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Secondary caries detection by DIAGNOdent and visual examination: A comparative clinical study.

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Abstract

Purpose: Composite resins have been used as restorative materials in dentistry for a long time. However recurrent caries is the main etiologic factor for replacing these restorations. Early diagnosis of recurrent caries process is of utmost importance. The present study aimed to determine the agreement between the visual and DIAGNOdent® techniques in the diagnosis of recurrent caries.

Methods: Seventy-two tooth samples (36 deciduous second molars and 36 permanent first molars) with Cl I occlusal composite restorations were examined visually by two pedodontist. The results of the examinations were recorded using a valid technique referred to as ICDAS (International Caries Detection and Assessment System). Then a third trained dentist examined the teeth again with the DIAGNOdent® tool. The data were compared using statistical analysis.

Results: There was a high rate of agreement between the results of the two techniques in the diagnosis of recurrent caries.

Conclusion: The DIAGNOdent® system can be used as an adjunctive technique for the diagnosis and screening of dental caries.

Keywords: Recurrent caries, Composite restoration; Diagnosis, Dentistry, Tooth,

Introduction

Composite resins have been used as restorative materials in dentistry for a long time. There is a higher demand for composite resin restorations compared to amalgam due to its tooth-colored nature and absence of mercury toxicity. However, despite these positive aspects, the use of composite resins is associated with some problems, such as abrasion, microleakage and recurrent caries. The main etiologic factor for microleakage is the polymerization shrinkage of composite resins, which results in gap formation between the tooth and the restorative material. This gap provides a path for the penetration of bacteria and fluids, resulting in postoperative sensitivity, margin discoloration, and finally recurrent caries. Recurrent caries is defined as the re-initiation of dental caries at restoration margins [1] and is the main etiologic factor for replacing composite resin restorations [2]. Mjor and Toffenetti (2000) reported that 50–60% of restorations are replaced due to recurrent caries [1].

It is very difficult to diagnose these carious lesions in their initial stages, and they are diagnosed only when they have progressed to destroy a large area of the tooth structure. Early diagnosis of these caries process is of utmost importance because the longevity of the restoration and tooth are determined by several factors, including recurrent caries.

Different techniques have been used to detect dental carries, including visual techniques (by observing color changes), tactile examinations with the use of mirrors and dental explorers, radiography and fiber-optic technique (by the illumination of the enamel by optic fibers and measuring the light scattering and refraction).

The diagnostic techniques for dental caries have undergone major changes, concomitant with advances in the treatment of dental caries. However, the conventional clinical techniques for the detection of dental caries are not compatible with its dynamic nature and cannot detect these lesions in their early stages. An ideal technique for examining and detecting dental caries should be non-invasive, simple, accurate and valid. It should not hurt or injure the patient so that it can be accepted by the patient and make them satisfied. Researchers are trying to find new techniques to not only improve the accuracy of treatment and decrease errors but also to make it possible to present or provide early treatment for carious lesions [3].

DIAGNOdent® laser is used in dentistry for the diagnosis of proximal caries. The technique relies on the measurement of the fluorescence reflected by the organic components of dental lesions, such as caries and calculus, which is displayed on the tool's monitor as a numeric value, with a range of 0–99 [4].

In this technique, laser beams with a wavelength of 655 nm are used to create a light differentiation. The carious structures of the tooth become luminescent after receiving light rays at wavelengths >680 nm, which is the basis for the diagnosis of caries by the DIAGNOdent® technique [5]. Some studies have been undertaken to evaluate the results of different techniques for the diagnosis of dental caries, indicating that the visual technique has exhibited the highest accuracy [6]. On the other hand, the use of the DIAGNOdent® technique is on the increase by dentists for the diagnosis of caries as an adjunctive tool.

Considering the increased use of DIAGNOdent® for the diagnosis of dental caries and since no clinical study has evaluated recurrent caries at the margins of composite resin restorations in children to the best of our knowledge, the present study aimed to determine the

agreement between the visual and DIAGNOdent® techniques in the diagnosis of recurrent caries at the margins of composite resin restorations in 7–12-yer-old children.

