advantage of maintaining consistency in factors which may influence aesthetic judgements. The use of a web-based questionnaire allowed it to be administered simultaneously to a number of participants, while the random order of

picture presentation and mandatory fields helped make the methodology more rigorous.

Teenagers were chosen for this investigation, to allow comparison with previous studies, and also because of their awareness of tooth appearances, one study having found the children of this age-group to have greater aesthetic concerns about fluorosis than others (28). The subject used was of the same age as the sample group, hence the aesthetic assessment was being made on a peer, rather than on an individual from another age-group. The study was carried out in an area which had a naturally low water fluoride concentration.

The reproducibility of the process of undertaking a web-based survey with this cohort was satisfactory, with the percentage showing total agreement being 67%. The indication of the 'desire for treatment' also acted, in general, as a check for the validity of the data, as most who found the appearance to be 'unacceptable' indicated their wish for treatment, and vice versa. The use of a mean acceptability score was useful, as it gave a single-figure summary, which could also be used in statistical analysis. The allocation of mid-quartile values was an alternative, but equivalent, method to the more traditional 0, 1, 2, 3 scoring.

The concept of comparing 'teeth' and 'lips' views when assessing public perceptions was felt to be important, as teeth are normally viewed surrounded by the lips, so both views were taken from the same distance, the only difference being the use of retractors. Although dentists may be familiar with standard intra-oral views, these may fail to give representative feedback from lay people, as it was clear from many of the pupils' comments that the images of teeth were distasteful. Thus, the mere addition of lips to the 'teeth' image increased the acceptability of dental appearance significantly when comparing the 'teeth' and 'lips' views. This was noticeable even when no fluorosis was present, although at each of the TF levels, acceptability for the nonretracted 'lips' pictures was higher. Thus, the severity of fluorosis can appear less when the teeth affected are surrounded more naturally with soft tissue, perhaps due in part to the shadow created by the lips. Therefore, this result may question the findings of previous fluorosis aesthetic research, where lay observers have been asked to comment only on lip-retracted images (13–16).

As found in previous studies (14, 15), it is clear that the present lay observers were able to distinguish between different levels of fluorosis when shown photographs of teeth. However, the acceptability of the 'teeth' view showing TF0, at only 62%, was found to be lower than that in previous studies, where around 70% of subjects judged nonfluorosed teeth to be acceptable (15, 20, 22, 26). Acceptability fell as fluorosis increased for the 'teeth' images, especially when fluorosis became more severe (TF3 and TF4). Even at D4, when the central incisors measured only 8 mm on-screen, 50% of subjects scored TF0 as 'acceptable', compared with only 20% at TF4. This finding was entirely in keeping with the results of other studies where either pictures were viewed (15) or where parental opinions were sought (20, 22).

When TF comparisons were made at each 'distance', a similar pattern of lower acceptability with more severe fluorosis continued to be evident, and many significant differences were noted. Previous fluorosis studies have used methods other than simply viewing intra-oral pictures (26, 27). One such investigation, which showed the subject's face *in toto* by viewing 'live' patients at a conversational distance (26), found that the proportion who thought dental appearance pleasing, fell as the TF level increased. Another study (27) did not specify its viewing distance, but noted that moderate or severe hypomineralization (TF2–5) was a greater aesthetic stimulus than mild hypomineralization (TF1). Nonetheless, the current project is the first to elucidate that TF levels can be distinguished at a variety of predetermined 'distances'.

To test the hypothesis that, although acceptability might fall as fluorosis worsened, fluorosed teeth might become more acceptable as the viewing distance increased, teeth were viewed within the face as a whole, as recommended by a previous investigator (14). The current finding that teeth which had previously been 'unacceptable' became 'acceptable' as viewing 'distance' increased, had not been described before. This showed that tooth markings which had previously been discernible became less noticeable as they are seen from further away. Crucially, this trend was particularly evident for higher levels of fluorosis (TF2 and over), where it might have been expected that mottling presence would be evident regardless of distance.

In the recent past, there has been progression in fluorosis research, from gaining only a professional assessment, to the seeking of lay opinions. However, if these judgements are made using close-up photographs, such images may adversely affect aesthetic decisions. Teeth are always seen by the

public in the context of the face, and this research has highlighted the importance of tooth size and surrounding features in such judgements. However, additional studies could help determine further the threshold distance at which 'unacceptability' turns to 'acceptability' at different levels of fluorosis.

The question regarding 'desire for treatment' had previously been shown (15) to match closely the unacceptability of the appearance – a result reflected here. Even at the various distances used in the current investigation, the proportion expressing a desire for treatment continued to show good agreement with the proportion stating dissatisfaction with appearance. However, increasing the viewing distance lessens the negative impact of fluorosis, with fewer claiming that treatment was necessary.

The pupils' feedback was extremely useful, revealing that they believed the 'marks' on the teeth to be due to poor oral hygiene, despite a preliminary tutorial which indicated this was not the case. Another determinant highlighted by the comments, which could influence aesthetic judgements made at the greater distances, is the actual facial appearance of a subject. Further research could utilise several model faces with the same fluorosis patterns to study any effect of facial appearance on fluorosis assessment.

Conclusions

This newly developed model, designed to assess public perceptions of fluorosis, has shown that teenagers are indeed able to discriminate between different levels of fluorosis, even at a variety of distances. However, more crucially, it has been found that fluorosis can be detected less readily from a distance. This may be due to a decrease in the size and contrast of the fluorosis pattern as distance increases, or simply be the effect of viewing the teeth within the context of the face, when other features may cause more distraction. Therefore, dental aesthetic judgements should also be considered from a distance, with tooth appearance judged within the whole facial context, as would occur in normal social interaction. Hence, previous studies (13–16) which have shown fluorosis to be aesthetically unacceptable should be interpreted with caution, as these teeth may have been viewed under artificial conditions.

