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Effect of dental material fluorescence on DIAGNOdent readings

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Abstract

Objective. Diagnosis of secondary caries with the DIAGNOdent device has been found to be comparable to visual and radiographic diagnostic methods, but the fluorescence of restorative materials might affect DIAGNOdent values and result in false-positive diagnosis. The aims of this study were: (1) to measure baseline fluorescence of restorative materials and fluorescence changes induced by aging, bleaching, staining, and polishing; (2) to assess intra-examiner reproducibility of these measurements; and (3) to compare the values obtained with the DIAGNOdent against the threshold values for enamel and dentinal caries. ***Material and Methods.*** 270 disk-shaped specimens fabricated from 15 different restorative materials were divided into 3 groups, which were aged in water, bleached with 10% carbamide peroxide, and stained with red wine. Specimen fluorescence was measured with the DIAGNOdent before and after these treatments. The red-wine-stained specimens were also polished and measured again. ***Results.*** Intra-examiner reproducibility of the measurements was excellent. For all materials, baseline DIAGNOdent values, as well as the values of aged and bleached samples, were considerably lower than the dentinal caries threshold. The values of one stained filled resin fissure sealant, one stained resin composite, and one stained resin-modified glass ionomer exceeded the dentinal caries threshold. Polishing reduced these DIAGNOdent values to below the dentinal caries threshold, except for the filled resin fissure sealant specimen. ***Conclusions.*** Stained dental materials might affect DIAGNOdent readings and consequently result in false-positive diagnoses of secondary caries. Dental fillings should be polished prior to DIAGNOdent measurement.

Key Words: *Composite resins, dental polishing, fluorescence, glass ionomer cements, pit and fissure sealants*

Introduction

Secondary caries is the most frequently cited reason for replacement of all types of restorations in general practice [1], and represents up to half of all operative dentistry procedures performed on adults [2]. Currently used diagnostic procedures for secondary caries detection, i.e. visual inspection, tactile examination, and bitewing radiography, are considered poorly defined [2] and subjective [3]. Exploratory removal of restoration can ultimately be used to confirm or reject diagnosis, but this is an invasive and costly method [3]. Recently, a laser fluorescence device, DIAGNOdent (DD), was found to be comparable to visual [4] and radiographic diagnosis [5,6] of secondary caries.

The fluorescence of restorative materials might affect the DD values and result in false-positive diagnosis. Variation in DD values among restorative materials has been reported for a limited range of materials immediately after placement of fillings [7]. Similarly, variation in DD values has been reported for tooth-colored restorations on extracted teeth [4]. On the contrary, only little or no restoration fluorescence was reported in a similar study [5]. Consequently, the present data on the fluorescence of restorative materials measured with DD are inconclusive. In addition, optical properties of restorative materials can be affected by aging [8,9], bleaching [10], staining [11], and polishing [12,13], but their influence on DD values has not yet been investigated. A recent study reported that polishing can decrease material DD values when measured with the new DIAGNOdent pen (DDP) [13]. However, this observation might not be applicable to the old DD, as DD and DDP differ in optics and in filters for fluorescent light separation, transmitting wavelengths above 680 and 665 nm, respectively [14,15]. The lack of data on restorative material

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fluorescence still precludes the potential use of DD and DDP for the diagnosis of secondary caries, and a need to address this issue has been expressed recently [14,16].

The aims of this study were: (1) to measure baseline DD values of restorative materials and changes induced by aging, bleaching, staining, and polishing with DD; (2) to assess intra-examiner reproducibility of these measurements; and (3) to compare the obtained DD values against the threshold values for enamel and dentinal caries. We hypothesized that the material DD values would not reach the proposed DD threshold values, suggesting that there is no considerable effect of the adjacent restorative material.

Material and methods

Description of DIAGNOdent

The DD diagnostic device (DIAGNOdent, KaVo, Biberach, Germany) contains a laser diode (655 nm) as the excitation light source. A photo-detector measures the amount of fluorescent light and displays a value between 0 and 99. A set zero procedure on a healthy tooth surface is recommended by the manufacturer to eliminate the effect of sound dental tissue fluorescence [15]. As this was an *in vitro* study utilizing only restorative dental materials, the set zero procedure was not performed.

