# An *in vitro* study of the correlation between clinical and radiographic examinations of proximal carious lesions in primary molars

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*The present* in vitro *study assessed the correlation between clinical and interproximal radiographic examinations in diagnosing proximal caries of primary molars. A total of 223 mesial and distal surfaces, from 125 primary teeth, were evaluated clinically and radiographically. The results demonstrated a strong correlation between the increase of depth of radiolucency in radiographic examination and the clinical stage of lesions. The interproximal radiographic examination presented an excellent capability for discriminating surfaces with and without cavities in primary molars.*
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## INTRODUCTION

Interproximal carious lesions present a particular problem for the dental practitioner. Difficulties in determining the presence or absence of a lesion (sensitivity and specificity of the exam), as well as the progression speed of mineral alterations have been the target of several publications.[6,13,19,22,29] In other sites, the first macroscopic evidence of proximal carious lesions is the white spot. With the progress of the carious process, demineralization may extend into open surfaces in a buccal-lingual direction from the initial lesion under the contact area.[20]

The next stage, enamel destruction occurs (cavitation) and the formation of a dark or grayish shadow may be observed through the occlusal surface. This observation, however, is not apparent in the primary dentition until the advanced stages of the lesion because of the wide contact area between adjacent teeth.[9]

Since the introduction of interproximal radiographic techniques, several publications have confirmed the supremacy of the radiographic examination over the clinical examination in the detection of interproximal carious lesions.[4,10,13,21,23,26,28]

Pitts[26] concluded that the clinical exam, when isolated, detected less than 50% of the total proximal lesions, while the radiographic exams detected approximately 90% of the total number of proximal lesions. Machiulskiene, Nyvad, and Baelum[13] found similar results.

In the primary dentition, according to Martins, Dos Santos and Cornacchia[15], the radiographic examination is capable of detecting 50% more lesions than the clinical exam. Looking at posterior primary teeth as well, Noronha *et al.*[23] observed that 73% of 419 proximal lesions were detected only through a radiographic examination.

Fiber Optic Transillumination (FOTI) and the temporary separation of posterior teeth have also been suggested as resources for the auxiliary diagnosis of

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lesions in proximal surfaces. Although these techniques possess diagnostic sensitivity, they are not considered substitutes for interproximal radiographs.[2,7,8,25,33]

On the other hand, the literature has presented promising results with digital radiography systems, especially when utilized in primary teeth.[22,31]

Although having some limitations, the radiographic exam is considered to be the most reliable method for the detection of proximal lesions in posterior teeth of both dentitions.[3,24] Furthermore, it is presumed that the radiographic image is not only capable of identifying the presence of lesions, but is also capable of distinguishing lesions that need surgical intervention from others that may be treated with non-invasive methods; thus complying with a very important pre-requisite for diagnostic methods.[29]

Because of the difficulties in establishing the correct diagnosis of proximal caries lesions in the primary dentition, and the reduced number of publications that evaluate the correlation between clinical and radiographic examinations in this dentition, the purpose of this *in vitro* study is to establish the correlation between the clinical and radiographic appearance of proximal carious lesions in primary molars. In this way, there is intent to assist the dentist in comprehending the images that the radiographic exam offers and its probable clinical significance.

## MATERIALS AND METHODS

In total, 125 first and second primary molars, upper and lower, were selected from previously extracted or exfoliated teeth. Of the 250 proximal surfaces, 114 mesial and 109 distal were used. The remainder of the surfaces were excluded from the sample because they presented restorations, caries lesions that were too extensive, or hypoplasias.

The teeth were individually mounted by adding acrylic to the inferior base, inside a plastic cylinder of 2.5 cm high by 2.5 cm diameter and filled with plaster. Each proximal surface was numbered and later classified as superior or inferior, right or left, and mesial or distal. Further the data was obtained through clinical and radiographic evaluations of both proximal surfaces.

### Clinical evaluation

The clinical evaluation was performed always by the same operator, after training and calibration. The *kappa* value obtained during calibration, utilizing 12% of the samples, was 1.0 (Perfect Concordance).

