

Influence of Different Professional Prophylactic Methods on Fluorescence Measurements for Detection of Occlusal Caries

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Key Words

Caries detection • Fluorescence • Occlusal caries • Permanent teeth • Professional prophylaxis • Prophylactic paste

Abstract

This study aimed to evaluate the influence of professional prophylactic methods on the DIAGNOdent 2095, DIAGNOdent 2190 and VistaProof performance in detecting occlusal caries. Assessments were performed in 110 permanent teeth at baseline and after bicarbonate jet or prophylactic paste and rinsing. Performance in terms of sensitivity improved after rinsing of the occlusal surfaces when the prophylactic paste was used. However, the sodium bicarbonate jet did not significantly influence the performance of the fluorescence-based methods. It can be concluded that different professional prophylactic methods can significantly influence the performance of fluorescence-based methods for occlusal caries detection.

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the laser fluorescence devices (LF, DIAGNOdent 2095; LFpen – DIAGNOdent 2190, from KaVo, Biberach, Germany) and a fluorescence camera (FC, VistaProof, Dürr Dental, Bietigheim-Bissingen, Germany) have been developed and proposed to detect and quantify early carious lesions [Hibst et al., 2001; Lussi and Hellwig, 2006; Thoms, 2006; Rodrigues et al., 2008].

Although some studies have shown that LF, LFpen and FC present good validity and reproducibility for occlusal caries detection [Lussi and Hellwig, 2006; Rodrigues et al., 2008; Diniz et al., 2009; De Benedetto et al., 2010], it is important to stress that dental plaque and remnants of material such as pastes, powders or gels from the cleaning procedure may emit some fluorescence and lead to false positive results [Hosoya et al., 2004; Mendes et al., 2004; Anttonen et al., 2005; Lussi and Reich, 2005]. Thus, professional cleaning and drying are advised to ensure the correct detection of caries lesions through fluorescence measurements. To our knowledge, the influence of professional prophylactic procedures on the LFpen and FC devices has not been yet evaluated.

Therefore, the aim of this in vitro study was to evaluate the influence of two professional prophylactic procedures (sodium bicarbonate jet and a prophylactic paste) on LFpen and FC performance in detecting occlusal caries in permanent teeth.

Early caries detection is a challenge in dentistry due to changes in the behaviour of carious lesions in recent decades. Some fluorescence-based methods, such as

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Materials and Methods

The research protocol was approved by the Local Ethics Committee in Araraquara, São Paulo, Brazil (protocol 04/08). One hundred and ten extracted third permanent human molars from sound to carious were selected from a pool of extracted teeth that were stored at -20°C until use [Francescuti et al., 2006]. The teeth were defrosted for 3 h, and then cleaned using a hand scaler and a toothbrush.

The occlusal surfaces were photographed at $\times 10$ magnification using a stereomicroscope (SZX7, Olympus, Tokyo, Japan). One occlusal site per tooth was selected and marked as the test site on the photograph by an independent person who was not an examiner of this study. Each photograph, printed on draft quality paper, had a dot covering the test site to allow the examiners to localise the test site precisely during the exams without being biased. All assessments were independently carried out by 2 experienced examiners using LF, LFpen and FC. The examinations were performed in three conditions: (1) before professional prophylaxis (baseline), (2) after professional prophylaxis for 10 s, rinsing for 3 s and drying for 3 s, and (3) after a second rinse for 3 s and drying for 3 s.

The LF and LFpen measurements were performed according to the manufacturer's instructions. The FC images were analysed by FC-specific software (DBSWIN, Dürr Dental, Bietigheim-Bissingen, Germany) that translates the rates of red and green fluorescence into numbers corresponding to lesion severity [Rodrigues et al., 2008].

After baseline measurements (condition 1), the teeth were then randomly divided according to the type of professional prophylaxis. An attempt was made to form groups with similar numbers of sound and carious teeth by visual inspection: group A ($n = 55$) – PROFI III BIOS® (Dabi Atlante, Ribeirão Preto, São Paulo, Brazil) using sodium bicarbonate powder applied in a jet; and group B ($n = 55$) – Odahcam® prophylactic paste (Dentsply, Petrópolis, Rio de Janeiro, Brazil) using a slow-rotating contra-angle handpiece with a Robinson brush.

After the prophylactic procedure, teeth were rinsed off for 3 s and dried for 3 s with a three-in-one syringe (condition 2). Then the fluorescence values were recorded again. New measurements were taken after rinsing again for 3 s and drying for 3 s (condition 3) [Lussi and Reich, 2005].

