The use of fibre-optic transillumination in general dental practice

G. M. Davies,[1] H. V. Worthington,[2] J. E. Clarkson,[4] P. Thomas,[5] R. M. Davies[3]

Objective To assess the use of fibre-optic transillumination (FOTI) as a diagnostic tool in general dental practice.
Design A cross-over quantitative study for the diagnosis of approximal carious lesions by two clinical methods with a qualitative component.
Subjects and methods Seven GDPs were trained to use FOTI as an adjunct to their usual clinical examination to diagnose approximal caries. After 12 weeks of use in their practices four of the GDPs took part in two assessment sessions, set a week apart, using 29 volunteer patients. Each patient was examined on two separate occasions by each GDP using either their standard clinical examination technique alone or supplemented by FOTI examination. The order of the techniques was randomised. Radiographs of each patient were also examined separately. An experienced FOTI user also examined the patients to provide a benchmark. From standard charts the number of enamel and dentinal lesions on approximal surfaces was summed and comparisons made between the techniques. Six GDPs took part in one-to-one interviews.
Main outcome measures Mean numbers of carious lesions recorded by each clinician using each technique.
Results There was a trend for all GDPs to find more enamel and dentinal lesions using FOTI, than with their standard clinical examination with or without radiographs. All GDPs found the FOTI technique a useful adjunct. They used FOTI in different ways and found a variety of uses for it other than caries diagnosis.
Conclusions The FOTI technique increased the detection of approximal carious lesions. It was reported to be a useful diagnostic tool in general dental practice. GDPs and staff enjoyed participating in a research project.

The diagnosis of approximal carious lesions, in the absence of cavitation, is often difficult and bitewing radiographs are frequently used to supplement the visual, clinical examination. Recommendations regarding the prescription and timing of bitewing radiography have been made recently[1] but there is still considerable variation in their use between individual dentists and different regions of the country[2]. Radiographs can enhance the detection of approximal lesions[3,4] but there is a need to keep exposure to radiation as low as possible.

[1]Dental Epidemiologist, Mancunian Trust, Mauldeth House, Mauldeth Road West, Manchester, M21 7RL; [2]Reader in Dental Statistics, University Dental Hospital of Manchester, Higher Cambridge Street, Manchester, M15 6FH; [3]Director, Dental Health Unit, Manchester Science Park, Lloyd Street North, Manchester M15 6SH; [4]Senior Lecturer, Dental Health Services Research Unit, Dundee Dental Hospital and School, University of Dundee, Scotland, DD1 4HR; [5]General Dental Practitioner, Maple Road Dental Practice, Manchester M23 9HN
**Correspondence to: G. M. Davies*
REFEREED PAPER
Received 18.01.00; Accepted 26.06.00

FOTI offers an alternative method of diagnosis that can be used to supplement the clinical examination[5]. It is a simple, non-invasive, painless procedure that can be used repeatedly with no risk to the patient. A narrow beam of bright white light is directed across areas of contact between approximal surfaces and the disruption of crystal structure, which occurs in demineralisation, deflects the light beam and produces shadows.

The procedure has been validated histologically and has levels of sensitivity and specificity that exceed those of radiographs[6,7]. This tool has been used in the research field for many years, particularly in clinical trials of anti-caries agents[8,9]. Despite its ability to enhance the diagnosis of approximal lesions, the technique is rarely taught in dental schools or used in general practice in the UK. The study reported here describes how this technology can be transferred from the research field to primary care. Its aim was to assess the use of FOTI as a diagnostic tool in general dental practice.

Method

Eight GDPs, previously involved in an epidemiological study, expressed an interest in participating in this study. At an initial meeting at the Dental Health Unit (DHU), the aims and the organisation of the study were discussed. The GDPs then received an explanation of how FOTI works from a trained and calibrated user. Its use was demonstrated using extracted teeth mounted in sets of four with approximal surfaces contacting. The teeth were chosen to demonstrate a range of approximal carious lesions. Six adults, previously screened and selected by the trainer as having approximal carious lesions suitable for diagnosis by FOTI, were then examined by the GDPs so that they could familiarise themselves with the technique and the appearance of the lesions when transilluminated.

Each GDP was provided with a light source, fibre-optic cable and sufficient probe tips to allow them to use the system in their own practices for a period of three months. They were encouraged to use the FOTI system routinely and the trainer visited each clinician and examined patients with them to ensure that FOTI was being used to maximum advantage.

