ORIGINAL ARTICLE

International Dental Journal 2013; 63: 97–102

doi: 10.1111/idj.12024

Comparison of laser fluorescence devices for detection of caries in primary teeth

Çağdaş Çınar, Didem Atabek, Mesut E. Odabaş and Ayşegül Ölmez

Department of Pediatric Dentistry, Faculty of Dentistry, Gazi University, Ankara, Turkey.

The aim of this *in vivo* study was to evaluate the performance of fluorescence-based devices in detecting occlusal caries lesions in primary molars compared with conventional methods. Two examiners assessed 44 occlusal surfaces of first and second primary molars in 20 patients using two fluorescence devices: DIAGNOdent (LF) and DIAGNOdent pen (LFpen). Teeth were also assessed by visual examination and bitewing radiograph. Histological examination served as the gold standard after extraction. By using the McNemar test, the sensitivity, specificity, accuracy, and area under the receiver operating curve were calculated as outer enamel (D1), inner enamel (D2) and dentine caries (D3) lesion thresholds. The intra- and inter-examiner reproducibility were calculated using the Cohen's unweighted kappa statistics. At the D1 threshold, the LFpen sensitivity was statistically higher than LF and radiographic examination ($P < 0.001$), whereas there was no statistically significant difference among the groups at the D2 and D3 thresholds ($P > 0.05$). All methods demonstrated the highest sensitivity values at D3. At the D1 and D2 thresholds, there were no significant differences between the LFpen specificity and the other methods. All methods presented similar performance in detecting all lesions considering the area under the receiver operating curve. The LFpen showed better performance than LF. Furthermore, visual examination and the LFpen device seem to be sufficient for detection of occlusal caries in primary molars.

Key words: *Laser fluorescence, caries diagnosis, DIAGNOdent, primary teeth*

INTRODUCTION

Occlusal surfaces are the most susceptible to development of caries. The early diagnosis of caries lesions provides for more efficient arrest thus avoiding operative treatment[1–3]. This process is especially important in deciduous teeth[4]. Deciduous teeth are more susceptible to demineralisation than permanent teeth[5], but permanent teeth have the higher level of caries[6]. Despite the practical and easily applicable methods available to dentists, visual examination, which is subjective, is most frequently used[7]. Visual examination has shown high specificity, and low sensitivity and reproducibility for occlusal caries detection[8,9]. Bitewing radiographs are used together with visual examination to aid diagnosis of occlusal caries[10] but radiographs only detect demineralisation in dentine and not the enamel lesion[11]. Thus, detection of dental caries and their early diagnoses is very difficult when conventional diagnostic methods are used[12]. In view of this, various methods and devices have been developed to detect early caries lesions.

Quantitative detection methods would allow the monitoring of changes in mineral content of caries lesions[1,2,13]. The laser fluorescence system, DIAGNOdent 2095 (LF) (DD2095; KaVo, Biberach, Germany) was introduced in dentistry for the quantitative determination of occlusal caries. The LF device consists of a diode emitting laser light at a wavelength of 655 nm, which is absorbed by the tooth substance. Some of this light is re-emitted as a near-infrared fluorescent light, and changes in the tooth substance related to the caries process are indicated by an increased amount of fluorescent light. This is detected by the instrument and digitally monitored[2,14]. A new KaVo device the DIAGNOdent pen (LFpen) which has the same physical principles as its predecessor was recently introduced. It allows detection of both occlusal and proximal caries[15,16]. Based on the conventional LF device, new tips had to be developed as a result of the different architecture of the new system[15,17].

In primary teeth, the performance of the LF device was evaluated and has demonstrated high reliability in the detection of occlusal caries; its performance was similar to that of visual and radiographic

examinations[12,18]. The aim of this study was to compare the efficiency of the two LF systems with two conventional methods for detection of occlusal caries in primary teeth.

MATERIALS AND METHODS

This study was approved by the Ethics Committee of the Faculty of Dentistry, Gazi University. The study was conducted in full accordance with the World Medical Association Declaration of Helsinki.

