ORIGINAL RESEARCH

A Comparative Evaluation of DIAGNOdent and Caries Detector Dye in Detection of Residual Caries in Prepared Cavities

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ABSTRACT

Aim: The objective of this study was to determine the association between DIAGNOdent laser and caries detector dye in detection of the remaining caries in restorative cavities.

Materials and methods: The sample consisted of 100 cavities prepared in patients referring to the Department of Restorative Dentistry of Mashhad Dental School. After confirming caries absence by tactile examination, the presence of any residual caries was determined by a laser fluorescence (LF) device (DIAGNOdent Pen) and then by caries detector dye. The data were analyzed through McNemar test.

Results: When the cut off value was considered as ≥13, both DIAGNOdent Pen and caries detector dye found 54 cavities as without caries and 12 cavities as carious. There were 32 teeth diagnosed as decayed only by the dye and two cases that were diagnosed as having residual caries only by the DIAGNOdent. The McNemar test revealed a significant difference in the diagnosis of residual caries between the two methods ($p < 0.05$), as well as significant differences between each method and tactile examination ($p < 0.05$). When the cut off value was set at ≥25, no significant difference was found between laser fluorescence and tactile examination in residual caries detection ($p > 0.05$).

Conclusion: Both DIAGNOdent Pen and caries detector dye can be considered as adjuncts for detecting residual caries in prepared cavities. However, the use of laser fluorescence device can provide results that are more consistent with tactile examination, while relying on caries detector dye may result in excessive removal of tooth tissue, and thus increase the risk of pulpal exposure.

Clinical significance: Incomparision with caries detector dye, Residual caries detection by DIAGNOdent Pen is more consistent with tactile examination.

Keywords: Residual caries, DIAGNOdent, Dye detector, Laser fluorescence, Clinical trial, Remaining caries, Carity preparation.

INTRODUCTION

Remaining caries after cavity preparation continues to be a great concern for most clinicians, as the success of restorative treatment is largely dependent on removing unhealthy tooth tissues. Insufficient caries detection and removal can result in further loss of tooth structure under the restoration, causing pulpal inflammation and even loss of tooth vitality, which in turn makes the tooth more susceptible to future fracture.

In a clinical situation, several methods can be used for ensuring complete caries removal after excavation. The most frequently used technique is tactile examination by a dental explorer. Dentin discoloration and sound may also be used as supplementary though less precise adjuncts.[1,2] The diagnosis of caries removal with these methods is subjective, showing large variations depending on the experience of the practitioner. Therefore, other methods have been proposed for objective evaluation of residual caries during or after cavity preparation, which may be especially useful for dental students and those with insufficient clinical experience.

For many years, caries detector dyes have been used to stain the remaining areas of demineralization in prepared cavities.[3,4] This technique has been shown to well reveal carious dentin *in vivo*, however, it cannot sufficiently discriminate infected dentin from less mineralized normal dentin in circumpulpal areas and enamel-dentin junction.[5,6] Thus, the use of caries detector dye for diagnosis of residual caries may be associated with excessive removal of healthy tooth tissues and the resultant risk of pulpal exposure and tooth weakening.[5-7]

In the late 1990, a laser fluorescence (LF) technology was introduced for detection of dental caries on occlusal and flat tooth surfaces. DIAGNOdent (KaVo Dental,

Biberachl, Germany) is a neutral low power laser (wavelength 655 nm, 1 mW power) that has no interaction with the target tissue. The red light emitted from the DIAGNOdent is absorbed by healthy and carious tooth structures. Bacterial byproducts, especially protoporphyrin IX in carious tooth tissues are well absorbers of this wavelength,[8,9] fluorescing an infrared light following red absorption. The infrared light is detected by the device and is expressed as a value from 0 to 99, according to the stage of the caries process. The sensitivity and specificity of DIAGNOdent has been investigated in several studies,[10-13] and its appropriateness is well clear for caries detection on occlusal and flat surfaces.[14,15] The laser florescence measurement has also been used for detection of root caries[16,17] and secondary caries,[18,19] as well as for monitoring the caries process on teeth that are supposed to be remineralized after prophylactic treatments.[20,21] However, the efficacy of DIAGNOdent has not been sufficiently evaluated in the clinical conditions for detection of remaining caries after cavity preparation.