Materials and Methods

The Ethics Committee of Tehran University of Medical Sciences approved the protocol of the present descriptive study. The 7–12-year-old patients referring to the Faculty of Dentistry, Tehran University of Medical Sciences, were examined by two pedodontists on a dental unit under illumination by the unit light, using dental mirrors. Patients with Cl I occlusal restorations in permanent first molars or deciduous second molars were selected and included in the study. Seventy-two tooth samples (36 deciduous second molars and 36 permanent first molars) were selected. The minimum sample size was calculated at 36 for each group, using the mean comparison option for sample size determination of Minitab software by considering α=0.05, SD=0.015 and minimum significant difference of 0.01 [7].

After selecting the subjects, written informed consent was obtained from the parents. First, two pedodontists visually examined the tooth samples. To this end, first, the teeth were cleaned with the use of prophylactic brushes without any polishing agents by removing all the calculi and contaminants, followed by irrigation and drying. Each pedodontist visually examined the teeth separately with dental mirrors under the dental unit light. The results of the examinations were recorded on special datasheets using a valid technique referred to as ICDAS (International Caries Detection and Assessment System) [8]. The coding of the results of examinations in this system is as follows:

Code 0: No change in enamel luminescence after drying (>5 minutes of air syringe application). In this code, the sound tooth surfaces adjacent to the restoration or sealant should not exhibit any signs of caries. Marginal defects of the restorations, measuring <0.5 nm, which do not allow penetration of the round tip of a CPI probe, developmental defects, such as enamel hypoplasia, fluorosis, tooth abrasion, and internal and external stains, are classified in the category of sound teeth.

Code 1: The first visible changes in the tooth enamel. When the tooth is wet, there are no signs of color changes related to caries activity; however, after drying the tooth with an airstream for a long time (>5 seconds), opacity or color changes due to demineralization will become visible.

Code 2: Clear visual changes in the enamel or dentin adjacent to the margins of the restoration or fissure sealant. The tooth should be visualized while it is wet. In such a condition, the opacity related to demineralization or discoloration is visible.

Code 3: Carious lesions measuring <0.5 mm.

Code 4: Margin caries in the enamel and dentin adjacent to the restoration, along with the dark shadow of the dentin under it.

Code 5: A clearly visible cavity adjacent to the restoration, measuring >0.5 mm.

Code 6: A clearly visible cavity adjacent to the restoration with visible dentin on the cavity wall and floor, requiring replacement of the restoration.

It should be pointed out that code 0 indicates the absence of caries; codes 1 and 2 indicate enamel caries; and codes 3 to 6 indicate dentin caries.

Each clinician carried out tooth examinations separately; i.e., they were not aware of the examination results of the other clinician during the study. The tooth samples in which the two clinicians had reported different diagnostic results were excluded from the study. Then a

third trained dentist examined the teeth again with the DIAGNOdent® tool. To this end, according to the manufacturer's instructions (KAVO, Germany), first, the tip of the probe was calibrated on a piece of standard ceramic and then placed on the dried enamel of a sound tooth for initial calculations. After drying the tooth, the tip of the probe was placed on the tooth surface at the restoration margin and moved along the margin. All the displayed values were recorded, along with the maximum value. Data were classified as follows based on the Lussi & Hellwing method [9]:

0–13: Sound tooth structure

14–20: Initiation of enamel demineralization

21–29: Severe enamel demineralization

>30: Dentin lesions

SPSS 21.0 was used for the analysis of data. To this end, inter-observer agreement for the diagnosis of recurrent caries at composite rein restoration margins was separately determined and reported separately for deciduous and permanent teeth using the visual method. In addition, the agreement between visual and DIAGNOdent® techniques was determined and reported for both the deciduous and permanent teeth and for both observers. The means and standard deviations of the diagnostic results of the DIAGNOdent® technique were determined and reported separately for the ICDAS diagnostic codes.

Results

In this study considering observer No.1, the means and standard deviations of the quantitative diagnostic values of the DIAGNOdent® tool in the ICDAS codes in the deciduous and permanent teeth are shown in table 1 and 2 respectively.