Specimen preparation

Fifteen dental restorative materials were evaluated in this study (Table I) and 18 disk-shaped specimens were fabricated from each. A cylindrical mold was made from a 2-mm-thick steel plate with a 10-mm opening placed on a glass plate. After filling the material into the mold, a second glass plate was pressed on top to form a smooth surface without an oxygen inhibition layer. The resin fissure sealant, conventional resin composite, flowable resin composite, and resin-modified glass ionomer specimens were polymerized for 40 s with a LED curing light, Ultra-Lume LED 5 (Ultradent Products, South Jordan, Ut., USA), in accordance with the manufacturer's instructions. The intensity of the polymerizing light source was >600 mW/cm^2. Conventional glass ionomer specimens were removed from the mold after the manufacturer recommended setting time. All specimens were divided into three groups containing a set of six specimens of each material.

Fluorescence measurements

The fluorescence of each specimen was measured with the DD on a transparent acrylic plate with 8 mm diameter openings. The DD value, between 0 and 1, of transparent acrylic resin was found negligible. Before measuring each set, the DD was calibrated according to the manufacturer's instructions. Subsequently, the tapered tip (type A) of the device was placed in the center of the specimen perpendicular to the surface and the peak value was recorded. Each specimen was measured three times.

Aging, bleaching, staining, and polishing of the disks

To simulate a clinical situation where only one side of the material is exposed, the specimens of each group were embedded in vinyl polysiloxsane impression material (Examix NDS, GC Dental Products Corp., Aichi, Japan), leaving one side exposed. The first group was subjected to accelerated aging in water at a temperature of 60°C for 30 d [9]. The second group was covered with a 2-mm layer of 10% carbamide peroxide gel (Vivastyle, Ivoclar Vivadent, Schaan, Liechtenstein) for 14 d, 8 h per day [10] at a temperature of 37°C. Specimens were stored in tap water (37°C). The third group was immersed in red wine (Cabernet Sauvignon, 12.1 vol.% alcohol) for 10 d, 24 h per day [17] at a temperature of 37°C.

Table I. Restorative dental materials, utilized in the study

Abbreviation	Brand name	Shade	Type	Batch
HF	Helioseal F[a]	White	Resin fissure sealant	G07925
HC	Helioseal Clear[a]	Clear	Resin fissure sealant	E03221
HCC	Helioseal Clear Chroma[a]	Clear	Resin fissure sealant	C02116
TE A2	Tetric Evoceram[a]	A2	Conventional resin composite	H28233
TE T	Tetric Evoceram[a]	T	Conventional resin composite	H20175
GD A2	Gradia Direct[b]	A2	Conventional resin composite	0309032
GD NT	Gradia Direct[b]	NT	Conventional resin composite	0304242
FS A2E	Filtek Supreme XT[c]	A2E	Conventional resin composite	5BT
FS GT	Filtek Supreme XT[c]	GT	Conventional resin composite	5BF
TF A2	Tetric Flow[a]	A2	Flowable resin composite in syringe	D05498
TF T	Tetric Flow[a]	T	Flowable resin composite in syringe	E02093
F IX A2	Fuji IX GP Fast[b]	A2	Conventional glass ionomer	0508091
F VII	Fuji VII capsule command set[b]	Pink	Resin-modified glass ionomer fissure sealant	0102042
KM A2	Ketac Molar Quick Aplicap[c]	A2	Conventional glass ionomer	222990
PF A2	Photac Fil Quick Aplicap[c]	A2	Resin-modified glass ionomer	222134

Manufacturers of materials: [a]Ivoclar Vivadent, Schaan, Liechtenstein; [b]GC Corporation, Tokyo, Japan; [c]3M ESPE, St. Paul, Minn., USA.

Each day the specimens were washed under tap water and immersed in new wine. Red wine was used because it gave the highest DD values compared to tea and coffee in a preliminary study. After each treatment, the DD values were measured again. The specimens stained with red wine were polished with a cup-shaped rubber polisher (OptraPol, Ivoclar Vivadent, Schaan, Liechtenstein), with a low speed hand-piece under water spray for 5 s. The DD value of the polisher was 0. After polishing, the measurements were repeated.