After three months, four of the GDPs were randomly selected and attended the DHU to take part in two panel assessment exercises to measure the use of FOTI for approximal caries diagnosis. The panel of patient volunteers consisted of 29 adults, selected by the GDPs from among their own patients. Most of these had one or more approximal lesions that the GDPs considered could be diagnosed using FOTI. All 29 patients were examined by the four GDPs and the trainer on two occasions with a week's interval between visits. Using a randomised cross-over design, each GDP examined each patient on one occasion using their usual clinical examination technique and on the other occasion supplementing this with FOTI. Recent bitewing radiographs for each patient were also examined on one occasion by the GDPs in a separate room from the clinical examination. The radiographs were coded so that the GDPs were not aware of the patient's identity.

Table 1 Mean number of approximal enamel lesions found by four GDPs using their usual method of clinical examination with and without FOTI on 29 patients (standard deviations in parentheses)

GDP	Standard clinical examination				Mean difference	P-value
	Without FOTI		With FOTI			
1	1.03	(1.05)	1.66	(1.49)	-0.62	0.02*
2	1.03	(1.05)	1.07	(1.13)	-0.03	0.89
3	0.03	(0.19)	0.07	(0.26)	-0.03	0.57
4	0.66	(0.90)	0.83	(1.20)	-0.17	0.42

*p<0.05

Table 2 Mean number of approximal dentinal lesions found by four GDPs using their usual method of clinical examination with and without FOTI on 29 patients (standard deviations in parentheses)

GDP	Standard clinical examination				Mean difference	P-value
	Without FOTI		With FOTI			
1	0.72	(1.03)	0.76	(1.06)	-0.03	0.75
2	2.21	(2.40)	2.93	(2.52)	-0.72	0.03*
3	0.72	(1.07)	0.90	(1.11)	-0.17	0.28
4	0.45	(0.69)	0.72	(1.25)	-0.28	0.043*

*p<0.05

Table 3 Mean number of approximal enamel lesions found by four GDPs using their usual method of clinical examination of 27 patients with radiographs, with and without FOTI (standard deviations in parentheses)

GDP	Standard clinical examination				Mean difference	P-value
	Without FOTI		With FOTI			
1	1.93	(1.96)	2.44	(2.21)	-0.51	0.02*
2	1.56	(1.53)	1.67	(1.80)	-0.11	0.89
3	0.22	(0.64)	0.33	(0.88)	-0.11	0.57
4	0.93	(1.33)	1.19	(1.55)	-0.26	0.42

*p<0.05

Table 4 Mean number of approximal dentinal lesions found by four GDPs using their usual method of clinical examination of 27 patients with radiographs, with and without FOTI (standard deviations in parentheses)

GDP	Standard clinical examination				Mean difference	P-value
	Without FOTI		With FOTI			
1	2.33	(2.34)	2.41	(2.34)	-0.07	0.33
2	3.22	(3.32)	3.70	(3.18)	-0.48	0.19
3	1.52	(1.74)	1.78	(1.85)	-0.26	0.07
4	1.15	(1.38)	1.44	(1.72)	-0.30	0.043*

*P<0.05

The GDPs were asked to record the position of all enamel and dentinal approximal lesions on modified dental charts, which were translated and coded to allow statistical analysis. Comparisons were made between the mean number of approximal enamel and dentinal lesions found by each clinician using their usual clinical examination technique with and without FOTI. The mean number of lesions found by clinical examination supplemented by radiographs was also compared with the number found using FOTI. A final analysis compared the mean number of lesions found by the GDPs using their clinical examination method supplemented by FOTI and the number found by the trainer using the same methods.

Comparisons between techniques were analysed using paired *t*-tests and kappa statistics quantified the intra-examiner agreement of the trainer.

Finally, a qualitative assessment was made of the practitioner's views on the use of FOTI in their practices. All GDPs involved in the training were telephoned by a member of the project team after the familiarisation period and their responses, together with comments made during the calibration sessions were recorded.

Results

Of the eight GDPs who initially expressed an interest in the study, seven took part in the training and used FOTI equipment in their practices. Six clinicians shared their views about the use of FOTI in telephone interviews. Male and female dentists were involved and the number of years since qualifying ranged from nine to 33 years.

Quantitative phase

A total of 29 patients, provided by the GDPs, attended on both occasions and radiographs were available for 27 of them.

All four GDPs found more approximal enamel and dentinal lesions when using FOTI than when not (Tables 1 and 2). One GDP found statistically significantly more enamel lesions ($p < 0.05$) and two others found statistically significantly more dentinal lesions ($p < 0.05$) when using FOTI. The mean difference in enamel lesions ranged from 0.03 to 0.62 and for dentinal lesions ranged from 0.03 to 0.72 .

