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Comparison of two different methods of detecting residual caries

**Uzay Koç Vural*,
Zeynep Bilge Kütük,
Esra Ergin, Filiz Yalçın
Çakır, Sevil Gürgan**

Department of Restorative
Dentistry, Hacettepe University,
Sıhhıye, Ankara, Turkey

Objectives: The aim of this study was to investigate the ability of the fluorescence-aided caries excavation (FACE) device to detect residual caries by comparing conventional methods *in vivo*. **Materials and Methods:** A total of 301 females and 202 males with carious teeth participated in this study. The cavity preparations were done by grade 4 (Group 1, 154 teeth), grade 5 (Group 2, 176 teeth), and postgraduate (Group 3, 173 teeth) students. After caries excavation using a handpiece and hand instruments, the presence of residual caries was evaluated by 2 investigators who were previously calibrated for visual-tactile assessment with and without magnifying glasses and trained in the use of a FACE device. The tooth number, cavity type, and presence or absence of residual caries were recorded. The data were analyzed using the Chi-square test, the Fisher's Exact test, or the McNemar test as appropriate. Kappa statistics was used for calibration. In all tests, the level of significance was set at $p = 0.05$. **Results:** Almost half of the cavities prepared were Class II (Class I, 20.9%; Class II, 48.9%; Class III, 20.1%; Class IV, 3.4%; Class V, 6.8%). Higher numbers of cavities left with caries were observed in Groups 1 and 2 than in Group 3 for all examination methods. Significant differences were found between visual inspection with or without magnifying glasses and inspection with a FACE device for all groups ($p < 0.001$). More residual caries were detected through inspection with a FACE device (46.5%) than through either visual inspection (31.8%) or inspection with a magnifying glass (37.6%). **Conclusions:** Within the limitations of this study, the FACE device may be an effective method for the detection of residual caries. (*Restor Dent Endod* 2017;42(1):48-53)

Key words: Detection of residual caries; Fluorescence-aided caries excavation; Magnifying glass; Visual inspection; Visual-tactile examination

Koç Vural U, Kütük ZB, Ergin E,
Yalçın Çakır F, Gürgan S
*Correspondence to
Uzay Koç Vural, DDS, PhD.
Specialist, Department of
Restorative Dentistry, Hacettepe
University, Sıhhıye, Ankara, Turkey
06100
TEL, +905072122626; FAX, +90312
3051138; E-mail, uzaykoc@gmail.
com; uzaykocvural@gmail.com

Introduction

The widespread concept of minimally invasive dentistry implies that heavily infected and irreversibly denatured dentin should be selectively removed in order to preserve sound or potentially remineralizable tooth tissue as much as possible.[1,2] Pulp exposure can occur due to the over-excavation of carious lesions,[3] while residual caries left on the cavity floor may lead to recurrent caries.[4] There are still no widely accepted guidelines to determine how much infected dentin can be left on the cavity floor. Therefore, an accurate method should be selected for the identification and removal of infected dentin layers.

A clinically relevant method for assessing the extent of caries excavation should quantify the remaining infected dentin in the cavity after excavation.[5] In the past, culturing methods have been used to quantify bacteria in dentin.[6] Hardness has been regarded as a principal criterion for the therapeutic endpoint of caries removal using the conventional excavation method for over 60 years.[7] Visual-tactile inspection is still accepted as the gold standard for residual caries detection.[1] The criterion is that 'the probe should not stick in the dentin and should not give a tug-back sensation'.[8] However, probing dental hard tissue can cause iatrogenic pulp injuries and false-positive diagnoses.[9]

A caries-detecting device known as the fluorescence-aided caries excavation (FACE) device has been recently introduced for the visual detection of residual caries to differentiate infected and affected carious dentin. This device, by visualizing the metabolic products of oral microorganisms known as porphyrins,[10] can be beneficial to minimize the risk of caries recurrence.[11] When an exposed cavity is illuminated with violet light, the dental hard tissues auto-fluoresce (wavelength, 405 nm), because porphyrins reflect red fluorescence, indicating the required caries excavation locations.[12] Sound tissues fluoresce green, while carious tissue fluoresces orange-red with the FACE device. Thereby, the FACE device allows the selective removal of infected dentin and the preservation of non-infected dentin.[13,14]

The aim of the present study was to compare the ability of the FACE device and conventional visual-tactile assessment to detect residual caries in the cavities of permanent teeth, which were prepared by students in grades 4 and 5 and postgraduate students. The null hypothesis was that no difference would be present in the incidence of residual caries detected through FACE device inspection and visual-tactile assessment performed with or without magnifying glasses.

