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ORIGINAL ARTICLE

# Proximal caries lesion detection in primary teeth: does this justify the association of diagnostic methods?

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**Abstract** The aim of this clinical study was to evaluate and compare the performance of visual exam with use of the Nyvad criteria (visual examination - (VE)), interproximal radiography (BW), laser fluorescence device (DIAGNOdent Pen-DDPen), and their association in the diagnosis of proximal lesions in primary teeth. For this purpose, 45 children ($n$= 59 surfaces) of both sexes, aged between 5 and 9 years were selected, who presented healthy primary molars or primary molars with signs suggestive of the presence of caries lesions. The surfaces were clinically evaluated and coded according to the Nyvad criteria and immediately afterwards with the DDPen. Radiographic exam was performed only on the surfaces coded with Nyvad scores 2, 3, 5, or 6. Active caries lesions and/or those with discontinuous surfaces were restored, considering the depth of lesion as reference standard. Sensitivity, specificity, accuracy, and area under ROC curve were calculated for each technique and its associations. Visual exam with Nyvad criteria presented the highest specificity, accuracy, and area under ROC curve values. The DDPen presented the highest sensitivity values. Association with one or more methods resulted in an increase in specificity. The performance of visual, radiographic, and DDpen exams and their associations were good; however, the clinical examination with the Nyvad criteria was sufficient for the diagnosis of interproximal lesions in primary teeth.

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## Introduction

Direct visual inspection of caries lesions on the proximal surface is made difficult by the point of contact [1, 2], thus making it challenging for the clinician to diagnose this type of lesion. For this reason, the clinical/visual exam has frequently been complemented by interproximal radiographs (BW) [3, 4]. However, the radiographic image underestimates the lesion depth and is incapable of detecting lesions in enamel, in addition to being a technique-sensitive method that inevitably exposes the patient to ionizing radiation [1]. In view of the preventive approach of modern dentistry recommends, the development of visual systems and tools that help with the detection of the first alterations in enamel is fundamental.

Codification of the signs suggestive of caries lesion proposed by Nyvad [5] takes into consideration the dynamic nature of the disease and evaluates its activity. Thus, the scores of this system do not envisage evaluation of the lesion depth, but rather the parameters that may alter the approach to and treatment of caries lesions, since active and cavitated lesions demand operative treatment, whereas active lesions without cavitation may receive preventive treatment [6]. The performance of this criterion has been evaluated in primary [7–9] and permanent teeth [5], and the results have shown good validity and reliability in the detection of caries lesions.

In addition to diagnosis, the auxiliary tools must allow monitoring of lesion progression, providing objective data that represent the condition of the tooth. The Diagnodent Pen 2190 (laser-induced fluorescence device (LF)) is a device that quantifies the carious process by means of laser-induced fluorescence. Clinical [1, 10, 11] and laboratory studies [12–14] in primary teeth have evaluated the capacity of the appliance to detect proximal lesions, and the results have been controversial.

Few studies have used the Nyvad visual criteria associated with the Diagnodent Pen in their methodology, as an aid in the diagnosis of proximal caries lesions [15, 16], and this association has not yet been studied in the proximal surfaces of primary teeth. Therefore, we proposed to evaluate and compare the NYVAD criteria (visual examination (VE)) with interproximal radiographs (BW), the Diagnodent Pen (LF), and their associations in the diagnosis of proximal caries lesions.

## Materials and methods

This study was approved by the Research Ethics Committee of the Araraquara Dental School—UNESP (Process 30/11). Written consent was obtained from the children's legal guardians before the study began.

### Sample selection

For this study, 45 children of both genders, aged between 5 and 9 years, who sought the Pediatric Dentistry Clinic of the Araraquara Dental School—UNESP for treatment were invited to participate. To be included in the study, patients had to present sound or carious primary molars in proximal contact. Teeth with restoration, occlusal caries, hypoplasias, and an advanced stage of rhizolysis were not included. A maximum of three tooth surfaces per child were selected. The sample size was calculated taking into consideration the equivalence of the methods tested (equivalence limit of 25 %), power of 80 %, and an estimated 90 % percentage of success [17] (Julious SA, 2009), making it necessary to have 50 contact surfaces.