The study sample consisted of 9- to 11-year-old children. Twenty children were selected from the patient population at the Gazi University, Faculty of Dentistry, Department of Paediatric Dentistry, Ankara, Turkey. The children were healthy and cooperative. Forty-four occlusal sites were selected for this study from first and second primary molars in the final process of exfoliation or with extraction indicated for orthodontic reasons. Teeth with any restoration, fissure sealants or fissures with brownish pigments were excluded from the study. Written informed consent was obtained from parents or guardians before the start of the examinations.

Teeth were assessed by visual examination, bitewing radiograph and LF devices in the selected sites. Examinations were carried out for each individual from the sample on the same day independently by two experienced paediatric dentists with no communication between them. Digital photographs were taken and selected sites were marked in the photographs.

All assessment with visual examination and LF were performed twice each by the same examiners with a 2-week interval between measurements. Before the visual examination and LF, the teeth were professionally cleaned with non-fluorescent paste (Nupra Fine Mint; Dentsply, York, PA, USA).

Visual examination was performed with the patient positioned in a dental unit with the aid of dental light, oil-free air/water spray and dental mirror using the criteria[19] shown in *Table 1*.

Bitewing radiographs were taken for all teeth selected. The radiographic films (Ekstraspeed Plus; Kodak, Rochester, NY, USA) were held by Kwik-biteH film holders (Kwik-bite; Hawe Neos Dental, Bioggio, Switzerland). The X-ray machine was set at 70 kV, 8 mA and the exposure time was set at 0.25 s. Radiographs were developed in an automatic film processor (Velopex, Extra-X; Medivance Instruments, London, UK) with fresh solution. The film radiographs were examined in a masked light box and a 2× magnification x-viewer (Luminosa; CSN Industrie, Cinisello Balsamo, Italy) by examiners independently under constant conditions. The radiographic appearance is classified[19] in *Table 1*.

The test sites were assesed using two laser fluorescence devices: LF (DIAGNOdent 2095; KaVo) and LFpen (DIAGNOdent 2190; KaVo). Devices were calibrated using the ceramic standard provided by the manufacturer. The teeth were isolated with cotton rolls and air-dried. The fluorescence value of a sound spot on the coronal part of the buccal surface (zero value) was then recorded for later subtraction from the peak value. For measurements, tip A (for the LF) and cylindrical sapphire fibre tip for occlusal surfaces (for the LFpen) were used. The device was placed perpendicularly to the test site and turned around until the highest value was recorded. The presence or absence of occlusal caries was determined using the manufacturer's suggested cut-off points, as shown in *Table 2*.

After the examinations, the teeth were extracted within a maximum period of 30 days. The teeth were sectioned bucco-lingually in approximately 400 μm thick sections (Mecatome T201; Presi, Grenoble, France) for histological assessment. Sections were serially ground wet on 600–1200 grit silicon carbide paper before being assessed on both sides regarding the presence or absence of caries and the depth of the lesions using a microscope at a magnification of ×16 by two observers. Sites were assessed for caries extension and classified[19] in *Table 1*.

Table 1 Criteria used for visual and radiographic examination and actual lesion depth

Score	Visual examination	Radiographic examination	Lesion depth
0	No or slight change in enamel translucency after prolonged air (> 5 s)	No radiolucency visible	No enamel demineralisation or a narrow surface zone of opacity
1	Opacity or white and brown discoloration hardly visible on the wet surface, but distinctly visible after air drying	Radiolucency visible in the enamel	Enamel demineralisation limited to the outer 50% of the enamel layer
2	Opacity or white and brown discoloration distinctly visible without air drying	Radiolucency visible in the dentine but restricted to the outer third of the dentine	Demineralisation involving between 50% of the enamel and 1/3 of dentine
3	Localised enamel breakdown in opaque or discoloured enamel and/or grayish discolouration from the underlying dentine	Radiolucency extending to the middle third of dentine	Demineralisation involving the middle one-third of dentine
4	Cavitation in opaque or discoloured enamel exposing the dentine	Radiolucency in the pulpal third of dentine	Demineralisation involving the inner one-third of dentine

Table 2 Manufacturer's selected cut-off points for the LF measurements

Score	LF	LFpen	Criteria
0	0–5	0–13	No demineralisation – sound
1	6–14	14–20	Outer enamel demineralisation
2	15–20	21–29	Inner enamel demineralisation
3	21–99	>30	Dentin demineralisation

LF, DIAGNOdent 2095; LFpen, DIAGNOdent 2190.