Materials and Methods

Patient selection

A total of 503 non-hospitalized volunteer patients (301 females and 202 males) were selected for this study. The procedures and the aims of this study were explained to the patients, and informed consent was obtained before their participation. All procedures were performed in accordance with the Declaration of Helsinki, and ethics committee approval was obtained from the local ethics commission (GO 14/106). Class I, II, III, IV, and V lesions on the permanent dentition were included in the study if they were clinically and radiographically diagnosed free from any pulpitis symptoms. Teeth with pulp exposure were excluded from the study.

Cavity preparation

Cavity preparations were performed by grade 4 (Group 1), grade 5 (Group 2), and postgraduate (Group 3) students. For cavity access, enamel walls were prepared using a high-speed hand piece with diamond burs under continuous water cooling. The superficial, soft, infected dentin was then excavated using sharp spoon excavators and round steel burs of different sizes, without water-cooling.

Visual-tactile assessment with and without magnifying glasses

Two experienced examiners (SG and FYC) assessed all cavities for residual caries using visual-tactile assessment. The examiners made a decision about the presence or absence of residual caries according to the hardness of the lesion area. The teeth were dried briefly using compressed air, isolated with cotton rolls and a saliva ejector, and viewed under standard dental lighting. The cavity preparation was considered as caries-free when a hard cavity floor was felt upon gentle pressure with a dental explorer[14] that did not stick in the dentin. The presence of residual caries was recorded.

In the second step, the investigators used magnifying glasses (Keeler, Windsor, UK, ×3 magnification) to assess the cavities, and the recording process was repeated. Disagreements between the examiners were resolved through consensus.

FACE device assessment

Following the visual-tactile assessments, overhead fluorescent lighting was turned off and the light in the room was dimmed. Fluorescent violet light (405 nm, FaceLight, W&H Dentalwerk Bürmoos GmbH, Burmoos, Austria) was generated using a 100 - 130 watt xenon discharge lamp to evaluate caries removal. The operators inspected the cavity through a 500 nm red long-pass glass filter that was compatible with standard corrective goggles to visualize the orange-red fluorescing areas representing the bacteria-infected dentin surfaces (Figure 1). Green fluorescing areas and infected dentin tissue, which appeared dark brown or black, were recorded as caries-free.

Finally, all remaining carious areas that were diagnosed using these 3 methods were checked again and removed before the final restoration procedure.

Statistical analysis

Kappa statistics was used to evaluate inter-examiner and intra-examiner agreement regarding the clinical calibration for visual-tactile inspection with or without magnifying glasses and the FACE device. The data were analyzed using

Figure 1. View of residual caries (orange color) observed with a fluorescence-aided caries excavation device.

frequency analysis and the Chi-square test for independent groups. If the expected count in a cell was less than 5, the Fisher's Exact test was used. The McNemar test was used for the comparison of dependent groups (SPSS 20.0, IBM Corp., Armonk, NY, USA). The level of significance was set at $\alpha = 0.05$. The relationship between the grade of the operators and the assessment methods was assessed. Furthermore, the obtained values for different diagnostic techniques were compared with each other.

Results

A total of 503 teeth (Class I, 105; Class II, 246; Class III, 101; Class IV, 17; Class V, 34 cavities) with carious lesions were prepared by students in grades 4 (Group 1) and 5 (Group 2), and postgraduate students (Group 3). The Chi-square statistical analysis revealed no significant relationship between the grade of students and the prepared cavity type ($p > 0.05$). Thus, the prevalence and variability of the prepared cavities were sufficient to perform statistical analyses. The distribution of the cavities is shown in Table 1.

