Acta Odontologica Scandinavica, 2007; 65: 60–63

informa
healthcare

ORIGINAL ARTICLE

In vitro quantification of smooth surface caries with DIAGNOdent and the DIAGNOdent pen

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Abstract

Objective. A new generation of the laser fluorescence device, DIAGNOdent, for caries detection and quantification has been introduced recently. It is the DIAGNOdent pen. The aim of this study was to compare the validity and reliability of both laser-based devices, DIAGNOdent and the DIAGNOdent pen, in quantifying smooth surface caries. ***Material and Methods.*** The material comprised a sample of 52 premolar teeth extracted on orthodontic indication. The teeth were visually sound or had various stages of non-cavitated carious lesions on smooth surfaces. All teeth were photographed and measured with both DIAGNOdent and the DIAGNOdent pen by two examiners independently. The teeth were then sectioned into 300-μm slices and analysed under a microscope for verification of lesion depth. Histopathological analyses were performed by two observers to assess lesion depth, which was classified into five categories ranging from sound to dentinal caries. Reliability and validity of the two devices were evaluated in terms of intra-class coefficients and Spearman rank correlation coefficient, respectively. The relation between measurements performed by DIAGNOdent and the DIAGNOdent pen was analyzed using Pearson's correlation coefficient. ***Results.*** Both DIAGNOdent and the DIAGNOdent pen had excellent intra-observer agreement and acceptable inter-observer agreement. The correlation with histology for DIAGNOdent and the DIAGNOdent pen ranged between 0.47 and 0.57, although the correlation between DIAGNOdent and the DIAGNOdent pen was high. ***Conclusions.*** In this *in vitro* study, the new laser fluorescence device, the DIAGNOdent pen, showed similar reliability and validity at quantification of smooth surface caries compared to the conventional DIAGNOdent device. Agreement between DIAGNOdent and the DIAGNOdent pen was excellent.

Key Words: *Fluorescence, carious lesions, smooth surface*

Introduction

In clinical dental practice, the diagnostic challenge has become more complex because presentation and distribution of dental caries have changed over time and the range of preventive and operative treatment options has expanded. A less invasive approach is now taken to managing the disease. Methods offering accurate detection and quantification of smooth surface caries would have extensive application not just as aids to obtaining a correct clinical diagnosis, but also in evaluating the outcome of preventive and non-invasive treatment interventions by monitoring lesion changes on a longitudinal basis. Smooth surface carious lesions are frequently found among patients with high caries activity caused by unfavorable factors such as frequent sugar intake and insufficient oral hygiene, and in orthodontic patients after removal of fixed orthodontic appliances. For several decades, the accepted method for detecting carious lesions on smooth surfaces was visual inspection, which is based on subjective and qualitative evaluations. Of great impact on the management of such lesions would be a method quantifying lesion severity and even monitoring the progress or regression of lesions. DIAGNOdent (KaVo, Biberach, Germany), introduced in 1998, was intended as a method by which to quantify early carious lesions accurately.

Since then, DIAGNOdent has generated a great deal of research interest. Many studies have been published during the past few years, i.e. *in vitro* and *in vivo* evaluations of its reliability and validity in detecting and quantifying carious lesions on occlusal and smooth surfaces of permanent or deciduous teeth [1–14]. Several attempts have been made to use the device for proximal surfaces too, but its cone-shaped tip, designed for the detection of occlusal

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(Received 2 April 2006; accepted 9 October 2006)

ISSN 0001-6357 print/ISSN 1502-3850 online
DOI: 10.1080/00016350601058051

caries, was unable to penetrate far enough into the proximal space or deflect the light laterally [15]. Today, a new generation of this technique, the DIAGNOdent pen, has appeared on the market with a probe designed to enable access to the contact area close enough to capture fluorescence emerging from a carious proximal surface. Compared with DIAGNOdent, the DIAGNOdent pen is a less bulky, flexible, and cordless mobile instrument with differently shaped tips for different purposes. The mechanism behind the principle function of the DIAGNOdent pen is the same as for the conventional DIAGNOdent system, which has been described in detail previously [16]. *In vitro* application of the DIAGNOdent pen on quantification of carious lesions on occlusal and approximal surfaces has been studied and compared with the original DIAGNOdent device [17,18], and the conclusion is that the new DIAGNOdent pen might be a useful additional tool for caries quantification on both occlusal and approximal surfaces.