When radiographs were used to supplement their standard examination all GDPs detected more enamel and dentinal lesions when FOTI was used (Tables 3 and 4). One GDP found statistically significantly more enamel lesions ($p < 0.05$) and another found statistically significantly more dentinal lesions ($p < 0.05$). The difference between the mean number of lesions detected when FOTI was added to standard examination supplemented with radiographs ranged from 0.11 to 0.51 for enamel lesions and 0.07 to 0.48 for dentinal lesions.

The trainer's intra-examiner agreement for detecting caries using a visual examination together with FOTI was 'high' according to the Landis and Koch classification[10], with weighted kappa statistics ranging from 0.81 to 0.88 (Table 5).

When the mean number of enamel lesions observed by the GDPs and the trainer were compared using the clinical examination and FOTI (Table 6), the difference was statistically significant in two instances ($p < 0.01$). For dentinal lesions (see Table 6) the differences reached statistical significance in three instances ($p < 0.005$) and the same number were significantly different when enamel and dentinal lesions were combined.

Qualitative phase

In the telephone interviews all GDPs reported that they and their staff had enjoyed taking part in the research exercise. *'I enjoyed getting out of the practice and meeting other dentists. The project was well organised and I would do it again. GDPs need partnership in research.'*

All the GDPs were positive about the use of FOTI and most would be willing to purchase the system for their practices if a more compactly designed unit could be manufactured at a reasonable cost.

'Yes, I would buy one. I miss it now it's gone.'

'Yes, if it could be made more compact – a portable would be good in a multiple practice.'

Criticisms of the FOTI system were mainly related to noise of the unit and the cumbersome design. Most would have preferred a light source that was incorporated into the dental unit, perhaps within a handpiece. The tips that guide the light to a very narrow beam and shine it between the teeth were found to be too long. The FOTI tech-

Table 5 Kappa statistics measuring the intra-examiner agreement for the trainer using a visual examination plus FOTI (N=29)

	Kappa	95% CI
Enamel lesions	0.81	(0.67, 0.94)
Dentinal lesions	0.83	(0.67, 0.99)
Both enamel and dentinal lesions	0.88	(0.79, 0.97)

Table 6 Mean number of approximal lesions found by each dentist and the trainer using a clinical examination plus FOTI on the same 29 patients.

GDP	Mean number of enamel lesions	P-value	Mean number of dentinal lesions	P-value	Mean number of enamel and dentinal lesions	P-value
1	1.66 (1.49)	0.01*	0.76 (1.06)	0.005*	2.41 (2.23)	0.65
2	1.07 (1.13)	0.75	2.93 (2.52)	<0.001*	4.00 (2.88)	<0.001*
3	0.07 (0.26)	<0.001*	0.90 (1.11)	0.17	0.97 (1.12)	0.002*
4	0.83 (1.20)	0.47	0.72 (1.25)	<0.001*	1.55 (2.25)	0.005*
Trainer	1.00 (1.13)		1.31 (1.67)		2.31 (2.32)	

P-value comparing each GDP with the trainer
*p<0.05

nique was no help where large approximal restorations prevented the light beam from passing.

When asked what they liked and disliked about the system all the participating GDPs felt it was beneficial to have FOTI as a diagnostic tool. Each cited clinical situations when it was particularly useful to have a quick method of looking at these surfaces without taking radiographs.

'Particularly good for children and regular patients with few fillings.'

'An advantage over x-rays for children and patients who had radiographs six months ago.'

Although the clinicians were encouraged to use the FOTI technique routinely at all examinations most preferred to use it selectively. Some used it to investigate further if their normal examination method had alerted their suspicions about caries activity on a particular surface. This may have prompted the taking of radiographs to confirm FOTI findings. In contrast, some clinicians used FOTI to confirm the appearance of caries found on radiographs. One clinician used it both ways – sometimes to decide whether or not to take radiographs, others to gain more detail about lesions found on radiographs.

Those clinicians who used a probe routinely for tactile information during examination tended not to use FOTI routinely. Those who used visual examination only with air drying were more likely to hold the FOTI probe and use it during routine examination.

'I routinely use a probe and air-dry so I would use FOTI to confirm radiographic findings.'

'I don't use a probe so I would use FOTI routinely.'

'I routinely hold a probe but only use it sparingly, I could imagine the FOTI tip taking its place.'

Some GDPs found alternative uses for the system and these included the identification of cracked cusps and fractures in porcelain crowns and to distinguish between subgingival calculus and caries.