For observers No.2 also the means and standard deviations of the quantitative diagnostic values of the DIAGNOdent® tool in the ICDAS codes in the deciduous and permanent teeth are shown in table 3 and 4 respectively.

Considering the agreement rates of the diagnosis of recurrent caries in deciduous teeth (based on the ICDAS scale), the value made by the two observers were similar with the code 0 in 12 teeth (19.0%), the code 1 in 10 teeth (15.9%), the code 2 in 16 teeth (25.21%), the code 3 in 4 teeth (6.3%), the code 4 in 2 teeth (3.2%), the code 5 in 2 teeth (3.2%) and the code 6 in 3 teeth (4.8%). There were differences in the remaining cases between the two observers.

For permanent teeth the diagnoses made by the observers were similar with the code 0 in 20 teeth (33.3%), the code 1 in 14 teeth (23.3%), the cod 2 in 7 teeth (11.7%), the code 3 in 4 teeth (6.7%) and the code 4 in 2 teeth (3.2%). In the remaining cases, there were diagnostic differences between the two observers.

Discussion

The diagnosis of recurrent caries is still considered a challenge due to the increase in the application of composite resins to restore teeth. Early detection of dental caries might be useful in preventing its progression. Conventional methods used for the diagnosis of recurrent caries, including visual and radiographic techniques, have some limitations; the accuracy of the visual method is limited for the diagnosis of recurrent caries, and this type of caries might be masked by restorations and superimposition of radiopaque structures or restorations on the carious lesion along the central beam line on bitewing radiographs [5]. Another limitation of bitewing radiographs in the clinic is that it is difficult to place radiographic films in the patients' oral cavities, which is attributed to differences in anatomic structures in

different individuals. Incorrect film placement and beam angulation, too, might result in overlapping of proximal angles, leading to incorrect radiographic interpretation [10]. On the other hand, use of the DIAGNOdent® has yielded promising results concerning the early diagnosis of different carious lesions; the use of this technique allows the dentist to evaluate the caries progression, too [11].

In the present study, the agreement of the diagnosis of recurrent caries at composite resin restoration margins was evaluated between visual and DIAGNOdent® techniques clinically in the deciduous and permanent teeth of 7–12-year-old children.

Based on the results of the present study, there was a high rate of agreement between the results of the two techniques in the diagnosis of recurrent caries; an increase in the extent of caries in the visual technique (extension of caries from the enamel to dentin), the quantitative values of the DIAGNOdent® system, too, increased considerably, and vice versa. In the code 0 of the visual technique, which indicates the absence of caries, the mean diagnostic values of the DIAGNOdent® technique in the two observers were 9.88 and 10.04, which are lower than the threshold value of 14 for the diagnosis of caries. In addition, in the codes 3 and 6 of the visual technique, which indicate dentinal caries, the DIAGNOdent® readings were more than 30 (the threshold for the diagnosis of dentinal caries). In this group, the mean DIAGNOdent® readings increased with an increase in the code for the diagnosis of caries; the reading was 99.0 in the diagnostic code of 6 (i.e., a clearly visible cavity adjacent to the restoration with the dentin visible on the cavity wall and floor, requiring the replacement of the restoration). On the other hand, in the diagnostic codes of 1 and 2, which are related to enamel caries, the mean DIAGNOdent® readings were more than 14 and less than 30, and the mean reading for code 2 was higher than that for code 1. These readings were reported for both observers and for both the deciduous and permanent teeth of t he subjects. Therefore, the DIAGNOdent technique exhibited favorable agreement and compatibility with the diagnostic results of recurrent caries in deciduous and permanent teeth and can be used as an adjunctive tool for the diagnosis and screening of recurrent caries.

Several studies have reported favorable reproducibility for DIAGNOdent® for the diagnosis of caries [12,13,14]. However, the present study evaluated the reproducibility of DIAGNOdent and the visual technique for the diagnosis of recurrent caries clinically in the permanent and deciduous teeth in children.