### Visual examination

Before all the exams, the proximal surfaces were carefully cleaned with a Robinson brush at low speed, using prophylactic paste and dental floss, guaranteeing biofilm removal from the selected site. The exams were performed by an experienced examiner, with the subjects positioned in a dental unit with operating light illumination, a 3-in-1 syringe, a front surface buccal mirror, and a WHO probe. The criteria recommended by Nyvad 1999 [5] were used for visual inspection of the surfaces: (0) healthy, (1) active lesion with intact surface, (2) active lesion with discontinuous surface, (3) cavitated active lesion, (4) inactive lesion with intact surface, (5) inactive lesion with discontinuous surface, and (6) cavitated inactive lesion. The exploratory probe used for evaluating the surface texture was allowed to slide gently over the area investigated. In addition, the interdental papillae of the selected surfaces were evaluated with regard to the absence (0) or presence (1) of gingivitis and absence (0) or presence (1) of transparency on the occlusal surface with origin on the proximal surface of the tooth.

### Exam with laser-induced fluorescence device

Analyses were performed with the DIAGNOdent pen 2190 (Kavo, Biberach, Germany), and the type 1 tip for proximal surfaces was used in accordance with the manufacturer's recommendations. The appliance was calibrated against a ceramic standard and, afterwards, also against a smooth, healthy surface of the same tooth under analysis. This procedure was repeated for every surface analyzed. After drying for 3 s, the tip was inserted below the surface of contact, on both the vestibular and palatine/lingual surface, making exploratory movements until the highest peak value was obtained. The site was evaluated from the vestibular and palatine/lingual sides, where the highest value obtained was noted [13]. The presence or absence of caries lesion was determined using the cutoff points suggested by Diniz et al. [18] and was categorized into scores as follows: 0–14, healthy tooth; 15–21, lesion in the enamel; 22–37, lesion in the external half of dentin; and higher than 38, lesion in the dentin.

### Radiographic exam (BW)

Posterior interproximal radiographs were taken only in the sites that presented shadowing or cavitations (Nyvad scores 2, 3, 5, and 6) using Kodak Insight films (22×35 mm, Kodak, Rochester, MN, USA) and a Spectro 70 X Seletronic X-ray appliance (Dabi Atlante, Ribeirão Preto, Brazil) operating at 60 kvp and 10 mA, with exposure time of 0.50 s. To facilitate standardized exposure, film supports oriented for vertical and horizontal angulation were used. The films were processed in an automatic processor (9000, DENT-X, USA). The images were analyzed with reduced room lighting in a negatoscope (Fabinjet Dental, São Paulo, Brazil) and classified in accordance with the criteria proposed by Ekstrand et al. [19] as follows: (1) absence of radiolucence, (2) radiolucence in the external half of enamel, (3) in the internal half of enamel, (4) radiolucence in the external half of dentin, and (5) radiolucence in the internal half of dentin. The sites without indication for radiographic exam were classified as healthy (code 0).

### Reference standard method

The reference method was performed by two trained and experienced examiners (R.C.L. and L.S-P.). For this purpose, orthodontic rubber rings with a thickness of 4 mm were placed around the selected contact surfaces for 7 days and after this period, the teeth were examined under the same conditions described in visual examination. The healthy surfaces

(Nyvad score 0), without the need for any type of treatment, received only preventive care and were classified with code 0. The surfaces that presented active lesions without loss of structure (Nyvad score 1) received nonoperative treatment with fluoridated varnish and were classified with score 1. Surfaces with signs of caries (Nyvad scores 2, 3, or 6 and/or radiographic scores 2, 3, or 4) were restored, with the caries being removed, and the cavity depth classified as follows: (2) cavity in enamel, (3) cavity in dentin, or (4) deep cavity in dentin.