The inter-examiner reliability between the examiners was over 80%, showing excellent agreement between the examiners (kappa = 0.864). Caries were detected in 160 teeth examined by visual-tactile assessment without magnifying glasses, in 189 teeth by visual-tactile assessment with magnifying glasses, and in 234 teeth using the FACE device. The undergraduate students left higher numbers of cavities with undetected caries than postgraduate students for all assessment methods (Table 2). The relationships between grade and the presence of detected carious lesions using visual inspection with or without magnifying glasses were not found to be significant ($p = 0.129$ and $p = 0.182$, respectively). However, a significant relationship was found between grade and the presence of detected carious lesions using the FACE device ($p = 0.018$, Table 2).

Table 1. Distribution of the cavities according to groups

Group	Cavity type												
	Class I		Class II		Class III		Class IV		Class V		Total	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	29	5.8	63	12.5	43	8.5	9	1.8	10	2.0	154	30.6
2	35	7.0	93	18.5	30	6.0	4	0.8	14	2.8	176	35.0
3	41	8.2	90	17.9	28	5.6	4	0.8	10	2.0	173	34.4
Total	105	20.9	246	48.9	101	20.1	17	3.4	34	6.8	503	100.0

Table 2. Relationships between the grade of the student operators and assessment methods

Group	Visual inspection without magnifying glasses				Visual inspection with magnifying glasses				FACE device			
	Caries-free		Caries detected		Caries-free		Caries detected		Caries-free		Caries detected	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	100	64.9	54	35.1	88	57.1	66	42.9	79	51.3	75	48.7
2	115	65.3	61	34.7	110	62.5	66	37.5	83	47.2	93	52.8
3	128	74.0	45	26.0	116	67.1	57	32.9	107	61.8	66	38.2
p	0.129 (*df* = 2)				0.182 (*df* = 2)				0.018 (*df* = 2)			

FACE, fluorescence-aided caries excavation.

Significant differences were found in visual-tactile assessments between Groups 1 and 3 (p < 0.001). The kappa values were substantial and mostly perfect (Table 3). A significant difference between inspection with the FACE device and visual-tactile inspection without magnifying glasses was found for Groups 1 and 2. The kappa values ranged from 0.463 to 0.761 (Table 4). A significant difference between inspection with the FACE device and visual-tactile inspection with magnifying glasses was found in Group 2. The FACE device detected more residual caries than visual-tactile inspection with magnifying glasses. The kappa values varied from moderate to substantial (Table 5).

Discussion

The null hypothesis was rejected, since the comparison of 2 caries-detecting techniques showed that the FACE device helped clinicians leave a cleaner dentin floor than the conventional visual-tactile method performed with or without using magnifying glasses. For the finalization of the caries excavation, visual-tactile assessment with or without magnifying glasses is still used by most clinicians. The problem is always to decide if the therapeutic endpoint has been reached and to distinguish between the dentin that should be removed and the dentin that can be safely

Table 3. Relationship between visual inspection without magnifying glasses and with magnifying glasses

		Visual inspection with magnifying glasses															
		Group 1					Group 2					Group 3					
		Caries-free		Caries detected		Total	Caries-free		Caries detected		Total	Caries-free		Caries detected		Total
		n	%	n	%	n	n	%	n	%	n	n	%	n	%	n
Visual inspection without magnifying glasses	Caries-free	87	87.0	13	13.0	100	107	93.0	8	7.0	115	114	89.1	14	10.9	128
	Caries detected	1	1.9	53	98.1	54	3	4.9	58	95.1	61	2	4.4	43	95.6	45
	Total	88	57.1	66	42.9	154	110	62.5	66	37.5	176	116	67.1	57	32.9	173
	p	0.002 (df = 1)					0.227 (df = 1)					0.004 (df = 1)				
	Kappa and p value	0.810, p < 0.001					0.865, p < 0.001					0.779, p < 0.001				

Table 4. Relationship between visual inspection and the use of a FACE device

		FACE device															
		Group 1					Group 2					Group 3					
		Caries-free		Caries detected		Total	Caries-free		Caries detected		Total	Caries-free		Caries detected		Total
		n	%	n	%	n	n	%	n	%	n	n	%	n	%	n
Visual inspection without magnifying glasses	Caries-free	69	69.0	31	31.0	100	73	63.5	42	36.5	115	102	79.7	26	20.3	128
	Caries detected	10	18.5	44	81.5	54	10	16.4	51	83.6	61	5	11.1	40	88.9	45
	Total	79	51.3	75	48.7	154	83	47.2	93	52.8	176	107	61.8	66	38.2	173
	p	0.001 (df = 1)					0.001 (df = 1)					0.064 (df = 1)				
	Kappa and p value	0.463, p < 0.001					0.473, p < 0.001					0.761, p < 0.001				

FACE, fluorescence-aided caries excavation.