After cleaning and drying, the proximal surfaces were visually inspected under the dental unit light. The evaluation was accomplished in a single session, without access to the radiography results. The criteria for clinical evaluation used was according to Marthaler and Germann:[14]

0 - Sound surface
1 - Surface with a white or brown spot (non-cavitated lesion)
2 - Cavitated surface

### Radiographic evaluation

Number 2 radiographic film (Ektaspeed Plus, Eastman Kodak Company, Rochester / N.Y., USA), and dental radiograph equipment (Spectro II Dabi Atlante), of 60 kV and 15 mA were used. The parallel cone technique, with a colimator and film positioner, was used with a focus-object distance of 40 cm and a film-object distance of 1.1 cm. The horizontal projection was tangential to the proximal surface, with the cone's vertical angulation at zero degrees. Exposure time was 1.0 second.

The radiographic films were automatically processed (Dent-X processor, model 9000), and the dry-to-dry cycle had a duration of 5 minutes. After processing the films were placed in slide mounts and the surfaces were numbered and classified.

The radiographic evaluation was performed in each dental element separately, always by the same operator, and after training and calibration. The *kappa* value obtained during calibration (12% of the samples) was 0.86. The radiographic interpretations were done in a single session, using a magnifying glass and an x-ray viewer. The data obtained followed criteria according to Hintze, Wenzel and Danielsen:[8]

0 - Sound;
1 - Radiolucency in the external half of the enamel;
2 - Radiolucency into the internal half of the enamel;
3 - Radiolucency into the external third of the dentin;
4 - Radiolucency into the internal two-thirds of the dentin.

### Statistical Analysis

The data were entered into a data bank specifically designed for this research, using the program Epinfo version 6.0. To avoid errors during entering, data were digitized twice in identical banks and cross-checked. Statistical analysis was made with the programs Epinfo version 6.0, ROC 50 and SPSS for Windows.

Chi-square and Spearman's correlation tests were used to evaluate the association and correlation between non-parametric variables. Sensitivity and specificity values were calculated with a confidence interval (CI) of 95%. Receiver Operator Characteristic (ROC) curves were made to evaluate the capability of the radiographic examination in discriminating teeth with and without alterations.

## RESULTS

The comparison of radiographic and clinical analysis of the mesial and distal proximal surfaces of the deciduous molars can be observed respectively in Tables 1 and 2.

The Chi-square test showed a strong association between clinical exam and radiolucency ($P < 0.001$). Because there was no statistical difference between any of the surfaces evaluated (mesial and distal), the results of mesial surfaces were used for the discussion.

**Table 1.** Correlation between radiographic and clinical examinations of the mesial surfaces of primary molars.

| Radiographic Examination | Clinic Examination 0 | 1 | 2 | Total |
|---|---|---|---|---|
| 0 | 40.6% (26) | 57.8% (37) | 1.6% (1) | 56.1% (64) |
| 1 | 10.5% (2) | 78.9% (15) | 10.5% (2) | 16.7% (19) |
| 2 | 33.3% (4) | 41.7% (5) | 25.0% (3) | 10.5% (12) |
| 3 | 0.0% (0) | 7.7% (1) | 92.3% (12) | 14.4% (13) |
| 4 | 0.0% (0) | 0.0% (0) | 100.0% (6) | 5.3% (6) |
| Total | 28.1% (32) | 50.9% (58) | 21.1% (24) | 100.0% (114) |

**Table 2.** Correlation between radiographic and clinical examinations of the distal surfaces of primary molars.

| Radiographic Examination | Clinic Examination 0 | 1 | 2 | Total |
|---|---|---|---|---|
| 0 | 26.4% (14) | 69.8% (37) | 3.8% (2) | 48.6% (53) |
| 1 | 0.0% (0) | 84.6% (11) | 15.4% (2) | 11.9% (13) |
| 2 | 12.5% (1) | 62.5% (5) | 25.0% (2) | 7.3% (8) |
| 3 | 0.0% (0) | 16.0% (4) | 84.0% (21) | 22.9% (25) |
| 4 | 0.0% (0) | 0.0% (0) | 100.0% (10) | 9.2% (10) |
| Total | 13.8% (15) | 52.3% (57) | 33.9% (37) | 100.0% (109) |

Figure 1 shows ROC curves related to the capability of the interproximal radiographic examination to discriminate between cavitated and non-cavitated mesial and distal surfaces.

Figure 2 shows ROC curves of the same surfaces, evaluating the capability of the radiographic examination to discriminate between sound surfaces and surfaces with white or brown spots.