At the chairside, it is not possible to confirm the presence or absence of residual caries by precise methods, such as histological examination and scanning electron or confocal laser scanning microscopes. Tactile sensation of dentin by an expert may be regarded as the standard technique in the mouth, but it is subjected to overlook some areas of remaining caries. The aim of this study was to determine the association between the two objective techniques of residual caries detection, i.e. LF and caries detector dye, and to define the association of each technique with tactile examination following excavation.

MATERIALS AND METHODS

The samples of this *in vivo* study consisted of 100 adult patients with mean age of 42 ± 8 years, who referred to the Department of Restorative Dentistry of Mashhad Dental School. Patients included in the study had anterior or posterior cavities in dentin with sufficient extension to allow DIAGNOdent placement within the excavation. Teeth having remaining restorative material or fissure sealants, as those with congenital dentin anomalies or teeth with orthodontic bands were excluded from the study. Only one restoration was performed for each individual. The study protocol was approved by the Ethics Committee of Mashhad University of Medical Sciences and an informed consent was obtained from each patient.

Following the standard cavity preparation, caries was removed by conventional round burs (Komet, lemgo, Germany) in a low speed handpiece (speed 700 rpm) without water coolant. Then, the tooth was rinsed and dried gently with compressed air. Complete caries removal was judged by a restorative dentist (MA) and approved when the dentin was hard during probing with a sharp explorer (tactile examination). Subsequently, a trained examiner (MJ) explored the presence of remaining caries in all excavated cavities, using LF measurement and caries detector dye, as follows:

Laser Fluorescence Measurement

DIAGNOdent Pen (KaVo, Biberach, Germany) was used to detect any remaining caries in different surfaces of the prepared cavity, giving values from 0 (no fluorescence) to 99 (maximum fluorescence). DIAGNOdent emits a wavelength of 655 nm that is not damaging to eyes, thus the laser is applicable without using protective glasses.

The fissure probe of DIAGNOdent Pen was used in this study which directs light in the direction of the probe and is designated by the manufacturer to be used for caries detection on occlusal surfaces. The DIAGNOdent device was calibrated prior to each examination using a special ceramic reference object according to the instructions of the manufacturer. The laser tip scanned different surfaces of each prepared cavity in contact mode and the peak value, showing the maximum amount of demineralization, was recorded for each surface. Two cut off points were considered to signify residual dental caries: Cut off value ≥ 13 or cut off value ≥ 25. The measurements were scored as 0 indicating absence of caries and 1, indicating residual caries.

Caries Detector Dye Evaluation

After caries detection by DIAGNOdent Pen, the cavity was colored by a Caries indicator, Sable Seek, Ultradent product, USA) to determine any residual caries after excavation. For this purpose, a sufficient amount of material was applied in the cavity and left in place for 10 seconds, then rinsed off by a copious amount of water. After air drying, the cavity was examined by a dental mirror to detect stained dentin sites. The caries detector dye evaluation was converted to numeric scores of 0, when the color of the dentin remained white (no caries) and 1, when the color of the dentin stained green (residual caries). The location of dentinal caries was also recorded in stained teeth.

Statistical analysis: For both DIAGNOdent laser and caries detector dye techniques, the presence or absence of caries was scaled as 0 = no caries and 1 = residual caries. The McNemar test was used to determine the association between the two diagnostic methods in detecting remaining caries in prepared cavities, as well as detecting the agreement between each technique and tactile examination.

Statistical calculation was done by SPSS (statistical package for social sciences, Version 11.5, Chicago, Illinois, USA) for windows, and p-value less than 0.05 was considered to be significant.

RESULTS

The dye detector revealed no caries in 56% of cases, whereas 44% showed staining in different surfaces. When the cut-off point of DIAGNOdent was set at ≥13 for detecting residual caries, 14 teeth were found to be carious, whereas 86 cavities were considered without residual caries. However, when the cut off point of ≥25 was set for the laser, the number of carious teeth decreased to 5, and the number of sound teeth increased to 95.

The McNemar test indicated a significant difference in detection of remaining caries between tactile examination and caries detector dye (p < 0.001) as well as a significant difference among tactile examination and DIAGNOdent Pen when the cut off point was set at ≥13 (p < 0.001). However, when the cut off point of ≥25 was considered, no significant difference was found between tactile examination and DIAGNOdent for residual caries detection (p = 0.07).