The DIAGNOdent pen has to be tested in the laboratory prior to clinical application. Since the original DIAGNOdent system has been validated against the well-established methods mentioned above, the DIAGNOdent pen is thus comparable with the conventional one in terms of validity and reliability. Therefore, in this *in vitro* study we aimed: 1) to compare the reliability of the DIAGNOdent pen with the conventional DIAGNOdent device for quantifying carious lesions on smooth surfaces and 2) to compare the validity of the DIAGNOdent pen with the conventional DIAGNOdent for quantifying carious lesions on smooth surfaces.

Material and methods

Teeth

The material comprised 52 premolar teeth extracted on orthodontic indication. The teeth were visually sound or had various stages of non-cavitated carious lesions on smooth surfaces. Teeth with stains, calculus, or hypomineralization were excluded from the study. The teeth were rinsed thoroughly under tap water, carefully cleaned with a toothbrush and stored in thymol-saturated saline under refrigeration. All test surfaces of all teeth to be diagnosed in the study were photographed digitally (Nikon COOLPIX 4500; Japan). The most opaque site, by visual examination, within each lesion was pre-selected as the measuring site. For those that were visually sound, the measuring sites were randomly selected on the smooth surfaces. The pre-selected measuring sites were marked on the prints of images, which were used to facilitate the laser fluorescence measurements and to define the section plane in the subsequent orientation of the tooth slice for histological analysis.

DIAGNOdent measurements

To determine the reliability of the measurements, two observers measured the 52 surfaces independently under identical conditions using the two devices, DIAGNOdent and the DIAGNOdent pen (KaVo Dental GmbH, Biberach/Riß, Germany). Each tooth was retrieved from the thymol-saturated saline, wiped with a paper tissue and dried in air for approximately 5 s. Laser fluorescence measurements with the two versions of DIAGNOdent were performed using a probe with a flat tip recommended for smooth surfaces. Measurement time was standardized to around 10 s. As recommended by the manufacturer, before every measurement session the instrument was calibrated against its own supplied ceramic standard. The standard value for each tooth was calibrated before each measurement by measuring at a sound site on the buccal surface. The measuring sites documented by digital photographs were scanned independently by the two observers using DIAGNOdent. Two days later the measurements were repeated by each of the observers at the registered measuring sites using the DIAGNOdent pen. After an interval of 1 week, the same measuring procedures were repeated by the same two observers using both devices. The observers again took independent readings of the same sites using the photographs as a guide. No records of DIAGNOdent readings from the first session were available at the second measurement session.

Histopathological analysis

After measurements with DIAGNOdent and the DIAGNOdent pen had been completed, the teeth were prepared for the histological examination, which served as the gold standard for validation of lesion depth. At the test sites indicated in the photographs, each tooth was embedded in methylmetacrylate and sectioned with a diamond saw perpendicular to the occlusal surface in a bucco-lingual or mesio-distal direction. Tooth slices, approximately 300-μm thick, were obtained and examined under a microscope at 16 × magnification by two observers independently. When a discrepancy occurred, consensus was reached by repeating the histological analyses at a joint session. A five-point scale was used to stratify the sites according to the histopathological appearance of demineralization: 0 = sound; 1 = enamel caries limited to the outer half of enamel; 2 = caries extending into inner half of the enamel, but not to the dentino-enamel junction (DEJ); 3 = caries penetrating the DEJ but limited to the outer half of the dentin; 4 = caries involving the inner half of the dentin.

Data analysis

Intra-class correlation coefficient (ICC) was used to evaluate the level of agreement between observers and within observers between the two measurement sessions for DIAGNOdent and the DIAGNOdent pen, respectively.

The correlation between DIAGNOdent and the DIAGNOdent pen was analyzed in terms of Pearson's correlation coefficient for the two observers. Mean values based on the data from the two observers were used for the calculation. The relationship between the gold standard, determined by histopathology, and the two DIAGNOdent devices was analyzed using Spearman's rank correlation.

Results

The ICC values for intra-examiner reproducibility of DIAGNOdent, given in Table I, were 0.99 and 0.97, respectively, with a mean of 0.98, indicating excellent intra-examiner agreement, whereas the ICC values for inter-examiner reproducibility were 0.72 and 0.67 for the first and second measurement, respectively.

Reliability of the DIAGNOdent pen in terms of intra- and inter-examiner agreement was similar to that of DIAGNOdent. The corresponding ICC values of the DIAGNOdent pen were 0.99 and 0.96 for agreement within the two examiners and 0.66 and 0.69 between the two examiners.

The correlations between DIAGNOdent and the DIAGNOdent pen assessed by Pearson's correlation coefficient were 0.92 and 0.96 for the first and second measurement sessions, respectively.