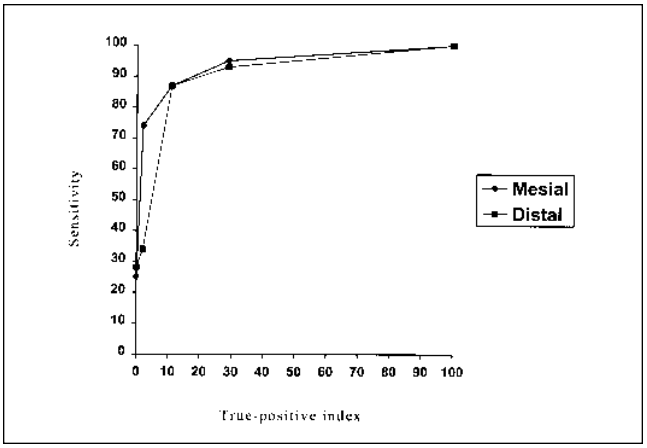


**Figure 1.** ROC curves of radiographic alterations and the diagnosis of cavitations in mesial and distal proximal surfaces True-positive index

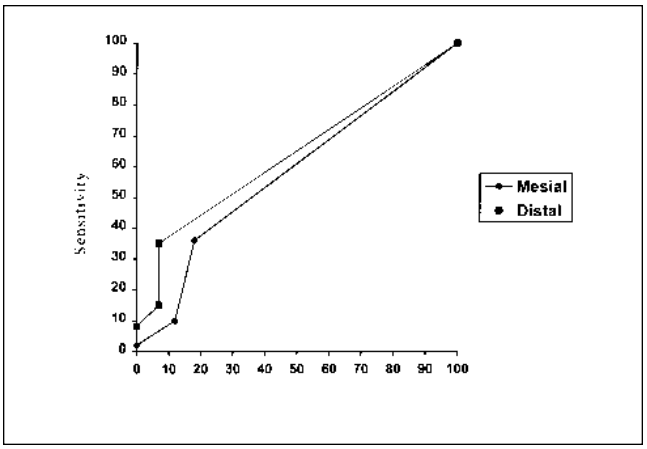


**Figure 2.** ROC curves of the radiographic alterations and the diagnosis of white or brown spots on the mesial and distal surfaces. Sensitivity

## DISCUSSION

In spite of some controversy, the great majority of authors agree that the determining factor for deciding to treat proximal surface lesions is the presence or absence of clinical cavitation.[16,17,26,29]

Although the radiographic examination does not completely discriminate between cavitated and non-cavitated proximal surfaces, this method seems to be the most reliable parameter in this sense. Thus, it is of great importance to evaluate the capability of the radiographic examination in detecting cavitated lesions in the primary dentition that therefore need restorative treatment.

In the present study, Spearman's correlation coefficient showed that there is a strong association between the increment of radiographic score and clinical score, for both tables, with $P < 0.001$.

In primary molars, according to the findings of the study, only 1.6% of cavitated mesial proximal lesions did not present radiographic evidence (score = 0), representing a false-negative radiographic diagnosis for the presence of cavitation. Assuming that invasive treatment not be rendered in this situation, the radiographic examination would be correct in 98.4% of surfaces.

In this same way, an interpretation can be made for the surfaces with radiolucency in the external and internal half of enamel, where 10.5% and 25% presented clinical cavitation, respectively. Therefore, the radiographic examination, suggesting a lesion restricted to the external and internal half of enamel and probably non-cavitated, was correct in 89.4% and 75% of cases, respectively. This leads to the conclusion that in those cases where the radiolucency is in the internal half of the enamel, there is a greater chance for the radiographic diagnosis to consider sound a cavitated surface (false negative diagnosis).

The margin of error, which leads the professional to observe and control, instead of restore, may be considered small in numerical value and of little clinical significance. This happens because the decision is not irreversible, and is reviewable in subsequent examination, so long as the patient is monitored, which the simple

presence of radiolucency suggests. In the studies of Waggoner and Crall[32] and Akapta *et al.*[1], all lesions with radiolucency in the external half of enamel were presented clinically without cavitation.

In relation to radiolucency in the internal half of enamel, Pitts and Rimmer[25] found cavitations in 10.5% of permanent teeth and 2.9% of primary teeth. Akapta *et al.*[1], in permanent teeth, found cavitations in 19.3% of the cases. Mejàre and Malmgren[18] and Thylstrup, Bille and Qvist[30] found 58% and 48% of the surfaces with cavities, respectively. Evaluating only the radiolucency restricted to enamel, Bille and Thylstrup[3] observed that 20% of the surfaces were cavitated. For Maltz and Weber[12] and Araújo *et al.*[2] 58% and 87% respectively did not exhibit cavitation.