Acknowledgements

The authors wish to thank Mr Robert McKerlie for his help in designing the website for this project.
They would also like to thank the subject who agreed to act as the model face.

References

1. Leverett D. Prevalence of dental fluorosis in fluoridated and non-fluoridated communities – a preliminary investigation. J Public Health Dent 1986;46:184–7.
2. McDonagh M, Whiting P, Bradley M, Cooper J, Sutton A, Chestnutt I, et al. A Systematic Review of Public Water Fluoridation. York: NHS Centre for Reviews and Dissemination, University of York; 2000.
3. Centers for Disease Control and Prevention. Recommendations for using fluoride to prevent and control dental caries in the United States. MMWR Recomm Rep 2001; 50:30. (RR-14).
4. Medical Research Council. Water Fluoridation and Health, Working Group Report. London: Medical Research Council; 2002.
5. de Liefde B, Herbison GP. Prevalence of developmental defects of enamel and dental caries in New Zealand children receiving differing fluoride supplementation. Community Dent Oral Epidemiol 1985;13:164–7.
6. Milsom K, Mitropoulous CM. Enamel defects in 8-year-old children in fluoridated and non-fluoridated parts of Cheshire. Caries Res 1990;24:286–9.
7. Clarkson J. A review of the developmental defects of enamel index (DDE Index). Int Dent J 1992;42:411–26.
8. Heifetz SB, Driscoll WS, Horowitz HS, Kingham A. Prevalence of dental caries and dental caries in areas of optimal and above-optimal water fluoride concentrations: a 5-year follow-up study. J Am Dent Assoc 1988;116:490–5.
9. Horowitz HS, Driscoll WS, Meyers RJ, Heifetz SB, Kingman A. A new method for assessing the relevance of dental fluorosis – the Tooth Surface Index of Fluorosis. J Am Dent Assoc 1984;109:37–41.
10. Osuji OO, Leake JL, Chipman ML, Nikiforuk G, Locker D, Levine N. Risk factors for dental fluorosis in a fluoridated community. J Dent Res 1988;67:1488–92.
11. Cochrane JA, Ketley CE, Arnadottir IB, Fernandes B, Koletsi-Kounari H, Olia A-M, et al. A comparison on the prevalence of fluorosis in 8-year-old children from seven European study sites using a standardized methodology. Community Dent Oral Epidemiol 2004;32:28–33.
12. Thylstrup A, Fejerskov O. Clinical appearance of dental fluorosis in permanent teeth in relation to histologic changes. Community Dent Oral Epidemiol 1978;6:315–28.
13. Stephen KW, McCall DR, Gilmour WH. Incisor enamel mottling prevalence in child cohorts which had or had not taken fluoride supplements from 0–12 years of age. Proc Finn Dent Soc 1991;87:595–605.

14. Clark DC. Evaluation of aesthetics for the different classifications of the Tooth Surface Index of Fluorosis. Community Dent Oral Epidemiol 1995;23:80–3.
15. Hawley GM, Ellwood RP, Davies RM. Dental caries, fluorosis and the cosmetic implications of different TF scores in 14-year-old adolescents. Community Dent Health 1996;13:189–92.
16. McKnight CB, Levy SM, Cooper SE, Jakobsen JR. A pilot study of esthetic perceptions of dental fluorosis vs. selected other dental conditions. J Dent Child 1998;65:233–8.
17. McKnight CB, Levy SM, Cooper SE, Jakobsen JR, Warren JJ. A pilot study of dental students' esthetic perceptions of computer-generated mild dental fluorosis compared to other conditions. J Public Health Dent 1999;59:18–23.
18. Levy SM, Warren JJ, Jakobsen JR. Follow-up study of dental students' esthetic perceptions of mild dental fluorosis. Community Dent Oral Epidemiol 2002; 30:24–8.
19. Clarkson JJ, O'Mullane DM. Prevalence of enamel defects/fluorosis in fluoridated areas and non-fluoridated areas in Ireland. Community Dent Oral Epidemiol 1992;20:196–9.
20. Clark DC, Hann HJ, Williamson MF, Berkowitz J. Aesthetic concerns of children and parents in relation to different classifications of the Tooth Surface Index of Fluorosis. Community Dent Oral Epidemiol 1993;21:360–4.
21. Fyffe HE, Deery C, Pitts NB. Developmental defects of enamel in regularly attending adolescent patients in Scotland; prevalence and patient awareness. Community Dent Health 1996;13:76–80.
22. Lalumandier JA, Rozier RG. Parents' satisfaction with children's tooth color: fluorosis as a contributing factor. J Am Dent Assoc 1998;129:1000–6.
23. Stephen KW. Fluoride prospects for the new millennium – community and individual patient aspects. Acta Odontol Scand 1999;57:352–5.
24. Milsom KM, Tickle M, Jenner A, Peers A. A comparison of normative and subjective assessment of the child prevalence of developmental defects of enamel amongst 12-year-olds living in the North West Region, UK. Public Health 2000;114:340–4.
25. Sigurjons H, Cochrane JA, Ketley CE, Holbrook WP, Lennon MA, O'Mullane DM. Parental perceptions of fluorosis among 8-year-old children living in three communities in Iceland, Ireland and England. Community Dent Oral Epidemiol 2004;32:34–8.
26. Riordan PJ. Perceptions of dental fluorosis. J Dent Res 1993;72:1268–74.
27. Ellwood RP, O'Mullane D. Enamel opacities and dental esthetics. J Public Health Dent 1995;55:171–6.
28. Clark DC, Berkowitz J. The influence of various fluoride exposures on the prevalence of esthetic problems resulting from dental fluorosis. J Public Health Dent 1997;57:144–9.