Sichani et al 2016 compared the accuracy of the DIAGNOdent® technique in the diagnosis of recurrent caries beneath the restorations in deciduous teeth with that of histological evaluations. They reported that the DIAGNOdent® technique exhibited high accuracy such cases compared to the radiographic technique and believed that it could be used as an adjunctive technique for the diagnosis of recurrent caries beneath composite resin restorations [15]. The findings above are consistent with those of the present study.

In addition, Saber Hamishaki et al 2014 compared the agreement of four different operators in the diagnosis of recurrent enamel and dentin caries in teeth restored with composite resin, under clinical conditions, and reported that the operators exhibited full agreement; therefore, DIAGNOdent® can be considered a useful adjunctive tool for the diagnosis of recurrent caries in posterior teeth [7].

Neuhaus et al 2012 compared the diagnostic results of DIAGNOdent® pen and conventional bitewing radiographs for the diagnosis of recurrent proximal caries at the margins of cervical amalgam restorations in vitro and reported that the DIAGNOdent® technique exhibited a better performance in these restorations compared to bitewing radiographs [16]. However, due to the accumulation of stains at restoration margins, the DIAGNOdent® pen readings were different, which resulted in false positive readings.

Rodrigues et al 2010 evaluated the diagnostic results of recurrent caries at composite resin restoration margins on the proximal tooth surfaces with the use of fluorescence laser, visual observations, bitewing radiographs and visual examinations + bitewing radiographs and reported that fluorescence laser exhibited performance comparable to routine techniques in the diagnosis of recurrent caries. Therefore, this tool can be used as an adjunctive technique for the diagnosis of recurrent proximal caries associated with composite resin restorations [17].

Nokhbatolfoghahaei et al 2013 carried out a systematic review and reported that DIAGNOdent® is a proper tool for the diagnosis of dental caries as an adjunct to other techniques; however, they believed that its use alone does not have adequate diagnostic accuracy [18].

However, Diniz et al 2016 compared the results of laboratory techniques for the diagnosis of dental caries and its evaluation with the ICDAS technique and visual observations, bitewing radiographs and DIAGNOdent for the diagnosis of dental caries at amalgam restoration margins on the proximal surfaces of permanent teeth and reported a lower diagnostic accuracy in such cases, with a better performance for ICDA and radiographic techniques in the diagnosis of carious lesions affecting the proximal surfaces in amalgam restorations [19]. The differences between the results of the present study and the study above might be attributed to differences in the type of restorations between the two studies. In addition, the diagnostic criteria used in the present study were different from those in the study above. Diniz et al used accuracy criteria and ROC (receiver operating characteristics) to compare the diagnostic performance of different diagnostic modalities. Since in the present study, composite resin restorations were used in all the cases, it might not be possible to compare the results with those of amalgam and other types of restorations. On the other hand, it has been shown that amalgam produces a better contrast between the restoration and caries on radiographs and improves the diagnostic results. In addition, amalgam affects the diagnostic accuracy of laser fluorescence techniques [19].

In the present study, since composite resin restorations were used in all the cases, it might have resulted in an improvement in the reproducibility of diagnostic observations in both techniques. Of course, it is necessary to accurately evaluate the role of the type of restoration in the diagnostic accuracy of different techniques to determine the effect of composite resin and amalgam restorations on the diagnostic results of dental caries.

In the present study, the diagnostic results of the visual observations and DIAGNOdent® techniques in the diagnosis of recurrent caries were determined at composite resin restoration margins in both deciduous and permanent teeth. Considering the differences in the dentin between the deciduous and permanent teeth, including the presence of more numerous s-shaped and straight dentinal tubes in deciduous teeth that accelerate the progression of caries and the lower amount of dentin