Statistical analysis

Sensitivity, specificity, accuracy, and area under the receiver operating characteristic (ROC) curve A_z were calculated for each method at three different thresholds: outer enamel (D1), inner enamel (D2) and dentine (D3).

Data analysis was performed by using SPSS for Windows, version 11.5 (SPSS Inc., Chicago, IL, USA). The intra- and inter-examiner reproducibility were calculated using Cohen's unweighted kappa test considering all of the scores of visual examination and radiographic methods or values of the LF and LFpen readings. Coefficients of kappa over 0.75 were considered to be excellent, 0.40–0.75 as fair to good, and below 0.40 as poor. The optimal cut-off point of alternative assessments to discriminate groups regarding histopathology (the gold standard) was evaluated by ROC analysis as giving the maximum sum of sensitivity and specificity for the significance test. Diagnostic performances (i.e. sensitivity, specificity and accuracy) of alternative assessments regarding histopathology were also calculated. Statistical significance of differences between diagnostic methods regarding sensitivity, specificity and accuracy were evaluated by a McNemar test. A P value of < 0.05 was considered statistically significant.

RESULTS

Histological evaluation revealed that from 44 selected sites, 11 teeth were sound (score 0), 12 had demineralisation limited to the outer 50% of the enamel (score 1), 12 teeth had demineralisation involving 50% of the enamel and one-third of dentine (score 2), eight teeth had demineralisation involving the middle one-third of dentine (score 3) and only one tooth had demineralisation involving the inner one-third of dentine (score 4).

Sensitivity, specificity, accuracy, and A_z are shown in *Table 3*. The highest sensitivity values were observed for LFpen, LF and visual examination at the D3 thresholds. The LFpen also showed the highest sensitivity values at the D2 threshold. While bitewing radiographs presented the lowest values of sensitivity at the D2 and D3 thresholds, LF showed lowest values at the D1 threshold. The LFpen and visual examination showed similar sensitivity and specificity values at the D3 thresholds. The McNemar square test showed that LFpen sensitivity was statistically higher than LF and radiography at the D1 threshold ($P < 0.001$), and that there was no statistically significant difference compared with all methods at the D2 and D3 thresholds ($P > 0.05$). There were no statistically significant differences between LFpen specificity compared with the other methods at the D1 and D2 thresholds ($P > 0.05$). The LFpen showed the highest accuracy values at the D2 thresholds. Considering the AUC, all methods demonstrated similar performance in detecting all lesions (D1, D2, and D3).

Kappa values for intra- and inter-examiner agreement are shown in *Table 4*. The reproducibility was excellent for all diagnostic methods by two examiners. In addition, inter-examiner agreement was excellent for all diagnostic methods.

DISCUSSION

Visual examination and bitewing radiographs have long been used to detect occlusal caries lesions[20]. The subjectivity of these methods and their limitations in monitoring the progression of the caries process has led to the development of new quantitative technologies[20]. In this study, fluorescence-based devices were tested in order to compare their findings with those from visual and radiographic examinations in primary teeth. The first LF device used generally in clinical

Table 3 Sensitivity, specificity, accuracy and A_z values at D_1, D_2 and D_3 thresholds. D_1, 0 = sound, 1–4 decayed; D_2, 0–1 = sound, 2–4 = decayed; D_3, 0–2 = sound, 3–4 = decayed

	Sensitivity			Specificity			Accuracy			A_z		
	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
Visual inspection	0.848^{a}	0.857^{a}	1.000^{a}	0.818^{a}	0.870^{a}	0.400^{a}	0.841^{a}	$0.864^{a,b}$	0.523^{a}	0.891^{a}	0.900^{a}	0.797^{a}
Radiography	$0.697^{a,b}$	0.762^{a}	0.889^{a}	0.818^{a}	0.609^{a}	0.514^{a}	$0.728^{a,b}$	0.682^{b}	0.591^{a}	0.814^{a}	0.766^{a}	0.737^{a}
LF	0.545^{b}	0.952^{a}	1.000^{a}	1.000^{a}	0.783^{a}	0.743^{b}	0.659^{b}	0.864^{a}	0.796^{b}	0.836^{a}	0.913^{a}	0.871^{a}
LFpen	0.848^{a}	1.000^{a}	1.000^{a}	0.818^{a}	0.870^{a}	$0.571^{a,b}$	0.841^{a}	0.932^{a}	$0.660^{a,b}$	0.833^{a}	0.941^{a}	0.795^{a}

A_z, area under the receiver operating characteristic curve.
D1, outer enamel; D2, inner enamel; D3, dentine; LF, DIAGNOdent 2095; LFpen, DIAGNOdent 2190.
Different superscript letters show statistically significant differences between diagnostic methods ($P < 0.05$).

