Comparison of three diagnostic techniques for detecting occlusal dental caries in primary molars: An in vivo study

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ABSTRACT

Aim: To compare the accuracy and repeatability of three diagnostic systems; visual inspection, bitewing radiography, and CarieScan PRO for occlusal caries diagnosis in primary molars.

Materials and Methods: 216 occlusal surfaces of primary molars examined in turn by two examiners using each of three diagnostic systems (visual inspection, bitewing radiography, and CarieScan PRO). Examiners indicated operative intervention (validation method) for 104 teeth which were used for statistical analysis. The validation method was cavity preparation when the two examiners agreed about the presence of dentinal caries. Sensitivity, specificity, likelihood ratio, positive predictive value (PPV), and negative predictive value (NPV) were calculated for each diagnostic technique. Inter- and intra-examiner repeatability was calculated for each diagnostic system using the Cohen’s kappa statistics.

Results: Visual inspection showed the highest sensitivity (0.93). The highest sensitivity and NPVs were provided by CarieScan PRO (0.97 and 0.95, respectively) however this was offset by a lower specificity (0.82) compared to other techniques. The CarieScan PRO gave the highest values of Cohen’s kappa statistics.

Conclusion: This study showed low sensitivity but substantial specificity with visual inspection. Bitewing radiography performed poorly overall when compared with the other two systems. The CarieScan PRO technique gave the highest overall combination of sensitivity and specificity for detection of occlusal caries.

Key words: Bitewing radiography, caries, sensitivity, specificity

Original research

There is an increase in the incidence of dental caries in children and developed nations due to lifestyle changes. Easy availability of sweets, chocolates, colas, and sweetened fruit juices are the cause for the increase in caries. As a result, there is greater risk of carious attack on occlusal surfaces. The more sensitive and reproducible diagnostic tools for precise caries detection in children are needed because of the complex occlusal anatomy.[1] Early detection of dental caries will minimize extensive treatment and reduce pain and sensitivity in a child. The management of dental caries demands detection of carious lesions at an early stage.[2] Visual inspection is most commonly used method for detection of dental caries. The use of bitewing radiographs for occlusal caries diagnosis has been questioned, due to the lack of its accuracy.[3,4] However, the value of this method has been reconsidered because of its importance in the diagnosis of occult caries.[5] Advances in caries research led to the introduction of novel technologies to help the clinician in diagnosis of early carious lesions. CarieScan PRO based on alternating current impedance spectroscopy is one of the recent examples of such novel technology. This device relies on the application of a small alternating electrical signal which is undetectable by the patient, through the tooth while monitoring the response on the sensor. The result is displayed on the liquid crystal display

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screen and the color light emitting diode (LED) display that enables dental professionals to evaluate the depth of the carious lesion.[6]

This is an in vivo study which compares the accuracy and repeatability of three diagnostic techniques that is visual, bitewing radiograph, and CarieScan PRO device for occlusal caries detection in primary molars.

MATERIALS AND METHODS

Study design
The study was conducted in Department of Pedodontics and Preventive Dentistry. 216 primary maxillary and mandibular molars from 38 patients (22 males and 16 females) aged 6–9 years were selected for the study. The teeth were selected with apparent absence of occlusal restorations, occlusal fissure sealants, hypoplastic teeth, or frank occlusal cavitation resulting from carious attack.

Approval to conduct the study was sought and obtained from the Institutional Review Board of Ethics. Signed informed consent was obtained from parents or legal guardian of selected children.

Two examiners, experienced in caries diagnosis, were trained to use CarieScan PRO device according to the manufacturer’s instructions. A pilot study was conducted using 32 teeth prior to this study to calibrate the examiners for interpretation of visual inspection and bitewing radiography. Both examiners validated all the three diagnostic techniques.

Visual inspection
After cleaning and drying the tooth surface, visual inspection was performed with mouth mirror under artificial light without probing or magnification. The presence or absence of occlusal caries was recorded using the scores [Table 1].

The criteria used to record the visual appearance of teeth were based on the scoring given by Ekstrand et al.[7] A sound tooth (Score 0) was the one in which the fissure showed no change in enamel translucency after drying. Enamel caries (Score 1) was defined as an opaque white spot lesion around the fissure that appears after tooth drying. When the enamel area had a gray discoloration from the underlying dentin, it was considered as dentinal caries (Score 2). Stained fissures were not considered as carious lesion [Figure 1].

