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Clinical Research

Clinical Evaluation of DIAGNOdent in Detection of Occlusal Caries in Newly Erupted Noncavitated First Permanent Molars in Caries-Active Children

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Clinical Relevance

This paper indicates that DIAGNOdent readings are not reliable for the detection of early occlusal caries in young permanent teeth.

SUMMARY

Objective: **The aim of this study was to compare the in vivo diagnostic ability of a laser fluorescence system (DIAGNOdent, KaVo, Biberac, Germany) with that of visual inspection in the early detection of occlusal caries in newly erupted noncavitated first permanent molars among caries-active children.**

Materials and Methods: **A total of 505 mandibular first permanent molar teeth in 307 children aged 6 to 7 years with decayed, missing, and filled tooth surfaces (DMFS)>8 were examined. Visual examination and DIAGNOdent measurement of caries were compared for teeth with intact occlusal surfaces or varying degrees of fissure discoloration, but with no radiologic evidence of enamel or dentin caries. Teeth were classified according to caries status as sound, enamel caries, or dentin caries using visual examination and DIAGNOdent scoring systems corresponding to histologic definitions of caries depth. Analysis of the**

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results was performed using Cohen's unweighted kappa statistic.

Results: **Statistical analysis revealed "poor" agreement between the two diagnostic methods (κ=0.231).**

Conclusion: **Clinical results suggest that the DIAGNOdent device does not seem to be suitable for accurate diagnosis of early caries lesions in newly erupted first permanent molars.**

INTRODUCTION

During the early stage of eruption, teeth are porous and highly susceptible to caries.[1-3] In addition, permanent first molars erupt at a time when oral hygiene is not fully maintained, and they continue to generate retention regions for food remnants until they grow to full, functional occlusion.[4,5] Because of their recent eruption, as well as the anatomic configuration of their occlusal surfaces, these teeth are at risk of developing caries.[6]

Studies conducted among children aged six to nine years found caries on 22% to 36% of newly erupted permanent first molars, and occlusal surface caries on 21% to 42% of permanent maxillary first molars and 25% to 48% of permanent mandibular first molars.[7,8] Moreover, occlusal surface caries were found to constitute 93% of all caries.[7] Epidemiologic studies conducted in Turkey reported that caries prevalence among permanent first molars increased by 15% during the first two years following eruption,[4] and that 50% of permanent first molars developed caries within three to four years following eruption.[9]

Recent studies have shown that carious lesions may progress into the dentin without giving rise to a macroscopically visible breakdown of the outer enamel surface, thus masking the spread of dentinal caries.[10]

Bite-wing radiographs have been combined with clinical inspection to diagnose proximal surface lesions and to aid in the diagnosis of occlusal caries.[11,12] However, bite-wing radiographs are unable to reliably detect noncavitated occlusal caries.[13,14] For this reason, it has been necessary to develop more sensitive diagnostic methods, such as the laser fluoresence (LF) system, which has been recommended for detecting and determining the depth of occlusal caries. DIAGNOdent was developed and designed based on the fact that laser light is absorbed by both the organic and inorganic structure of teeth, and it has the putative advantage of being able to quantify early mineral loss from dental caries.[10,15,16]

The accuracy of DIAGNOdent has been the subject of both *in vitro* and clinical studies. Although some authors have reported good to excellent performance of the LF device,[10,14-20] others have concluded that for noncavitated teeth, the performance of the DIAGNOdent system is no better than that of visual examination.[21–23]

In light of these facts, this study aimed to compare the *in vivo* diagnostic capability of laser fluoresence versus that of visual inspection for the detection of early occlusal caries in newly erupted noncavitated permanent first molars in caries-active children.

MATERIALS AND METHODS

Sample Collection

This study was conducted on 505 teeth (262 mandibular right molars and 243 mandibular left molars) in 307 caries-active (decayed, missing, and filled tooth surfaces [DMFS]>8) children aged six to seven years with newly erupted permanent first molars who attended the Pedodontics Clinic at the Ankara University Faculty of Dentistry. Teeth were selected for this study according to the following criteria: 1) fully erupted mandibular permanent first molars (crowns completely visible), 2) no visible macroscopic cavitation on occlusal, buccal, lingual, or proximal surfaces, 3) no enamel hypoplasia/hypomineralization defects or fluorosis, and 4) no orthodontic bands on teeth.[19,23]

Teeth with varying degrees of fissure discoloration were not excluded from the study.