In this study, when the radiolucency reached the external third of dentin, 92.3% of the cases had cavitations, which means that the radiographic exam would result in an error of only 7.7% (diagnostic false-positive for cavitation). If radiographic imaging were the sole determinant for restoring lesions in the external third of dentin, over-treatment would occur at the described percentage. Espelid and Tveit,[5] evaluating the external half of dentin, reported that 93% of surfaces were cavitated, similar to the data found in this study. Akapta *et al.,*[1] evaluating the external half of dentin as well, reported that 79.1% were cavitated.

When the radiolucency reaches the internal two-thirds of dentin, the radiographic exam showed exact correlation with the clinical evaluation, since 100% of cases were cavitated. If only the radiographic result "radiolucency in dentin" is considered, independent of depth, from a total of 19 surfaces that presented this condition, 18 were cavitated clinically and only one surface showed a white or brown spot. This means that making a decision to restore in cases where there is radiolucency into dentin, the dentist would be wrong in only 5.24% of cases (a false-positive diagnosis for cavitation). For Maltz and Weber[12] and Akapta *et al.,*[1] all surfaces with radiographic alterations in the internal dentin were associated with cavitations. For Rugg-Gunn[27] and Mejàre *et al.,*[17] all cases of radiolucency in dentin presented clinical cavitation.

It must still be considered that interproximal radiographs may be used, not only in the detection of lesions, but also as a baseline to measure progression,[24] observing the success or not of conservative therapy.[11]

The capability of radiographic examination in discriminating between clinically altered and unaltered proximal surfaces may be observed in ROC curves. The greater the area below the curve, the greater is the examination discriminatory power. Thus, the analysis of ROC curves in Figure 1 for the detection of cavitations in distal (95% CI, 0.87654 - 0.98826) and mesial (95% CI, 0.885424 - 1.0) surfaces demonstrate an excellent capability of interproximal radiographs in diagnosing proximal surfaces with and without cavitations.

In Figure 2, the capability of radiographic examination of discriminating between sound surfaces and surfaces with white or brown spots is displayed. It is noted that the areas under the curves are much smaller than the areas for detection of cavitations, thus concluding that the radiographic examination had little discriminatory power to discern between teeth with and without white or brown spots, because the area for distal surfaces is equal to 0.6380, IC 95% (0.494332 - 0.781668) and the area for mesial surfaces is equal to 0.5754, IC 95% (0.452116 - 0.698684) are close to 0.5, that is, possess little discriminatory power.

The dots on the curve are reported upwards and to the right, where the first dot represents the radiolucency in the internal two-thirds of dentin; the second dot, radiolucency in the external third of dentin; the third dot, radiolucency in the internal half of enamel and the fourth dot, radiolucency in the external half of enamel. So the best Inflexion Point (the point that presents the best sensitivity without loss of specificity) of the curve for distal surfaces, for example, was the point that represents radiolucency in the external third of dentin, with a sensitivity of 83.8% and specificity of 94.4%, determining that the radiographic image presents greater capability for the prediction of clinical cavitations. The curve for mesial surfaces presents similar results.

According to the results of ROC curves, it is observed that mesial and distal proximal surfaces behave in a similar manner in a radiographic examination in relation to clinical alterations, both for white or brown spots as for cavitations.

Nielsen, Hoernoe and Wenzel,[22] also observed similar results in respect to ROC curves when investigating 72 proximal surfaces of extracted primary molars, showing that the majority of the cavitated lesions presented radiolucency reaching the dentin. Thus, indicating that the radiographic examination has a high predicting value for detecting cavitated surfaces.

We agree with the opinion of Stecksèn-Blicks and Wahlin,[28] according to whom there are no reasons for the dental professional to restrain himself in making a radiographic examination when well indicated, taking advantage of modern and safe radiographic techniques. The reduction of caries prevalence means not only more children without caries lesions, but also that the damage is less extensive and besides that, more difficult to diagnose. Interproximal radiography may be the most important instrument for diagnosing and monitoring these lesions.

## CONCLUSION

The analysis of the results lead us to conclude that:

1. There is a strong correlation between the depth of radiolucency in the radiographic examination and the presence of cavitation in proximal surfaces of primary molars;

2. The interproximal radiographic examination showed a high sensitivity when diagnosing cavitated lesions, whose characteristic image, in the sample used, showed the presence of radiolucency in dentin;
3. The interproximal radiographic examination showed low power of discriminating sound teeth from teeth with a non-cavitated lesion.

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