LF and LFpen values of both prophylactic materials were tested. The first layer of each product was discarded. The products were placed on a piece of glass, and the values were obtained by putting the tips in close contact with both materials. The tips were cleaned with ethanol (100%) and the procedure repeated 10 times, and average values were obtained.

For validation, the teeth were sectioned longitudinally perpendicular to the test site with a water-cooled diamond blade (ISOMET 1000, Buehler Ltd., Lake Bluff, Ill., USA) and ground using silicon carbide paper with decreasing grain sizes. The tooth surfaces were then coloured with saturated rhodamine B (Fluka, Buchs, Switzerland), using a brush and immediately rinsed in tap water for 10 s to remove the dye remnants. The sites were assessed for caries extension (magnification $\times 10$) according to Lussi et al. [1999]: caries-free (0), caries extending up to halfway through the enamel (1), caries extending into the inner half of enamel (2), caries in dentine (3) and deep dentine caries (4). Two experienced histological examiners, who also performed the other assess-

Table 1. Comparison of LF, LFpen and FC measurements (means \pm SD) between the two groups in the three conditions

	Group	Condition 1	Condition 2	Condition 3
LF	A	22.1 ± 22.0^a	23.2 ± 25.7^a	25.0 ± 26.8^a
	B	21.5 ± 24.8^a	35.8 ± 32.0^b	36.4 ± 32.0^b
LFpen	A	31.2 ± 28.0^a	36.0 ± 32.1^a	38.4 ± 32.7^a
	B	28.8 ± 27.7^a	44.5 ± 33.9^b	43.1 ± 34.3^b
FC	A	1.5 ± 0.4^a	1.5 ± 0.4^a	1.6 ± 0.5^a
	B	1.4 ± 0.3^a	1.5 ± 0.4^a	1.5 ± 0.4^a

Significant differences are represented by different superscript letters in a single column (Mann-Whitney test, $p < 0.05$).

ments, examined each tooth section independently. The results from the 2 examiners were compared to achieve a consensus score for each test site. Where the examiners disagreed the sections were re-examined and agreement reached.

Statistical Analysis

For each method, the data from both examiners in each condition were combined and analysed by descriptive methods. A Mann-Whitney U test was applied to compare the fluorescence values between the two groups for different conditions. The optimal cutoff limits for LF, LFpen and FC were determined by the highest sum of sensitivity and specificity at each threshold using the baseline measurements from both examiners. Sensitivity, specificity, accuracy and area under the ROC curve were calculated at D_1 (considering as disease gold standard scores from 1 to 4) and D_3 (considering as disease gold standard scores of 3 and 4) diagnostic thresholds (MedCalc for Windows, version 9.3.0.0, Mariakerke, Belgium). The McNemar test was applied to compare the performance in the different conditions and a non-parametric statistical test was applied to assess the difference in areas under the ROC curves. The level of significance for all tests was chosen as $p < 0.05$. Intraclass correlation (ICC) was used to assess inter-examiner reproducibility in the three conditions for each group.

Results

Of the 55 occlusal test sites analysed in group A, the histological examination showed that 2 were caries-free, 8 had caries extending up to halfway through the enamel, 34 had caries extending to the inner half of enamel, 10 had caries in dentine and 1 had deep dentinal caries. For group B ($n = 55$), 6 were caries-free, 9 had caries extending up to halfway through the enamel, 34 had caries extending to the inner half of enamel, 4 had caries in dentine and 2 had deep dentinal caries.

The measurements performed after using different prophylactic procedures are shown in table 1. For the LF

Table 2. Sensitivity (Se), specificity (Sp), accuracy (Ac) and area under the ROC curve (A_z) for LF, LFpen and FC for group A (sodium bicarbonate jet) in all conditions

Condition		LF				LFpen				FC			
		Se	Sp	Ac	A_z	Se	Sp	Ac	A_z	Se	Sp	Ac	A_z
D ₁ threshold	1	0.50 ^a	1.00 ^a	0.52 ^a	0.86 ^a	0.75 ^a	1.00 ^a	0.75 ^a	0.85 ^a	0.81 ^a	0.50 ^a	0.80 ^a	0.73 ^a
	2	0.51 ^a	1.00 ^a	0.53 ^a	0.80 ^a	0.68 ^a	1.00 ^a	0.69 ^a	0.81 ^a	0.77 ^a	0.50 ^a	0.76 ^a	0.76 ^a
	3	0.57 ^a	1.00 ^a	0.58 ^a	0.86 ^a	0.70 ^a	0.75 ^a	0.70 ^a	0.83 ^a	0.79 ^a	0.50 ^a	0.78 ^a	0.76 ^a
D ₃ threshold	1	0.50 ^a	0.73 ^a	0.68 ^a	0.64 ^a	0.45 ^a	0.74 ^a	0.68 ^a	0.62 ^a	0.55 ^a	0.81 ^a	0.75 ^a	0.65 ^a
	2	0.50 ^a	0.76 ^a	0.71 ^a	0.60 ^a	0.50 ^a	0.60 ^b	0.58 ^b	0.56 ^a	0.55 ^a	0.74 ^a	0.70 ^a	0.65 ^a
	3	0.45 ^a	0.72 ^a	0.66 ^a	0.57 ^a	0.50 ^a	0.55 ^b	0.54 ^b	0.56 ^a	0.50 ^a	0.73 ^a	0.68 ^a	0.66 ^a