Table 4 Kappa values of intra- and inter-examiner reproducibility for each diagnostic system

	Visual inspection	Radiography	LF	LFpen
Examiner 1	0.97	0.81	0.80	0.88
Examiner 2	0.84	0.80	0.92	0.87
Examiner 1 versus examiner 2	0.76	0.75	0.75	0.87

LF, DIAGNOdent 2095; LFpen, DIAGNOdent 2190.

studies has shown similar performance in both primary and permanent teeth[18,21,22]. Matos *et al.*[22] stated that although the first LF device works using the same principle as the new LFpen, its performance in primary teeth should also be better than in permanent teeth. These differences could be explained in that primary and permanent teeth have different morphological characteristics. The enamel of primary teeth has about half the thickness of permanent teeth. Some areas present prismless enamel, and the mineral content of primary enamel is relatively lower than in permanent teeth. Therefore, the performance of the laser system could be affected by these differences[4,22]. In their study, Rodrigues *et al.*[23] compared the performance of the first LF device for detection of occlusal caries in permanent and primary teeth. They stated that the LF device might be a useful adjunct to conventional methods for the detection of occlusal caries. They also expressed that, for primary teeth, considering their differences from the permanent dentition, further *in vitro* and *in vivo* studies should be carried out to fully test this device.

The combination of visual examination and bitewing radiography could improve the correct diagnosis of dentine caries in permanent teeth[24]. The combination of visual examination and bitewing radiography has also led to correct classification of second primary molars as being without either enamel or dentine caries[25]. However, when compared with careful visual examination, bitewing radiography seems to be inadequate in the detection of enamel caries included within a sound surface[26]. In our study, bitewing radiography showed lower sensitivity than the visual examination at all thresholds and there was a statistical difference between visual examination and bitewing radiography at the D1 threshold. As expected, detection of enamel caries lesions is very difficult using radiography alone[19].

An ideal diagnostic method should offer high sensitivity and high specificity in the detection of caries. However, these conditions are difficult to achieve with available methods[4]. Visual examination and the LFpen provided a higher sensitivity and specificity in the detection of caries lesions in primary molars. There were no statistical differences between the visual examination and the LFpen. When visual examination is performed in clean and dried teeth, the method can detect early enamel lesions more judiciously[20,27]. Therefore, the LFpen would not have any advantages over visual examination. Novaes *et al.*[20] reported that visual examination presented higher sensitivity than the other methods in detecting initial enamel lesions. At the D1 threshold, the visual examination showed positive performance, as expressed in accuracy (0.841) and A_z (0.891). A previous study reported that, similar to our findings, visual examination gave the same values[20]. Rocha *et al.*[18] stated that the result is probably due to examiners' training and simpler morphology of primary molars. As our results demonstrated, the LFpen has shown higher values than the LF, and there was a statistical difference between the two LF devices. In contrast to our results, Neuhaus *et al.*[28] and Novaes *et al.*[20] reported that LF and the the LFpen had similar results, showing no significant difference in the values of sensitivity at the D1 thresholds.

The LFpen device showed a good performance at D2 threshold, expressed in accuracy (0.932) and A_z (0.941). We observed that the earlier the caries lesions, the worse the performance of the LFpen. Thus, the performance at inner enamel caries was better than at early enamel caries. Mendes *et al.*[3] stated that performance of the first LF device in detecting early enamel caries lesions is worse than detection of advanced enamel caries lesions on the smooth surface of primary teeth. The different optimal cut-off values were used for LF and the LFpen. We found that the LFpen, when measuring only the D2 threshold, had higher specificity values when compared with the LF device. This means that the LFpen gave fewer false positives at the D2 threshold when compared with the LF device. In addition, sensitivity was mostly better with the LFpen. It is obvious that these values are dependent upon the chosen cut-off values. The performance of LF could depend on the cut-off points for device readings. These can potentially explain the different results found in the literature, as there are great variations regarding adopted cut-off points[18]. In our study, we have chosen to use the manufacturer's suggested cut-off points. Considering that a rise in the proportion of false positives can be dangerous, as it can lead to overtreatment, a technique that offers high specificity, even at the expense of a reduction in sensitivity, seems to be more appropriate[17]. At the D2 threshold, the sensitivity and specificity of the LFpen were not significantly different from that of visual examination, radiography and LF.