Discussion

FOTI is a valid technique for diagnosing approximal caries so it may have been expected that clinicians, trained and experienced in the technique, would have detected more carious lesions than standard examination alone. This study showed a trend for all GDPs to detect more approximal enamel and dentinal lesions when FOTI was incorporated into the standard clinical examination. In several cases significantly more lesions were found with FOTI. The finding was apparent both with and without the addition of the radiographic assessment. There was poor agreement in the mean number of lesions detected when comparing the four GDPs with the trainer.

The use of FOTI allowed one GDP to detect, on average, 0.62 more carious enamel surfaces whereas two other GDPs only detected 0.03 more surfaces. One GDP was able to detect 0.72 more surfaces that were considered to be carious at the dentinal level. Even with the assistance of radiographs, FOTI enabled one GDP to detect a mean of 0.51 more surfaces with enamel caries and another to detect 0.48 more with dentinal caries.

The variation between the GDPs is not surprising considering the variation in their routine clinical examination methods, the differences in clinical experience and postgraduate training. Some examined using mirror and probe, others used drying and occasional probing while the remainder used drying and visual examination alone. Even with these variations, clear trends were evident with FOTI being a useful adjunct to all examinations.

The panel assessment was designed in a similar way to a calibration exercise for an epidemiological study. The mean number of lesions detected by the trainer, who diagnosed caries according to specific criteria, was between those for the four GDPs. A possible implication of this is reassurance that, despite wide variation in clinical cultures, there is no apparent systematic difference between the two approaches to diagnosis.

The qualitative phase also showed a positive outcome. It showed that the GDPs thought FOTI was a valuable additional technique which they would like to purchase for their practices. They recognised the additional assistance FOTI could give before, after or instead of radiographs. They regarded it as a useful tool in ways that the quantitative phase could not have detected.

A valuable outcome of this research project was the demonstration that GDPs and academic researchers can collaborate and this partnership enabled the design and conduct of high-quality clinical research in primary care. The dental teams involved expressed their enjoyment in both taking part and the learning experience. As more of these joint ventures are undertaken and GDPs acquire more research experience, they will be able to choose their level of participation, ranging from collecting data to being the lead researcher.

The authors wish to thank the University of Manchester Dental Health Unit for its generous assistance in terms of training and surgery facilities and administration. They are thankful for the willing cooperation of the GDPs; Mrs Jill Jagger, Mrs Gill Shea, Mr Terry McHale, Mr Ian Hunt, Mr Scott Rimmer and Mr Don McGrath and their chairside assistants. Similarly they acknowledge the help of the volunteer patients. Dr J Clarkson acknowledges funding from the Scottish Council for Postgraduate Medical and Dental Education and the Scottish Office Department of Health. This project was funded by the Primary Dental Care R&D Programme. The comments and views expressed in this paper are those of the authors and not of the Programme organisers, nor of the author's employers.

1. Faculty of General Dental Practitioners. Radiographs in Dental Caries Diagnosis. Selection Criteria for Dental Radiography 1998 FGDP (UK)
2. Dental Treatment. GDS Quarterly Statistics. January-March 1999. DPB
3. Kidd E A M, Pitts N B. A reappraisal of the value of the bitewing radiograph in the diagnosis of posterior approximal caries. *Br Dent J* 1990; **169**: 195.
4. Pitts N B. Advances in radiographic detection methods and caries management rationale. In Stookey G. *Proceedings of the First Annual Indiana Conference: Early Detection of Dental Caries.* Indiana: Indiana University 1996.
5. Pitts N B. Diagnostic tools and measurements – impact on appropriate care. *Community Dent Oral Epidemiol* 1997; **25**: 24-35.
6. Pine C M. Fibre-optic Transillumination (FOTI) in Caries Diagnosis. In Stookey G. *Proceedings of the First Annual Indiana Conference: Early Detection of Dental Caries.* Indiana: Indiana University 1996.
7. Peers A, Hill F J, Mitropoulos C M, Holloway P J. Validity and reproducibility of clinical examination, fibre-optic transillumination, and bite-wing radiology for the diagnosis of small approximal carious lesions : an *in vitro* study. *Caries Research* 1993; **27**: 307-311.
8. Mitropoulos C M. The use of fibre-optic transillumination in the diagnosis of posterior approximal caries in clinical trials. *Caries Research* 198 ; **19**: 379-384.
9. Mitropoulos C M, Holloway P J, Davies T G H, Worthington H V. Relative efficacy of dentifrices containing 250 or 1,000 ppm F- in preventing dental caries – report of a 32 month clinical trial. *Community Dental Health* 1984; **1**: 193-200.
10. Landis J R, Koch G C. The measurement of observer agreement for categorical data. *Biometrics* 1977; **33**:159-174.