## Statistical analysis

For statistical analysis, the statistical software SPSS v. 16.0 (SPSS inc., Chicago, USA) was used. The data of the proximal surfaces were dichotomized into two cutoff points, according to the gold standard, so that in D1, they were considered lesions in enamel and dentin (0=healthy and 1, 2, 3, and 4=diseased), and in D2, only lesions in dentin (0, 1, and 2=healthy and 3 and 4=diseased). When the methods were associated, the surface was classified as diseased only when all the methods obtained positive results for the presence of lesion [20].

The sensitivity, specificity, accuracy, and area under the ROC curve (Az) were calculated for the methods (VE, BW, and DDPen) and their associations (VE+BW, VE+DDPen, and VE+BW+DDPen). Comparison of the sensitivity and specificity values between the methods was made by analysis of variance (McNemar test, $\alpha$ error of 0.05). Correlation between the radiographic and fluorescence methods with the visual exam was found by the Spearman correlation coefficient (CI 95 %). Agreement between gingivitis and occlusal transparency with the presence of caries lesion was calculated with the Kappa test at 5 %. Association between lesion depth after cavity preparation and the visual and radiographic exam was determined by the chi-square test.

## Results

The final sample consisted of 45 patients presenting 59 eligible contact surfaces. The prevalence of proximal caries lesions was 71.2 %, with 13.6 % being noncavitated lesions (Nyvad score 1) and 57.6 % cavitated lesions (Nyvad scores 2, 3, 5, or 6). Caries-free surfaces (Nyvad scores 0 or 4) represented 28.8 % of the sample. The surfaces most frequently affected were the mesial surface of the primary second molar (35.5 %) and distal surface of the primary first molar (33.3 %).

The values of sensitivity, specificity, accuracy, and area under the ROC curve of the methods alone, and of their associations, for lesions in enamel and dentin (D1) and in dentin only (D2) are shown in Tables 1 and 2, respectively. When the methods were evaluated alone, both for D1 and D2, the VE presented the highest values of specificity, accuracy, and area under the ROC curve, while its sensitivity values were exceeded only by the DDpen.

**Table 1** Sensitivity, specificity, accuracy, and area under ROC curve of diagnostic methods for lesions in enamel and dentin (D1)

| Associated methods | Sensitivity | Specificity | Accuracy | ROC |
|---|---|---|---|---|
| VE | 0.957 | 0.846 | 0.940 | 0.901 |
| BW | 0.761 | 0.615 | 0.729 | 0.688 |
| DDPen | 0.978 | 0.626 | 0.898 | 0.797 |
| VE+BW | 0.717 | 0.919 | 0.763 | 0.820 |
| VE+DDpen | 0.935 | 0.923 | 0.932 | 0.929 |
| NY+BW+DDpen | 0.728 | 1.000 | 0.779 | 0.859 |

In D1, the highest sensitivity values of the methods used alone and those of their respective associations were observed, and an increase in the specificity values in the association between diagnostic methods, these being superior when the three methods were used (1.00).

For lesions in dentin (D2), both VE and the DDPen presented higher sensitivity values than BW, with the association VE+DDpen presenting higher values than those of the other associations. Whereas, the specificity value was considered excellent when the three methods or VE+DDpen (1.00) were used.

For accuracy under the ROC curve, the values were higher for VE and its association with the DDpen, for both D1 and D2.

The values of correlation between VE and BW were 0.774; 0.678 for VE and DDpen and 0.548 for BW and DDpen (Spearman, $p<0.001$). Agreement between the presence of proximal caries lesion and gingivitis or occlusal transparency was statistically significant only for gingivitis (Kappa, $p=0.024$). The association between lesion depth after cavity preparation was significant with the visual exam ($p=0.002$) and with the radiographic exam ($p=0.006$).