Following clinical examination, bite-wing radiographs were exposed using E speed (ultraspeed) bite-wing film (Kodak, Kodak Company, Rochester, NY, USA) with an Image X System of 70 kVp and 10 mA (Italy), and an exposure time of 0.32 second. Radiographs were developed using an automatic processor (Dürr Dental, XR 25 S/ DL 24, Bietigheim-Bissengen, Germany). Radiographs were assessed by the examiners under standardized conditions using a light box with no magnification. Radiographs exhibiting dentin or enamel radiolucency were excluded from the study.

Parents and guardians of all participating children gave their written informed consent, and the study was reviewed and approved by the Ankara University Faculty of Dentistry Ethics Committee (Report No. 83).

Each tooth was examined by visual examination and DIAGNOdent by two previously calibrated blind examiners.

Examiner Training and Calibration

Prior to evaluation, examiners were trained and calibrated using 50 extracted molars that had no visible macroscopic cavitation. Both examiners visually assessed each tooth and agreed on the criteria to be used in evaluating fissure discoloration. The examiners were also trained in the use of DIAGNOdent in line with the manufacturer's directions. The examiners were not trained in radiographic interpretation, because teeth showing radiographic radiolucency were excluded from the study.

Visual Examination

All examinations were conducted under standard conditions in a professional dental unit with a dental light, a mirror, and an oil-free air syringe for drying teeth. Prior to inspection, molar occlusal surfaces were professionally cleaned with polishing rubber and pumice and were air-dried. For each participant, teeth were examined independently by two examiners in random order on the same day. Clinical inspection was performed according to a slightly modified version of the visual ranking method of Ekstrand and others.[24] The visual appearance of fissures was recorded using the criteria shown in Table 1. Teeth found to have local enamel defects or dentin caries were excluded from the study (scores 3 and 4). Intraexaminer reproducibility was assessed by having each examiner re-evaluate 50 teeth (10%) under similar conditions after a 30-day interval.

DIAGNOdent Measurements

Teeth in which neither enamel nor dentin caries cavities were detected by visual or radiographic examination were measured using DIAGNOdent (KaVo, Biberac, Germany). Before each reading was taken, the device was calibrated using the ceramic standard provided by the manufacturer. Teeth were isolated using cotton rolls and were dried with an air spray for two seconds. The standard value for each tooth was obtained by assessing the fluorescence in a sound region located on the buccal surface of each tooth and was recalibrated prior to each measurement. The occlusal site was measured by placing the tip of the device's probe on the fissure perpendicular to the long axis of the tooth, and the maximum reading obtained from the fissure pattern mesiodistally and buccolingually was recorded. Each tooth was examined and measured by two independent examiners, and the mean of the two measurements was recorded. Intraexaminer reproducibility was assessed by having each examiner re-evaluate 50 teeth (10%) by taking DIAGNOdent readings from the same locations and under similar conditions after a 30-day interval.

Table 1: *Visual Examination Criteria*

Score	Criteria
0	No change on enamel after longer than 5 seconds of drying
1	Opacity and discoloration on enamel after drying
2	Opacity and discoloration on enamel without drying
3	Localized enamel breakdown and grayish discoloration from the underlying dentin
4	Cavitation exposing the dentin

Interpretation of Results

Because of the absence of histologic examination, DIAGNOdent data were analyzed using the manufacturer's cutoff points, and visual data were analyzed using the system validated *in vivo* by Ekstrand and others,[25] in which visual scores are classified according to corresponding histologic depths (Table 2).[19] Accordingly, teeth were classified as sound, having enamel caries, or having dentin caries. In addition, DIAGNOdent measurements were classified using adjusted values with cutoff limits 1 point below and 1 point above the manufacturer's recommendations. LF fluorescence value ranges as stated by the manufacturer are given in Table 3 (KaVo DIAGNOdent, 1999).