At the D3 threshold, all methods showed good and similar performances. In general, all methods presented the highest sensitivity values and there were no significant differences among the diagnostic methods.

The specificity of the LFpen was not significantly different from that of visual examination, radiography and LF. These results could prove the importance of detailed visual examinations. However, in our study, the specificity values of the LFpen were lower than in other *in vivo*[22] and *in vitro* studies[20].

The A_z values confirmed the good performance of all diagnostic methods in detecting occlusal caries in primary molars. The bitewing radiographs showed the lowest values, which was was similar to results in previous studies[28]. In our study, visual examination and the LFpen device showed the highest A_z values at all thresholds when compared with the other methods. However, there were no statistical differences between all diagnostic methods. Burin *et al.*[29] stated that there was no statistical difference in A_z among LF, visual examination and radiographic examination.

A diagnostic tool should be reliable and valid and inter-examiner reliability is an important factor in this[30]. In addition, the experience of examiners may effect intra- and inter-examiner agreement. The values obtained were lower than reported by Kavvadia & Lagouvardos[12]. The LFpen showed the highest values for inter-examiner reproducibility and kappa values for intra- and inter-examiner agreement were close to the values found by Neuhaus *et al.*[28] and Novaes *et al.*[20].

It can be concluded that, for detection of occlusal caries in primary molars, the LFpen performs better than LF. In addition, the LFpen had similar results when compared with visual examination. Furthermore, visual examination and the LFpen device appear to be adequate for clinical practice.

Acknowledgement

We thank the Scientific Research Foundation of the University of Gazi; Number: 03/2009-01.

Conflict of interest

None declared.