## Discussion

Different methods have been proposed as auxiliary tools for the diagnosis of the proximal surface condition, with

**Table 2** Sensitivity, specificity, accuracy, and area under ROC curve of diagnostic methods for lesions in dentin (D2)

| Diagnostic method | Sensitivity | Specificity | Accuracy | ROC |
|---|---|---|---|---|
| VE | 0.938 | 0.963 | 0.949 | 0.950 |
| BW | 0.781 | 0.926 | 0.856 | 0.854 |
| DDPen | 0.969 | 0.704 | 0.847 | 0.836 |
| VE+BW | 0.750 | 0.923 | 0.873 | 0.856 |
| VE+DDpen | 0.942 | 1.000 | 0.966 | 0.969 |
| NY+BW+DDpen | 0.750 | 1.000 | 0.864 | 0.875 |

controversies about which would be the most appropriate technique or criterion for the detection of lesions on this surface.

The results of this clinical study showed good performance of the methods used, both in the detection of lesions in enamel and in dentin. The radiographic exam is the method most commonly used, showing good performance only for lesions in dentin [21, 22]. For this type of lesion, in this study, radiography presented high specificity (0.926), while in D1, the capacity of the method for diagnosing the absence of this lesion diminished (0.615). This may be attributed to the performance of the method, which is directly related to the severity of the lesion, compromised mineral content, and to the contrast between the healthy area and the carious tissue [23], underestimating the extension of the lesion [3]. In our methodology, the radiographic exam was performed when the surfaces were coded with Nyvad scores 2, 3, 5, and 6. We believe that this may have favored the performance of the radiographic exam because this exam was only performed when losses of structure were clinically detected. If the radiographic exam had been performed in all the surfaces, lower sensitivity values and, consequently, of accuracy and area under the ROC curve would have been obtained. This was clear in the surfaces that presented Nyvad score 1, that is, were diseased and would have been diagnosed as healthy by the radiographic exam, thereby representing a false negative.

Combination of the clinical exam with the radiographic did not result in an improvement in the capacity to diagnose the presence of lesion, when compared with the results of the clinical exam alone, both in D1 and D2, suggesting that the radiographic exam had negatively influenced the performance of the visual exam. Thus, bitewing radiographs for the detection of proximal caries lesions would be indicated in cases of suspected presence of lesion, evaluation of the depth, and proximity to the pulp [24, 25], but not as the main technique for establishing the diagnosis.

There are no doubts about the visual exam being the technique most used for the detection of caries lesions. In this study, the Nyvad criteria contributed to the excellent performance of the visual exam for the diagnosis of proximal caries lesions, both in enamel and dentin (Tables 1 and 2). These criteria are clearly described and allow differentiation between cavitated and noncavitated, active and inactive lesions, and surface characteristics, in addition to being a reliable and precise strategy for the detection of initial caries lesions [5, 9, 13, 26], and, therefore, minimize subjective interpretation and contribute to improving the sensitivity of this exam [23].

In this study, the DDPen presented the highest sensitivity values in both D1 and D2, although without great differences from the findings of VE. Bader et al. [27], in their systematic review, affirmed that the DIAGNOdent always presented the highest sensitivity and lowest specificity values. The greatest differences between these methods were with regard to specificity. Therefore, as the proximal surface presents a large quantity of plaque, due to the difficulty of cleaning even after prophylaxis, the readouts may result in false-positive readings [28].

The association of techniques for establishment of the diagnosis has been a controversial topic. Different authors have suggested that the association of diagnostic methods may increase the performance of the visual clinical exam [29–32], leading to better decision-making as regards diagnosis and treatment. However, Baelum [33] affirmed that the use of auxiliary methods in the visual exam involves suppositions, since they are based on physical phenomena, and do not adequately reflect the characteristics of the surface and activity of the lesion, suggesting that the use of yet another tool does not necessarily lead to better diagnostic decisions.