Statistical Analysis

All data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 11.5 software program (SPSS Inc, Chicago, IL, USA), with a value of $p<0.05$ considered to be statistically significant. Intraexaminer reproducibility for visual examination and DIAGNOdent measurements was assessed using the intraclass correlation coefficient (ICC). Interexaminer reproducibility and agreement between visual examination results and DIAGNOdent measurements were calculated using Cohen's unweighted kappa (κ), with a value greater than 0.75

Table 2: *Histologic Scoring System for Visual and LF Systems for Caries Diagnosis*

Caries Diagnosis System	Histologic Examination Criteria		
	Sound Enamel	Enamel Caries	Dentinal Caries
Histologic score for visual examination	0	1–2	3–4
Histologic score for DIAGNOdent measurements	D_0	D_1-D_2	D_3-D_4
DIAGNOdent cutoff limits	0–13	14–19	>19
	0–14[a]	15–20[a]	>20[a]
	0–15	16–21	>21

[a] *Ranges recommended by the manufacturer.*

denoting excellent, 0.40 to 0.75 fair to good, and below 0.40 poor agreement.[26]

RESULTS

Reproducibility was "perfect" for the LF system (ICC=1.00) and for visual evaluation by the first examiner (ICC=0.96), and was "high" (ICC=0.94) for visual evaluation by the second examiner. Interexaminer agreement was "excellent" for all diagnostic methods (κ=0.969 for visual examination, κ=1.00 for radiograph examination and LF).

The relationship between visual and LF scores using the manufacturer's cutoff points for the DIAGNOdent readings is shown in Table 4. Visual examination scored 322 teeth as sound (0) and 183 as having enamel caries (1 to 2). Of 322 teeth scored as clinically sound according to visual examination, DIAGNOdent scored only 217 (67.4%) as sound, 60 (18%) as having enamel caries (D_1 to D_2), and 45 (14%) as having dentin caries (D_3 to D_4). Of 183 teeth scored as having enamel caries according to visual examination, DIAGNOdent scored 20 (10.9%) as sound (D_0), 45 (24.6%) as having enamel caries (D_1 to D_2), and 118 (59%) as having dentin caries (D_3 to D_4).

Statistical analysis found agreement between visual examination and DIAGNOdent measurements to be "poor" (κ=0.231) when the manufacturer's recommended cutoff points were used, and "poor" when the cutoff limit was lowered (κ=0.175) and raised (κ=0.263).

Table 3: *Ranges for DIAGNOdent Measurements Recommended by the Manufacturer*

DIAGNOdent Cutoff Limits	Criteria
0–14	Sound
15–20	Enamel caries
>21	Dentinal caries

DISCUSSION

The enamel of newly erupted teeth is immature and hypomineralized, making them highly permeable and susceptible to caries during the two to four years following eruption.[1-3] Early diagnosis of caries, especially among caries-active children, is therefore critical for protecting newly erupted first molar teeth from being lost to caries.[2] However, the diagnosis of noncavitated occlusal caries is generally considered problematic because the appearance of early caries in the occlusal surface—as a white-spot lesion, with brown discoloration around the fissure—may not be noticed by the naked eye, despite the high possibility of the presence of dentinal caries beneath discolored fissures; in fact, 60% to 71% of seemingly intact teeth have been found to have dentinal caries.[23,27] In spite of its high specificity (the ability to correctly recognize sound teeth), the low sensitivity (the ability to correctly recognize decayed teeth) of visual inspection has prompted recommendations that new diagnostic methods with high sensitivity be developed to aid in the detection of occlusal caries.[12,14,18,19]

Conventional radiography also has poor sensitivity in detecting early occlusal carious lesions that are limited to the enamel and the outer layers of dentin.[10,12,17,18,25] For this reason, radiography has been recommended as a supplementary tool only in the diagnosis of occlusal caries that extend to the inner layers of dentin.[15,25]

Some studies have indicated that the LF system is superior to visual and radiographic examination in terms of sensitivity in the detection of noncavitated occlusal dentin caries. Accordingly, DIAGNOdent seems to be a promising diagnostic tool as an adjunct to visual examination in this regard.[10,14,16,27] However, different conclusions in the literature are related to the performance of the DIAGNOdent

Table 4: *Comparison of Visual Caries Scores With DIAGNOdent Scores*

DIAGNOdent			Visual Examination		
Caries	**Score**	**Cutoff Limits**	**Score 0 (Sound) N**	**Score 1to 2 (Enamel Caries) N**	**κ Value**
Sound	D_0	[b] 0–13	195	14	0.467
	D_0	[a] 0–14	217	20	0.513
	D_0	[c] 0–15	231	25	0.539
Enamel caries	D_1-D_2	[b] 14–19	78	38	−0.038
	D_1-D_2	[a] 15–20	60	45	0.066
	D_1-D_2	[c] 16–21	49	48	0.123
Dentin caries	D_3-D_4	[b] >19	49	131	-
	D_3-D_4	[a] >20	45	118	-
	D_3-D_4	[c] >21	42	110	-
TOTAL			**322**	**183**	