Table 5. Relationship between inspection with magnifying glasses and using a FACE device

		FACE device														
		Group 1						Group 2						Group 3				
		Caries-free		Caries detected		Total	Caries-free		Caries detected		Total	Caries-free		Caries detected		Total
		n	%	n	%	n	n	%	n	%	n	n	%	n	%	n
Visual inspection with magnifying glasses	Caries-free	67	76.1	21	23.9	88	73	66.4	37	33.6	110	102	87.9	14	12.1	116
	Caries detected	12	18.2	54	81.8	66	10	15.2	56	84.8	66	5	8.8	52	91.2	57
	Total	79	51.3	75	48.7	154	83	47.2	93	52.8	176	107	61.8	66	38.2	173
	p	0.163 (*df* = 1)					0.001 (*df* = 1)					0.064 (*df* = 1)				
	Kappa and *p* value	0.570, *p* < 0.001					0.473, *p* < 0.001					0.761, *p* < 0.001				

FACE, fluorescence-aided caries excavation.

left behind. In the ideal caries excavation technique, all carious tissue should be removed selectively, while leaving potentially remineralizable tissue on the cavity floor.[13]

Current caries excavation techniques are not considered sufficient to remove only the irreversibly destroyed carious tissue.[1,15] Various methods and devices have been introduced for detecting residual caries, including caries detector dyes (CDDs), electronic caries monitors, and laser fluorescence light.[17,18] However, it has been reported that CDDs were not specific for infected dentin detection and mostly stained the dental-enamel junction or the circumpulpal dentin.[19]

Conflicting results have been reported for various fluorescence-based devices.[3,17,20,21] Lennon *et al.*[21] found that the FACE device was more effective in removing infected dentin than conventional excavation and excavation with the aid of CDDs. Lennon *et al.*[22] also investigated the time required to excavate the infected dentin and reported a significantly shorter excavation time with FACE. Zhang *et al.*[16] reported that the caries detection ability of the FACE technique was highly consistent and effective compared to laser-induced fluorescence, chemomechanical excavation, and conventional excavation.

The present study showed that use of the FACE device led to superior results in terms of detecting bacteria remaining in the dentin after excavation. Since more residual caries were detected using the FACE device, it can be asserted that the FACE device can provide a clinical aid in the detection of bacterially infected tissue. The only similar published data, in the study of Peskersoy *et al.*,[23] also demonstrated that the FACE device led to a higher detectability than CDDs in the diagnosis and removal of carious dentin.

The present study also found that visual caries assessment performance was influenced by the use of magnifying glasses. More caries-free cavities were observed when magnifying glasses were used. This may have been due to the detailed visualization of the cavities provided by the magnifying glasses.[24-26] Zaugg *et al.*[27] reported that dentists using magnifying glasses found more defects than their colleagues using no magnification tools at all. Studies conducted by Narula *et al.*,[24] and Maggio *et al.*[25] showed that magnification loupes significantly enhanced student performance in preclinical dental education and were considered an effective adjunct by the students who used them.

It should be noted that the present study has several limitations related to the FACE device and the study design. As the first step of the assessment process with the FACE device, which is based on light technology, the cavity should be fully opened and accessible. Therefore, unsupported but sound enamel may need to be sacrificed. The size of the light source also restricts the range of application of this technique.[16] For example, it was more reliable for the examination of the cavity floor, rather than the cavity walls, due to the field of view. The FACE device works only on cavity locations that can be seen clearly. The lack of standardization of the cavity types and patient-related factors is a limitation related to the study design. Additionally, the caries excavation and examination procedures were more difficult in patients with limited mouth openings.

Conclusions

Although further studies are needed, the promising results of this study suggest that fluorescence-assisted operative techniques may improve the efficiency of caries excavation and the detection of residual caries during cavity preparation.

Orcid number
Uzay Koç Vural, 0000-0002-8764-2174

Conflict of Interest: No potential conflict of interest relevant to this article was reported.

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