in deciduous teeth, it appears that there are differences in the performance of the DIAGNOdent® tool between the deciduous and permanent teeth [20]. However, such a difference was not detected in the present study, and an almost similar performance was observed for the DIAGNOdent® diagnostic tool in both tooth types. On the other hand, since the only gold standard for the diagnosis of dental caries is the histologic technique and it is not possible to apply this technique in the clinic, in the present study, the accuracy of the visual technique and DIAGNOdent was not considered, and only the agreement between these two techniques was evaluated. Initial evaluations of the results of the DIAGNOdent® diagnostic system in the diagnosis of dental caries indicated several advantages for its clinical applications [15]. This technique provides the dentist with the quantitative results of the diagnosis of dental caries, and the patients' compliance is not required, with no radiations involved [18]. However, the presence of possible confounding variables, such as dental plaque, calculus and stains, and the need for cleaning them and drying the teeth affect the results of this diagnostic technique, possibly increasing false positive results [21]. The results of a systematic review showed that the use of the DIAGNOdent® technique is very effective in dentinal caries [22].

To apply the DIAGNOdent® system more effectively, the tooth surfaces should be cleaned before the examinations because this system is very sensitive to the presence of mineral deposits, plaque, calculus and prophylactic pastes, and their presence might lead to wrong diagnosis [22]. In addition, the evaluations made by DIAGNOdent® are very sensitive to color changes and stains. Therefore, the results of the evaluations made on discolored surfaces should be interpreted with caution. In addition, it should be remembered that in such cases the numeric values displayed might be higher than the real values. Furthermore, the tip of the probe should be properly rotated and tilted along its axis during the calculations to make sure that the maximum fluorescence of the tooth areas is achieved. In addition, fluorosis and hypo-mineralized tooth structures might lead to incorrect results; however, further studies are necessary on the subject. Nevertheless, application of accurate inclusion and exclusion criteria, in association with the use of continuous cleaning procedures, might decrease or eliminate the effects of confounding factors with this examination modality.

Conclusion

Evaluation of the agreement of the diagnostic results concerning recurrent caries with visual examinations and DIAGNOdent® technique in the posterior teeth restored with composite resin showed a high rate of agreement between the results of the two techniques in the diagnosis of recurrent caries. So Diagnodent can be used as an adjunctive technique for the diagnosis and screening of dental caries.

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Legend Tables

Table 1: The central distribution parameters of the diagnostic results of DIAGNOdent® for deciduous teeth caries separately for different ICDAS codes in observer No.1.

ICDAS diagnostic codes	No.	Mean	SD	Min	Max
Code 0	16	9.88	5.15	4	23
Code 1	13	18.0	12.66	4	53
Code 2	19	26.79	19.37	10	99
Code 3	5	35.8	8.87	24	45
Code 4	2	99.0	0	99	99
Code 5	4	83.5	31.0	37	99
Code 6	4	99.0	0	99	99

Table 2: The central distributions parameters of the diagnostic results of DIAGNOdent® for permanent teeth caries separately for different ICDAS codes in observer No.1

ICDAS diagnostic codes	No.	Mean	SD	Min	Max
Code 0	28	10.04	8.01	2	39
Code 1	18	17.94	7.46	5	37
Code 2	8	23.75	5.73	16	31
Code 3	5	42.4	33.12	18	99
Code 4	1	99.0		99	99

Table 3: The central distribution parameters of the diagnostic results of DIAGNOdent® for caries in deciduous teeth separately for different ICDAS codes in observer No.1

ICDAS diagnostic codes	No.	Mean	SD	Min	Max
Code 0	16	11.75	11.78	4	53
Code 1	17	15.24	4.83	8	25
Code 2	20	28.45	18.72	10	99
Code 3	4	37.0	9.76	24	45
Code 4	4	83.5	31.0	37	99
Code 5	3	99.0	0	99	99
Code 6	4	99.0	0	99	99

Table 4: The central distribution parameters of the diagnostic results of DIAGNOdent® for caries in permanent teeth separately for different ICDAS codes in observer No.1

ICDAS diagnostic codes	No.	Mean	SD	Min	Max
Code 0	21	19.9	12.8	2	39
Code 1	24	54.16	15.8	5	37
Code 2	10	1.22	45.5	16	31
Code 3	5	4.41	1.34	13	99
Code 6	1	0.99		99	99