[a] *ranges recommended by the manufacturer*
[b] *lower ranges*
[c] *upper ranges*

device, and these conflicting results are attributed to a range of factors, including type of teeth (primary or permanent)[17,18,20,28]; storage medium (used in *in vitro* studies)[18,27]; temperature of the physical enviroment[10]; stage of enamel maturation[17]; inadequacy of examiner training[18,28]; extent of occlusal caries examined (enamel or dentin caries)[28]; presence of exogenous stains, organic material, or calculus on the teeth[10,14-16,19,20]; type of study (*in vitro* or clinical)[10,15,16,22]; and variations in recommended cutoff points.[27,28] For this reason, it is difficult to make a judgment as to whether or not this device is reliable, and the present study aimed to make a contribution to this issue, especially because little information is available on the use of DIAGNOdent with newly erupted teeth.

Generally, *in vitro* studies on the detection and quantification of carious lesions regard histologic lesion depth as the "gold standard" with which results obtained from visual examination should be compared,[12,18] whereas *in vivo* studies regard clinical lesion depth as determined by excavation to be the "gold standard."[14,23] However, no excavation was required in the present study because of the absence of visible macroscopic cavitation; therefore, the results of visual examination were classified according to their hypothetical correspondence with histologic depths as described by Ekstrand and others[25] (Table 2). The reliability of this system has been evaluated and confirmed in other studies.[19,22,23,27]

Although several histologic examinations have been conducted under laboratory conditions in an effort to determine the optimal "cutoff" limits for DIAGNOdent measurements of various caries thresholds,[10,16] the cutoff limits provided by the manufacturer are generally relied on for *in vivo* use (KaVo DIAGNOdent, 1999). However, because the fluorescence response of caries in extracted teeth is affected by the type of storage solution and the length of time teeth are kept in storage, and because in vitro histologic examination is able to capture even minute changes in dentin, the automatic transference of cutoff values obtained *in vitro* to *in vivo* situations is not recommended.[19,23] This study used the cutoff points recommended by the manufacturer for the DIAGNOdent readings, but also

looked at altered ranges slightly higher and slightly lower than the manufacturer's recommendations.

Of 322 teeth scored as clinically sound according to visual examination, DIAGNOdent scored 105 (32.6%) as having enamel or dentin caries (Table 4). Because of the high sensitivity of DIAGNOdent to discoloration, exogenous stains, deposits, and calculus in the fissure and/or on the tip, it tends to overscore discolored fissures, leading to false-positive readings (i.e., healthy fissures are often diagnosed as decayed).[10,12,14-16,19,23,29] In the present study, to minimize the potential for erroneous readings, all occlusal surfaces were thoroughly cleaned before assessment. Moreover, none of the teeth assessed as clinically sound had any discoloration, staining, opacity, or radiolucency on radiographs (i.e., there was no obvious reason for a false-positive reading).

As numerous reports have demonstrated, it is likely that the specificity of DIAGNOdent is lower than that of clinical inspection. In other words, sound surfaces may be correctly recognized more often by visual examination than by DIAGNOdent.[11,14,15,21,23] Considering that false-positive diagnoses may lead to overtreatment, it may be reasonable to consider a technique that offers high specificity, even at the expense of a slight reduction in sensitivity, to be more appropriate for detection of caries.[30] Accordingly, it may be contended that teeth may be accepted as sound when a meticulous clinical examination reveals no visible signs of the carious process.

Because the laser fluorescence technique relies on the ability to quantify early mineral loss from dental caries, the performance of an LF system may be affected by physical properties of the tooth structure. In fact, one earlier study demonstrated that any change in structure causes an increase in the DIAGNOdent reading.[10] It has been suggested that DIAGNOdent measurements may be affected by the level of tooth maturation[2] because of the immature, hypomineralized, and highly porous character of the enamel of newly erupted teeth.[1,3] However, little information is available on the use of DIAGNOdent in evaluating teeth at different stages of enamel maturation. Although some researchers have suggested that DIAGNOdent readings are not influenced by the degree of maturation,[17] others have stated that changes in the mineral content and porosity of the tooth surface result in changes in fluorescence patterns, because the amount of light scattering increases with enamel porosity.[18,20] It is therefore possible to suggest that false-positive DIAGNOdent readings from clinically intact teeth in the present study may be related to the structural properties of newly erupted teeth.