REFERENCES

1. Shi XQ, Tranaeus S, Angmar-Mansson B. Validation of DIAGNOdent for quantification of smooth-surface caries: an *in vitro* study. *Acta Odontol Scand* 2001 59: 74–78.
2. Pinelli C. Campos Serra M, de Castro Monteiro Loffredo L. Validity and reproducibility of a laser fluorescence system for detecting the activity of white-spot lesions on free smooth surfaces *in vivo*. *Caries Res* 2002 36: 19–24.
3. Mendes FM, Siqueira WL, Mazzitelli JF *et al.* Performance of DIAGNOdent for detection and quantification of smooth-surface caries in primary teeth. *J Dent* 2005 33: 79–84.
4. Lussi A, Francescut P. Performance of conventional and new methods for the detection of occlusal caries in deciduous teeth. *Caries Res* 2003 37: 2–7.
5. Shellis RP. Relationship between human enamel structure and the formation of caries-like lesions *in vitro*. *Arch Oral Biol* 1984 29: 975–981.
6. Helm S, Helm T. Correlation between caries experience in primary and permanent dentition in birth-cohorts 1950–70. *Scand J Dent Res* 1990 98: 225–227.
7. Braga MM, de Benedetto MS, Imparato JC *et al.* New methodology to assess activity status of occlusal caries in primary teeth using laser fluorescence device. *J Biomed Opt* 2010 15: 047005.
8. Lussi A, Imwinkelried S, Pitts N *et al.* Performance and reproducibility of a laser fluorescence system for detection of occlusal caries *in vitro*. *Caries Res* 1999 33: 261–266.
9. Toraman Alkurt M, Peker I, Deniz Arisu H *et al. In vivo* comparison of laser fluorescence measurements with conventional methods for occlusal caries detection. *Lasers Med Sci* 2008 23: 307–312.
10. Lussi A. Comparison of different methods for the diagnosis of fissure caries without cavitation. *Caries Res* 1993 27: 409–416.
11. Ricketts D, Kidd E, Weerheijm K *et al.* Hidden caries: what is it? Does it exist? Does it matter? *Int Dent J* 1997 47: 259–265.
12. Kavvadia K, Lagouvardos P. Clinical performance of a diode laser fluorescence device for the detection of occlusal caries in primary teeth. *Int J Paediatr Dent* 2008 18: 197–204.
13. Mendes FM, Nicolau J. Utilization of laser fluorescence to monitor caries lesions development in primary teeth. *J Dent Child (Chic)* 2004 71: 139–142.
14. Sheehy EC, Brailsford SR, Kidd EA *et al.* Comparison between visual examination and a laser fluorescence system for *in vivo* diagnosis of occlusal caries. *Caries Res* 2001 35: 421–426.
15. Krause F, Jepsen S, Braun A. Comparison of two laser fluorescence devices for the detection of occlusal caries *in vivo*. *Eur J Oral Sci* 2007 115: 252–256.
16. Lussi A, Zimmerli B, Hellwig E *et al.* Influence of the condition of the adjacent tooth surface on fluorescence measurements for the detection of approximal caries. *Eur J Oral Sci* 2006 114: 478–482.
17. Lussi A, Hellwig E. Performance of a new laser fluorescence device for the detection of occlusal caries *in vitro*. *J Dent* 2006 34: 467–471.
18. Rocha RO, Ardenghi TM, Oliveira LB *et al. In vivo* effectiveness of laser fluorescence compared to visual inspection and radiography for the detection of occlusal caries in primary teeth. *Caries Res* 2003 37: 437–441.
19. Ekstrand KR, Ricketts DN, Kidd EA. Reproducibility and accuracy of three methods for assessment of demineralization depth of the occlusal surface: an *in vitro* examination. *Caries Res* 1997 31: 224–231.
20. Novaes TF, Matos R, Gimenez T *et al.* Performance of fluorescence-based and conventional methods of occlusal caries detection in primary molars – an *in vitro* study. *Int J Paediatr Dent* 2012 22: 459–466.
21. Lussi A, Megert B, Longbottom C *et al.* Clinical performance of a laser fluorescence device for detection of occlusal caries lesions. *Eur J Oral Sci* 2001 109: 14–19.
22. Matos R, Novaes TF, Braga MM *et al.* Clinical performance of two fluorescence-based methods in detecting occlusal caries lesions in primary teeth. *Caries Res* 2011 45: 294–302.
23. Rodrigues JA, Diniz MB, Josgrilberg EB *et al. In vitro* comparison of laser fluorescence performance with visual examination for detection of occlusal caries in permanent and primary molars. *Lasers Med Sci* 2009 24: 501–506.
24. Rodrigues JA, Hug I, Diniz MB *et al.* Performance of fluorescence methods, radiographic examination and ICDAS II on occlusal surfaces *in vitro*. *Caries Res* 2008 42: 297–304.

25. Ketley CE, Holt RD. Visual and radiographic diagnosis of occlusal caries in first permanent molars and in second primary molars. *Br Dent J* 1993 174: 364–370.
26. Machiulskiene V, Nyvad B, Baelum V. A comparison of clinical and radiographic caries diagnoses in posterior teeth of 12-year-old Lithuanian children. *Caries Res* 1999 33: 340–348.
27. Ekstrand KR. Improving clinical visual detection-potential for caries clinical trials. *J Dent Res* 2004 83 Spec No C: C67–C71.
28. Neuhaus KW, Rodrigues JA, Hug I *et al.* Performance of laser fluorescence devices, visual and radiographic examination for the detection of occlusal caries in primary molars. *Clin Oral Invest* 2011 15: 635–641.
29. Burin C, Loguercio AD, Grande RH *et al.* Occlusal caries detection: a comparison of a laser fluorescence system and conventional methods. *Pediatr Dent* 2005 27: 307–312.
30. Alwas-Danowska HM, Plasschaert AJ, Suliborski S *et al.* Reliability and validity issues of laser fluorescence measurements in occlusal caries diagnosis. *J Dent* 2002 30: 129–134.

Correspondence to:
Dr Çağdaş Çınar,
Gazi Üniversitesi,
Dişhekimliği Fakültesi,
Pedodonti Anabilim Dalı,
Bişkek Cad. 82.Sok,
06510 Emek-Ankara Turkey,
Email: cinarcagdas@hotmail.com