In this study, no improvement in the performance of the methods was observed associated with the visual and radiographic exams in comparison with the radiographic exam alone. This does not necessarily mean to say that the use of bitewing radiographs is contraindicated, since there is relevant evidence of the importance of this method for the diagnosis and treatment plan of caries lesions [34, 35]. According to Baelum et al. [36], when diagnostic observations are translated into clinical decisions about how to treat caries lesions, the tactile visual method alone represents the superior strategy, resulting in more correct clinical decisions. Moreover, the authors have pointed out that the association of the visual with the radiographic exam may increase the risk of false-positive results and consequently lead to overtreatment [36]. On the other hand, the study by Newman et al. [34] showed that the use of interproximal radiography together with the visual exam may increase the rate of detection of proximal lesions by up to 48 %. However, this study was conducted at restorative threshold and did not take into consideration initial lesions that could not be radiographically detected. Machiulskiene et al. [37] affirmed that the contribution of the radiographic exam diminished the rate proximal lesion detection from 44 to 25.4 % when diagnostic thresholds that include noncavitated lesions in the initial stages are used. Considering these aspects, we agree with Smith [38], who emphasized that unnecessary bitewing radiographs must be avoided, especially in children, as it is important to evaluate the risk factors/markers to determine which children could be benefited by the radiographic exam.

The concomitant use of DDpen with the visual exam resulted in the increase in specificity, without change in the values of sensitivity, accuracy, and area under the ROC curve, both in D1 and D2, demonstrating this to be a valid association for decision-making. Nevertheless, the good performance of the DDpen alone does not justify its use without an adequate prior clinical exam because authors [27, 39] have suggested that this may substantially increase the number of invasive treatments, frequently resulting in overtreatment, and reduce the frequency of correct diagnoses. Our results and interpretations are in agreement with those of Attrill and Ashley [40] when they affirmed that the performance of the association visual exam+DDpen is similar to that of the visual exam after adequate training.

In spite of the use of VE+BW+DDpen having presented a good performance, both in D1 and D2, it did not show better results when compared with the visual method only. To the contrary, with respect to the presence of lesion, the association was shown to be less sensitive, and more specific, without differences in the values of accuracy and area under the ROC curve. Our results are in agreement with the conclusions of Pereira et al. [39] and Mendes et al. [10], who also did not obtain improvements in the precision of diagnosis when they associated different methods.

Although the associations improved the specificity values, they did not represent the overall improvement in the diagnosis of proximal lesions because the values of accuracy and area under the ROC curve of the associated methods were not discrepant in comparison to those of the methods alone. The type of strategy used for evaluation of the associations considered only the cases in which all the methods were in agreement about the presence of disease. This method of analysis is more indicated in evaluating the performance of methods in populations with high caries prevalence [10], such as that evaluated in this clinical study, and consequently, this approach increased the specificity values while it diminished those of sensitivity.

Some considerations about the methodology and interpretations of the results of this study should be made. The high performance obtained with the methods used is pointed out, especially with the Nyvad criteria. We emphasize that the clinical exam of the patients was performed by an evaluator who has differentiated training and knowledge of processes related to caries disease. Therefore, we believe that undergraduate courses should invest efforts in the teaching and calibration of visual criteria because, as demonstrated in this study and in the literature, their correct use is sufficient for the establishment of diagnosis, and consequently decision about the treatment. Moreover, to consider accuracy, a measure of validity of the method may be problematic when the prevalence in the sample studied diverges greatly from 50 %, or when the values of sensitivity and specificity were discrepant [41, 42]. Although the prevalence found in this study was high (77.9 %), we noted similarity between the values of accuracy and area under the ROC curve and little discrepancy between sensitivity and specificity. Considering the application of mathematical tests has limitations in clinical studies, no statistical analysis was performed to compare the values of sensitivity, specificity, and accuracy between the methods and their association because the McNemar test is dependent on the proportion between positive and negative cases [43]. We suggest that the reader makes a complete interpretation of the values presented, taking into account what each of the parameters measured represents. Only a generalized evaluation may indicate the real diagnostic performance of methods approached in this study, whereas the values of isolated $p$ values could lead to conclusions without much clinical relevance.

## Conclusion

In spite of the good performance of the clinical visual, radiographic, and DDpen exams and of their associations, the use of the visual exam with the Nyvad criteria was shown to be sufficient for the diagnosis of interproximal caries lesions in primary teeth.

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