D₁: 0 = sound; 1–4 = decayed. D₃: 0–2 = sound; 3–4 = decayed. Significant differences are represented by different superscript letters in a single column (McNemar test, $p < 0.05$ for Se, Sp and Ac; non-parametric statistical test for A_z).

Table 3. Sensitivity (Se), specificity (Sp), accuracy (Ac) and area under the ROC curve (A_z) for LF, LFpen and FC for group B (prophylactic paste) in all conditions

Condition		LF				LFpen				FC			
		Se	Sp	Ac	A_z	Se	Sp	Ac	A_z	Se	Sp	Ac	A_z
D ₁ threshold	1	0.42 ^a	0.92 ^a	0.47 ^a	0.63 ^a	0.71 ^a	0.58 ^a	0.70 ^a	0.66 ^a	0.76 ^a	1.00 ^a	0.78 ^a	0.87 ^a
	2	0.64 ^b	0.58 ^b	0.64 ^b	0.69 ^a	0.83 ^b	0.42 ^a	0.78 ^{a, b}	0.71 ^a	0.77 ^a	0.92 ^a	0.78 ^a	0.86 ^a
	3	0.69 ^b	0.50 ^b	0.67 ^b	0.72 ^a	0.86 ^b	0.50 ^a	0.82 ^b	0.76 ^a	0.81 ^a	0.92 ^a	0.82 ^a	0.90 ^a
D ₃ threshold	1	1.00 ^a	0.81 ^a	0.82 ^a	0.89 ^a	0.92 ^a	0.77 ^a	0.78 ^a	0.84 ^a	0.58 ^a	0.89 ^a	0.85 ^a	0.84 ^a
	2	0.75 ^a	0.58 ^b	0.60 ^b	0.61 ^b	0.75 ^a	0.52 ^b	0.55 ^b	0.65 ^b	0.67 ^a	0.81 ^{a, b}	0.79 ^{a, b}	0.80 ^a
	3	0.83 ^a	0.56 ^b	0.59 ^b	0.70 ^b	0.83 ^a	0.59 ^b	0.62 ^b	0.71 ^{a, b}	0.58 ^a	0.76 ^b	0.74 ^b	0.75 ^a

D₁: 0 = sound; 1–4 = decayed. D₃: 0–2 = sound; 3–4 = decayed. Significant differences are represented by different superscript letters in a single column (McNemar test, $p < 0.05$ for Se, Sp and Ac; non-parametric statistical test for A_z).

and LFpen measurements, statistically significant differences were observed between conditions 2 and 3. For FC measurements, there is no significant difference between all conditions.

The measurements of the Odahcam prophylactic paste revealed LF and LFpen values of up to 99. On the other hand, the sodium bicarbonate powder used with PROFI III BIOS showed an inherent fluorescence of 6.

The optimal cutoff limits for the LF were 0–15 (sound), 16–25 (enamel caries) and >25 (dentine caries); for the LFpen they were 0–10 (sound), 11–34 (enamel caries) and >34 (dentine caries); and for the FC they were 0–1.1 (sound), 1.2–1.7 (enamel caries) and >1.7 (dentine caries).

Specificity, sensitivity, accuracy and area under the ROC curve at the D₁ and D₃ thresholds are presented in tables 2 and 3 for groups A and B, respectively.

The ICCs for interexaminer reproducibility values ranged from 0.83 to 0.94 (LF), from 0.78 to 0.91 (LFpen) and from 0.85 to 0.94 (FC), indicating excellent agreement between the examiners for all examination conditions.