The comparison between DIAGNOdent pen at cut off ≥13 and caries detector dye revealed that from the 100 prepared cavities, 54 showed no caries by both the DIAGNOdent and the dye detector, while caries detection was found to be common in 12 teeth (Table 1). Two cases were positive for caries by only the DIAGNOdent laser, and 32 teeth were diagnosed by only the dye detector as being carious (Table 1). The McNemar test indicated a significant difference in detection of remaining caries between the two diagnostic techniques (p < 0.001).

Regarding residual caries detection when cut off value was considered as ≥25 for DIANOdent Pen (Table 2), it was found that in both techniques, 55 cases were diagnosed as having no caries and four cavities were detected as being carious. In one tooth, the presence of remaining caries was diagnosed only by the DIAGNOdent, while 40 teeth were found to be carious by the dye detector individually (Table 2). A significant difference was found between the two diagnostic methods in detection of residual dentin caries (p < 0.001).

Among the 14 cavities that had been diagnosed by DIAGNOdent Pen as being carious (cut off ≥13), the most common sites of remaining caries were lingual (44.4%) and buccal (38.8%) cavity walls. Most caries detected by caries detector dye were placed in axial surface (35%), followed by pulpal (18.3%) and lingual (14.2%) surfaces.

DISCUSSION

This study investigated the association between two objective methods of detecting residual caries including laser fluorescence measurement and caries detector dye. The cavities considered to be caries free by tactile examination were included in the study and all surfaces of the cavities were evaluated by both techniques. The results showed significant differences between the laser fluorescence device and caries detector dye in diagnosis of carious dentin either when the cutoff was set at ≥13 or when it was set at ≥25. At cut off value point of 13, there were 32 teeth that were diagnosed by detector dye as having residual caries, while DIGNOdent revealed them without caries. There were also two teeth that were found to be carious by DIGNOdent but were sound with caries detector dye. At cutoff point of ≥25, the number of teeth that were diagnosed carious by only detector dye was 40, and the number of cases that revealed residual caries by just DIAGNOdent was one. These findings imply that the main difference between the two diagnostic methods relates to the higher frequency of caries detection by caries detector dye compared to the laser fluorescence device, however, it is not possible to differentiate true-positives from false-positives at the chairside. Since, the dentin was found to be sound before performing the experiment, the high frequency of staining found in this study may be related to the inherent disadvantages of caries detector dyes in differentiating carious infected from less mineralized sound dentin in the circumpulpal area and enamel-dentin junction.[5,6] In contrast, laser fluorescence technique does not rely on measuring mineral content of the tooth but is based on detecting fluorescence caused by bacterial byproducts in carious tooth tissue, thus it may be more suitable to discriminate infected from affected dentin during or after cavity preparation.

In the present study, 44 teeth were diagnosed out of 100 to be carious by the detector dye. Through DIAGNOdent

Table 1: Comparison of DIAGNOdent pen (cut off ≥13) and caries detector dye in detecting residual caries in prepared cavities

DIAGNOdent laser	Caries detector dye		Total
	Caries	No caries	
Caries	12	2	14
No caries	32	54	86
Total	44	56	100

Table 2: Comparison of DIAGNOdent Pen (cut off ≥ 25) and caries detector dye in detecting residual caries in prepared cavities

DIAGNOdent laser	Caries detector dye		Total
	Caries	No caries	
Caries	4	1	5
No caries	40	55	95
Total	44	56	100

Pen at cut off ≥13, 14 teeth were found as being cariously involved, while using cut off ≥25, only 5 teeth were detected to be carious. There were significant differences between the results of tactile examination and caries detector dye and also between the results of tactile examination and DIAGNOdent at cut off ≥13, but when cutoff value of ≥25 was considered, the results of tactile examination and DIAGNOdent were comparable. Most caries detected by caries detector dye were placed in axial, pulpal and lingual surfaces. Frequently, the less mineralized affected dentin on axial and pulpal surfaces was remained consciously to reduce the risk of pulpal exposure. Since, the cavity preparation was judged by an expert to be complete before performing the experiments, the findings of this study suggest that the diagnosis of residual caries by laser fluorescence measurement is more consistent with the results of tactile examination, while relying on detector dye to remove residual caries can cause excessive removal of tooth tissue and may be associated with the risk of pulp exposure. On the other hand, both DIAGNOdent Pen and detector dye revealed a relatively high frequency of remaining caries on lingual walls of prepared cavities. This area is frequently overlooked even by experienced clinicians because the access to this surface is occasionally limited in the mouth. The use of diagnostic aids after confirming caries removal by tactile examination can reveal possible areas of carious dentin in the prepared cavity and thus prevents from the future consequences. However, these should always be used in combination with tactile examination and the results should be interpreted according to the clinical situation before removing or retaining carious tissue.