Statistical analysis

Intra-class correlation coefficients (ICCs) were calculated to assess intra-examiner reproducibility of the DD measurements using the three repeated measurements of the samples. A mean value of repeated measurements of each sample was calculated and used for further analysis. A two-way ANOVA with repeated measures in one factor (treatment) was used to evaluate the effect of material and treatment on the DD values ($\alpha = 0.05$) followed by Tukey's HSD test to calculate significant differences in DD values between materials within one treatment group ($\alpha = 0.05$). The 95% confidence interval (CI) of each material was compared with the DD threshold values for enamel and dentinal caries, respectively 14 and 21 [18]. The statistical analysis was performed with SPSS for Windows, v. 14.0 (SPSS, Chicago, Ill., USA).

Results

The mean ICC value was 0.86, indicating excellent intra-examiner reproducibility of the DD measurements. The two-way ANOVA with repeated measures in one factor (treatment) detected statistically significant effects of material, treatment, and interaction ($p < 0.0001$).

The results are given in Table II. In general, the baseline DD values of conventional and resin-modified glass ionomers were higher than the values of resin fissure sealants and conventional and flowable resin composites. Aging in water resulted in equal or higher values. However, bleaching was found to have an opposite effect. The samples bleached with 10% carbamide peroxide exhibited equal or lower values; only PF A2 exhibited a higher mean value. The highest DD values were observed in the stained samples. Staining resulted in higher DD values in all the materials. Clear resin fissure sealants (HC and HCC) and conventional glass ionomers (F IX A2 and KM A2) exhibited the smallest increase, while HF, PF A2, GD A2, and FS A2E exhibited an increase of more than 10 values. Polishing resulted in reduced mean DD values in all the materials. The highest reduction in DD values was found in materials exhibiting the highest values after staining. Therefore, the DD values of HF, PF A2, and GD A2 decreased the most. The smallest decrease was found in FS A2E.

The enamel caries threshold was exceeded by the 95% CI of stained FS A2E and F VII, and polished PF A2 and FS A2E, while the dentinal caries threshold was exceeded by the 95% CI of stained HF, GD A2, and PF A2, and only by polished HF.

Discussion

Excellent intra-examiner reproducibility of the DD measurements, found in our study, is comparable to the intra-examiner reprodicibility of the DD measurements made on teeth [15]. Baseline fluorescence values from our study are in accordance with *in vivo* values of conventional resin composite [7], although lower values for conventional glass ionomers, filled and unfilled resin fissure sealants were found. Our results for stained resin composites are also comparable with two recent studies reporting DD values of resin composite restorations on extracted teeth to be between 5 and 22 measured with DD [4] and 23 measured with DDP [13].

Since secondary caries is primary caries adjacent to restoration [2,19], the threshold values proposed for primary caries may also apply to secondary caries diagnosis if the fluorescence of the restorative material does not exceed caries threshold values; 14 for enamel and 21 for dentinal caries [18]. Baseline DD values in all the materials used in this study were below the enamel caries threshold, therefore their fluorescence would not result in a false-positive diagnosis. In addition, the DD values of the bleached and aged samples were below the enamel caries threshold. On the contrary, the samples stained with red wine revealed considerable increases in DD values. The enamel caries threshold was exceeded by two tested materials: FS A2E and F VII. Furthermore, the dentinal caries threshold was exceeded by three tested materials: HF, GD A2, and PF A2. In clinical practice, these materials may cause false-positive diagnosis of dentinal caries and thus overtreatment. A more pronounced increase in DD values was found in conventional resin composites compared to flowable resin composites, for A2 shades compared to translucent shades, and for resin-modified compared to conventional glass ionomers. These findings are in accordance with studies evaluating color changes after staining with red wine. More specifically, higher susceptibility to staining was reported for composite compared to unfilled resin [11], and for resin-modified glass ionomers compared to conventional glass ionomers [20]. In general, staining may depend on matrix/filler ratio, hydrophilicity of resin, hydrolysis of silane, among others, and therefore is individual rather than type-specific [20].