Discussion

In this study, the influence of two prophylactic materials on fluorescence measurements was evaluated and this is the first study on this subject concerning the FC. Concerning the fluorescence measurements in the three conditions of this study, there was a gradual increase in measurements after both prophylactic procedures and after the second rinse and drying when compared to the base-

line measurements. Anttonen et al. [2005] also observed an increase in LF values after professional cleaning. Contrary to this result, Lussi and Reich [2005] observed no difference with LF readings. In our study, the increase in values after prophylaxis could be explained by the short duration of rinsing to remove remnants of prophylactic materials.

It is important to point out that LF and LFpen measurements are statistically significantly higher when using the prophylactic paste than when using the sodium bicarbonate jet. This fact could be attributed to the degree of porosity of carious tissue, which could lead to some penetration of the prophylactic material, and to the higher inherent fluorescence value of this paste (i.e., 99). Lussi and Reich [2005] also observed high fluorescence values for some prophylactic pastes. Regarding FC measurements, no difference between the two prophylactic methods could be observed. However, it can be speculated that the amount of prophylactic materials used in this study may not be enough to become detectable in the FC image. Thus, it should be emphasized that FC examination is performed on the tooth indirectly, contrary to LF and LFpen measurements.

Considering the sodium bicarbonate jet (group A), the performance values did not vary significantly among the different conditions for all methods at the D₁ threshold. However, LFpen and FC showed superior results in terms of sensitivity, as did LF and LFpen in terms of specificity. A small increase in sensitivity and accuracy values after the second rinse and drying procedure could also be observed. If the teeth are not rinsed vigorously with a water spray, there could be a high chance of interference with fluorescence measurements [Lussi and Reich, 2005]. At the D₃ threshold, LF and LFpen presented similar performance in the three conditions. For LFpen, there was a significant decrease in the specificity and accuracy values between baseline and following the prophylactic procedure and between baseline and following the second rinse and drying. Rodrigues et al. [2008], after cleaning the teeth with a sodium bicarbonate jet, also observed lower values of specificity and accuracy for LFpen. The lower sensitivity values observed for all methods could be explained by the small number of dentine caries (20%) and the cutoff used for dentine caries (>34). Lower sensitivity was also found by Rodrigues et al. [2008] for LF.

Concerning the performance of the methods for the prophylactic paste group (group B), at D₁ threshold, the sensitivity values increased significantly for LF and LFpen after the cleaning procedure and after the second rinsing and drying procedure. In the present study the

increase in the sensitivity values might be due to an increase in fluorescence measurements or due to the light scattering pattern. Nevertheless, FC showed an excellent balance between sensitivity and specificity and the largest areas under the ROC curves, with no significant difference among the three conditions analysed in this study. At D₃ threshold, LF and LFpen showed higher sensitivity values, with no statistically significant difference among the three conditions. This fact can be attributed to the increased values of LF and LFpen measurements after the prophylaxis and after the second rinsing and drying procedure. On the other hand, a significant decrease in specificity and accuracy values after prophylaxis and after the second rinsing and drying procedure was also observed. FC presented lower sensitivity values and higher specificity and accuracy values.

The excellent reproducibility presented in all conditions shows that similar results can be found over different assessments and situations. Lussi and Hellwig [2006], Diniz et al. [2008] and Rodrigues et al. [2008] also described high ICC values for LF and LFpen in detecting carious lesions in occlusal surfaces *in vitro*. For FC, similar ICC values were also reported in previous studies [Rodrigues et al., 2008; De Benedetto et al., 2010].

In conclusion, the present results indicate that different professional prophylactic methods can significantly influence the performance of fluorescence-based methods for occlusal caries detection. This study therefore does not have the power to say what impact the prophylactic methods have on sound sites (as the number of sound sites was low) and the potential for increasing false positives. The performance in terms of sensitivity was improved after careful rinsing of the occlusal surfaces when the prophylactic paste was used. However, the professional prophylaxis using the sodium bicarbonate jet did not significantly influence the performance of the fluorescence-based methods. Despite the limitations of this *in vitro* study, it can be concluded that FC is less influenced by the choice of the prophylactic procedure than are LF and LFpen. It also underscores the necessity to rinse the teeth with water spray after prophylactic procedures to eliminate any remnants, especially of prophylactic paste, in pits and fissures. Further studies, mainly *in vivo*, should be performed to evaluate the possible influence of prophylactic materials used in dental practice on fluorescence measurements.

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Disclosure Statement

The authors declare that they have no proprietary, financial, professional or other personal interest of any nature or kind in any product, service and/or company that might introduce bias or affect their judgement or that could be construed as influencing the position presented herein or the review of the paper entitled 'Influence of professional prophylaxis methods on fluorescence measurements for detection of occlusal caries detection'.

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