The results of the histopathological examination are presented in Table I. Table II presents correlation with histopathology for DIAGNOdent and the DIAGNOdent pen. The correlation coefficients ranged between 0.47 and 0.57

Discussion

The shortcoming of conventional diagnostic methods in early caries detection has resulted in the development of several diagnostic techniques for early detection and quantification of carious lesions.

A fundamental requirement of a diagnostic method for both clinical and epidemiological studies of dental caries is that it has to provide consistent and standardized measurements between and within observers. This highlights the importance of establishing the reliability of new diagnostic methods. The present *in vitro* study evaluated a new laser method, KaVo DIAGNOdent pen in terms of validity and reliability.

Table I. Results of the histopathological examination

Lesion extension	Teeth
Sound	15
Lesions involving the outer half of enamel	13
Lesions involving the inner half of enamel	16
Lesions involving the outer half of dentin	7
Lesions involving the inner half of dentin	1
Total	52

Table II. Correlations between DIAGNOdent and the DIAGNOdent pen values on one side and histopathology on the other

	1st observer		2nd observer	
Observers Measurements	1st	2nd	1st	2nd
DIAGNOdent	0.53	0.53	0.53	0.57
DIAGNOdent pen	0.48	0.47	0.52	0.51

Observer agreement in terms of intra-class correlation coefficients was calculated, the results showing excellent intra-observer agreement for both devices. This is in agreement with the findings of recent studies on quantification of occlusal and approximal caries using the DIAGNOdent pen [17,18]. However, the ICC values of inter-observer agreements for both devices based on the present study were found to be much lower, 0.70 and 0.68, compared with those of intra-observer agreement. This might be attributable to an examiner effect, since the second observer was not experienced with DIAGNOdent, although she had conducted a short training period before the start of the study. Practical training of inexperienced examiners in application of the technique on a relatively high number of teeth is important [19]. In addition, calibration between observers is necessary to ensure that the DIAGNOdent values can be compared between observers.

The high correlation coefficients, 0.92 and 0.96, respectively, indicated excellent agreement between the two generations of DIAGNOdent devices. This may in turn imply that it is possible to monitor carious lesions and compare the outcome, even if the lesions are registered by different generations of DIAGNOdent, provided that the measurements are performed by the same operator.

Table II demonstrates the correlation between lesion depth, determined by histological examination, and readings from DIAGNOdent and the DIAGNOdent pen, in terms of Spearman's rank correlation coefficient. Correlation with the gold standard was similar for both devices and for both observers, indicating that the DIAGNOdent pen performs just as well as the DIAGNOdent at quantification of smooth surface carious lesions, with the advantage of being a less bulky, more practical and flexible instrument. Neither device gave as satisfactory correlation with histopathological analysis as was found in a previous study on smooth surfaces using DIAGNOdent [14]. One possible explanation could have been the sample distribution regarding lesion extension included in the study. For studying the correlation of categorical data, the sample should ideally comprise an even

distribution of each category. However, this is hard to achieve, since the sample selection based on visual inspection was done before the histopathological analysis. In the present study with a sample of 52 teeth, there was only one tooth that had a carious lesion extending into the inner half of the dentin; 7 teeth had carious lesions extending into the outer half.

In the clinical setting, potential sources of error have to be considered because variables are not as readily controlled as under *in vitro* conditions. DIAGNOdent readings may be influenced adversely by a number of variables in the oral environment. Several studies with the conventional DIAGNOdent device have reported that the presence of plaque, calculus, food deposits, toothpaste, prophylaxis paste, and stains could give false-positive readings [1,3,20]. As the new device is based on the same physical principles, it is very likely that these disadvantages exist for the new device, too. It is therefore recommended that DIAGNOdent readings serve as a second opinion, and that a decision to treat by operative intervention should not be based on DIAGNOdent values alone. Assessment should include variables such as the patient's case history, fluoride experience and dietary habits, as well as perceived caries activity and the status of the tooth surface.

In conclusion, the present *in vitro* investigation revealed that both DIAGNOdent and the DIAGNOdent pen had excellent intra-observer agreement and satisfactory inter-observer agreement for quantification of carious lesions on smooth surfaces. Although the DIAGNOdent pen performed equally compared with DIAGNOdent in quantifying carious lesions on smooth surfaces using histology as gold standard, recommendations based on validity must be supported by more *in vitro* and *in vivo* studies. In particular, scientific applications such as evaluation of preventive programs and the extent to which the changes of a lesion can be reliably detected need to be further explored *in vivo*.

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