Table II. Mean (SD) DD values at baseline and after the samples were aged in water, bleached with 10% carbamide peroxide, stained with red wine, and polished with cup-shaped polishing rubber

Material	Baseline	Subset	Aged	Subset	Bleached	Subset	Stained	Subset	Polished	Subset
HF	3.00 (0.00)	d	3.11 (0.32)	c	3.00 (0.00)	c	63.83 (3.93) **	h	31.11 (11.84) **	e
HC	1.00 (0.00)	a	1.00 (0.00)	a	1.00 (0.00)	a	2.22 (0.43)	a	1.00 (0.00)	a
HCC	1.30 (0.25)	b	1.94 (0.24)	b	1.00 (0.00)	a	2.00 (0.00)	a	1.89 (0.32)	a, b
TE A2	2.00 (0.00)	c	2.89 (0.32)	c	2.00 (0.00)	b	10.72 (0.96)	c, d, e	3.33 (0.49)	a, b
TE T	2.06 (0.13)	c	3.00 (0.00)	c	2.00 (0.00)	b	8.67 (2.35)	b, c, d	3.00 (0.34)	a, b
GD A2	4.35 (0.37)	f	4.00 (0.00)	d	4.00 (0.00)	e	19.61 (1.79) **	f	7.39 (1.50)	a, b, c, d
GD NT	4.00 (0.00)	e	3.22 (0.43)	c	3.00 (0.00)	c	10.44 (1.20)	c, d, e	6.94 (1.47)	a, b, c, d
FS A2E	2.00 (0.00)	c	2.00 (0.00)	b	2.00 (0.00)	b	12.17 (1.69) *	d, e	11.83 (2.07) *	d
FS GT	1.00 (0.00)	a	1.94 (0.24)	b	1.00 (0.00)	a	5.44 (0.62)	a, b	3.94 (0.94)	a, b, c
TF A2	2.00 (0.00)	c	2.00 (0.00)	b	1.94 (0.24)	b	7.61 (0.70)	b, c	2.83 (0.38)	a, b
TF T	1.28 (0.26)	a, b	1.94 (0.24)	b	1.17 (0.38)	a	5.94 (0.42)	b	2.00 (0.00)	a, b
F IX A2	3.96 (0.53)	e	3.56 (0.51)	c, d	3.44 (0.51)	d	5.44 (0.70)	a, b	4.56 (0.51)	a, b, c
F VII	6.87 (0.55)	g	6.44 (1.04)	e	5.00 (0.00)	f	12.78 (3.42) *	e	8.17 (0.51)	b, c, d
KM A2	6.89 (0.26)	g	6.78 (0.65)	e	5.50 (0.51)	g	9.89 (0.96)	c, d, e	7.11 (0.68)	a, b, c, d
PF A2	1.07 (0.18)	a, b	3.28 (0.46)	c, d	2.67 (0.49)	c	25.00 (2.06) **	g	10.50 (2.07) *	c, d

For material abbreviations, see Table I.
Subsets demonstrating similar means ($p < 0.05$).
* 95 CI exceeds enamel caries threshold value.
** 95 CI exceeds dentinal caries threshold value.

Polishing reduced DD values in all the materials in our study, probably because it removed surface stains [12]. For most of the materials, the mean DD values were still up to 3 DD values higher than the baseline. Although there were three exceptions, i.e. PF A2, FS A2E, and HF, where the mean values were more than nine values higher than the baseline. Consequently, the enamel caries threshold was exceeded by PF A2 and FS A2E, while the dentinal caries threshold was exceeded only by HF. Polishing inefficacy for these materials could be attributed to material hardness or subsurface staining.

DD has also been proposed for the detection of caries underneath unfilled fissure sealants [21], an application that has been clinically confirmed [22]. In our study, both unfilled resin fissure sealants HC and HCC exhibited negligible baseline and post-treatment values, confirming their suitability for the suggested application. On the contrary, an exceptionally high DD value of stained and polished filled resin fissure sealant HF precludes its potential use in secondary caries diagnosis with DD.

It must be noted that an *in vitro* study cannot completely simulate the complex interactions of all factors in the oral cavity. Protective factors were omitted in our study, as the aim was to assess extreme influence of the evaluated factors. Staining in the oral cavity would probably not be so intensive, because of the intermittent nature of stain exposure, saliva protection and dilution, and wear of the material. Consequently, an *in vivo* increase in DD values and the possibility for false-positive diagnosis is presumed to be lower. Furthermore, performing the set zero procedure prior to measurement would decrease the displayed values for the fluorescence value of sound dental tissue. To minimize these effects, polishing dental fillings is recommended prior to measurements. However, polishing should not be performed with pumice containing polishing pastes, because pumice can increase DD values [23].

In conclusion, staining may affect DD readings of dental materials and consequently result in false-positive diagnosis of secondary caries. Therefore the use of dentinal rather than enamel threshold values and polishing of dental fillings is recommended prior to DD measurements.

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