Of 183 teeth visually assessed as having enamel caries based on opacity and discoloration, 118 (59%) were assessed by DIAGNOdent as having dentin caries (Table 4). This discrepancy indicates that the sensitivity of visual inspection is low or the LF system is more sensitive (i.e., visual examination is unable to distinguish dentin caries, or fissure discoloration is falsely evaluated as dentin decay by DIAGNOdent). The tendency of DIAGNOdent to overscore discolored fissures has been reported in other studies.[19,29] It has also been stated that high LF readings may indicate active caries or may be caused by staining, which indicates arrested lesions.[25] Because differential diagnosis of active and inactive initial caries is very important in terms of managing carious lesions, overscoring by LF may provide a distinct disadvantage; therefore, discolored fissures should be carefully analyzed before a treatment decision is made.[12,19,21]

It has been emphasized that DIAGNOdent measurements must not be relied on as the sole diagnostic tool in considering the need for operative intervention on a suspect fissure. Comparison of DIAGNOdent and visual scores suggests that unlike visual examination, DIAGNOdent is unable to distinguish between active and arrested enamel caries in fissures, which reinforces the recommendation that DIAGNOdent should be considered as a diagnostic aid only.[10,17,19] However, considering the absence of histologic validation in the present study, it is not possible to add further comments on visual or DIAGNOdent measurements, other than to emphasize that "clinical experience is a fundamental prerequisite for using the instrument."[10] Moreover, as mentioned earlier, the possibility that the structural properties of newly erupted teeth may result in overscoring by the LF machine needs to be taken into account. Because the nature of emitted fluorescence correlates with the degree of tooth demineralization, it is possible to suggest that mineral loss from hypomineralized young enamel increases the likelihood of enamel caries being wrongly identified as dentin caries.

It is interesting to note that of 183 teeth visually assessed as having enamel caries based on fissure discoloration, 20 (10.9%) were scored as sound by DIAGNOdent (Table 4). It is possible that highly sensitive systems do not result only in false-positive readings for enamel caries, but false-negative readings may also occur. Moreover,

Anttonen and others[17] have pointed out that sensitivity and specificity are not applicable in real clinical situations, but reveal only the ability of DIAGNOdent to distinguish a fissure with a true dentinal carious lesion from a completely sound surface.

Because the LF appraisal of caries is dependent on the cutoff points used,[28] a rather small difference on the LF scale can mean a shift from nonoperative to operative intervention.[27] When the DIAGNOdent cutoff value is raised, sensitivity decreases and specificity increases (i.e., the probability of false-positive readings diminishes).[17,29] Conversely, when the DIAGNOdent cutoff value is lowered, sensitivity increases and specificity decreases.[14,30] In the present study, results of DIAGNOdent measurements based on two different cutoff limits were compared with results obtained using the cutoff values recommended by the manufacturer; however, no improvement in agreement between the results of visual examination and those of DIAGNOdent was observed. For this reason, none of these value ranges appears to be applicable in the case of young permanent teeth.

CONCLUSION

In view of these findings, it was concluded that DIAGNOdent is not suitable for detection of occlusal caries in newly erupted first permanent molars. Moreover, to improve the performance of DIAGNOdent, the cutoff limits should be revised and reinterpreted according to clinical or histologic "gold standards" for these teeth. Until these issues are resolved, diagnosis of noncavitated occlusal caries should be based on careful visual inspection by experienced clinicians after cleaning and drying of teeth.

When fissures are sound or an inactive lesion is present, if the patient has a low caries risk, there is no need for any special treatment. Rather, the use of a fluoride toothpaste in conjunction with daily toothbrushing, regulation of dietary habits, and periodic re-evaluation of caries progression during regular check-ups should be sufficient. However, if the patient or the parents are not prepared to participate in such a preventive care program, or if the patient presents with a high caries risk, then fissures should be sealed, even if they are sound. When an active lesion is diagnosed, invasive fissure sealant is indicated, so as to allow observation of the extent of the lesion and removal of the carious decay.

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