There are different schools of thought regarding how much dentin should be removed during or after cavity preparation. An important factor that encourages complete caries removal in a prepared cavity is prevention of microleakage under the restoration, thus inhibiting recurrent caries and the possibility of tooth fracture and pulpal damage.[22] The study of Hevinga et al[23] revealed that the presence of residual caries under the restorations caused a significant decrease in fracture strength of the tooth restoration complex compared to the control group with complete excavation. Roeleveld et al[24] reported that the presence of residual caries combined with cervical gaps had a significant influence on the survival rate of class II glass ionomer restorations. In contrast, Bjorndal[25] indicated that if an excellent marginal adaptation is maintained, the presence of little remaining caries in the depth of the cavity may not cause a problem for short-term success of the restoration. Borczyk et al[26] reported that the presence of affected dentin did not predispose tooth tissue to secondary caries formation. Although, complete removal of all decayed

dentin had been advocated in the past during cavity preparation, a more conservative approach is to remove any demineralization in the external cavity walls (mesial, distal, gingival, buccal and lingual) during excavation, but leave softened affected dentin in pulpal and axial surfaces in order to prevent pulpal exposure. Therefore, in the present study the affected dentin was intentionally left in internal walls of deep cavities which caused a high frequency of staining when caries detector dye was used for diagnosis of residual caries.

Reviewing the literature, a large variation in cut off values of DIAGNOdent can be found in both *in vitro* and *in vivo* studies. Lussi et al[27] recommended the cut off values of ≥30 for operative intervention in dentinal caries. Regarding the occlusal and the flat surface caries, the potential of tooth structure for remineralization is relatively high, thus, a higher cut off point is justified to determine the necessity for treatment intervention. However, residual caries has a less potential for remineralization in a prepared cavity and the use of lower cut off point may be regarded more suitable. After comparing DIAGNOdent results with those of the gold standard, Lennon et al[28] selected 15 as the best cut off point to define presence or absence of dentin caries after cavity preparation. Boston and Sauble[29] reported a high accuracy for DIAGNOdent in differentiating dye-stainable from dye-unstainable surfaces when a cut off point of 11 or 12 was selected. In contrast, Unlu et al[30] considered the cut off point of 30 and over as indicating residual caries. The cut off value of ≥13, as used in the present study, may be regarded suitable to detect residual dentinal caries during excavation. A better strategy, however, is to consider a lower cut off values for detecting caries in external cavity walls and a greater cut off value for pulpal and axial surfaces.

Previous studies compared different modalities to detect residual dentinal caries, but most of these studies have been performed on extracted teeth,[28, 30] and so the results cannot be generalized to clinical conditions. Yacizi et al[31] reported significantly greater sensitivity but lower specificity for DIAGNOdent as compared with caries detector dye for detecting residual dentinal caries. Lennon et al[28] indicated a higher sensitivity and specificity for DIGNOdent as compared to the visual tactile examination and caries detector in diagnosis of residual caries. Unlu et al[30] reported a high sensitivity but low specificity for LF in detecting residual caries, thus recommended the use of LF in association with another diagnostic tool in order to avoid excessive removal of affected dentin. They also found that caries detector dye had the lowest accuracy value among the diagnostic techniques, suggesting its cautious use to test the residual dentin caries in order to prevent over excavation or the incomplete removal of the carious lesion.[30]

A limitation of this study is that it was performed in the clinical environment, thus it was not possible to confirm the presence or absence of dentin caries by histologic examination as the gold standard. Further study is required in the clinical condition to evaluate the performance of diagnostic aids on teeth that are aimed to be extracted in near future, such as wisdom teeth or those with periodontal problems in order to compare the clinical results with those of the gold standard.

CONCLUSION

1. Caries detector dye revealed a large number of teeth as having residual caries, in which DIAGNOdent laser revealed no caries. Since, the cavity preparations were judged to be complete by an expert before performing the experiment, these results suggest cautious removal of stained tooth tissues.
2. In comparison with caries detector dye residual caries detection by DIAGNOdent was more consistent with tactile examination.

CLINICAL SIGNIFICANCE

The use of DIAGNOdent for detection of residual caries can provide results that are more consistent with tactile examination.

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