Bitewing radiography
Size 1 dental film (E-Speed, Kodak, New York, USA) held in bitewing film holders (Hawes-Neos, Bioggio, Switzerland) were used in combination with a 70 kV, 10 mA X-ray equipment (IntraSkan DC, Germany) with an exposure time of 0.8 s. A freshly prepared solution was used each time for film development. The same investigators examined the films on a viewing box (View-IOPA, Surat, India) without magnification 1 day after visual inspection. The radiological examination was conducted blindly and independently by the two examiners. Thus, they could not associate the visual appearance of the tooth and the radiographic film. The presence or absence of occlusal caries was established by the criteria shown in Table 1 and Figure 2.

CarieScan PRO
The CarieScan PRO (CarieScan Ltd., Dundee, Scotland) technology was used for the alternating current impedance spectroscopy assessment, calibrated, and handled according to the manufacturer’s manual. Each tooth was cleaned by applying prophylactic paste which was freshly prepared by mixing pumice powder and distilled water. The tooth was then isolated by cotton rolls followed by air drying for 5 s. The ends of the sensor tip were pressed into the fissures with the same light pressure as when using a pen, ensuring that the tip was not moving during measurement. The test value was registered when the device, three times showed a stable score at the preselected site. The CarieScan PRO is a handheld caries detection device which is applied to a tooth surface after it is isolated and properly dried. Red, yellow, and green LED pyramids are illuminated on the device to correspond with the numerical score. The green pyramid can be seen with scores from 0 to 50, the yellow with scores from 51 to 90, and red with scores from 91 to 100. The presence or absence of occlusal caries was recorded according to the instruction manual using the scores shown in Table 1, Figures 3 and 4.

Validation method
The validation method for diagnosis (gold standard) was determined by fissure eradication or enameloplasty using a Fissurotomy® carbide burs (SS White, New Jersey, USA) consisting of narrow taper fissure (micro NTF) and shallow taper fissure (micro STF) burs.[8] However, not all fissures could be validated as this is an invasive method. Thus, for ethical reasons, opening of the cavities occurred only in cases when both examiners agreed to the presence of dentinal caries (Score 2). The decision-making about invasive treatment was carried out when at least one diagnostic method showed Score 2 by each examiner.[9]

Table 1: Scores for diagnosis of occlusal caries by visual inspection, bitewing radiography, CarieScan PRO and validation method

| Score | Visual inspection | Bitewing radiograph | CarieScan PRO | Validation method |
|-------|-------------------|---------------------|---------------|-------------------|
| 0 | No caries | No radiolucency | 0-50 (green LED® pyramid) | No caries |
| 1 | Caries confined to enamel | Radiolucency confined to enamel | 51-90 (yellow LED® pyramid) | Enamel caries |
| 2 | Caries extending to dentin | Radiolucency extending to dentin | 91-100 (red LED® pyramid) | Dentine caries |

1LED=Light emitting diode

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When both examiners decided to conduct an operative intervention, a conservative preparation was used to remove the enamel until caries was reached. The carious tissue was then removed until hard dentin was found. The examiners used the dentin hardness criteria with an explorer to distinguish the carious and healthy dentin. Scores according to the severity of the lesion were established for each validated tooth [Table 1].

Statistical analysis
Index of sensitivity, specificity, likelihood ratio (LR), positive predictive values (PPVs), and negative predictive values (NPVs) and were calculated for all diagnostic methods. Repeatability of each method was assessed using Cohen’s kappa coefficient using the interpretation proposed by Landis and Koch.\(^{10}\) Statistical analysis was done using MedCalc statistical software version 13.3.1. (MedCalc Software, Ostend, Belgium).

RESULTS
A total of 216 teeth were examined with three methods by two examiners. Fifty-two teeth were not drilled because the examiners did not indicate restorative treatment. Sixty teeth were considered sound exhibiting absolutely no signs of caries or demineralization in the fissures. These sound teeth could not be drilled either. As these teeth could not be opened, they were excluded from the sample. Examiners indicated operative intervention for 104 teeth which were used for statistical analysis.

Sensitivity and specificity of the diagnostic systems for dentin caries are specified in Table 2. The clinical and radiographic examination had high specificity but low sensitivity. The Cariescan PRO method was characterized by highest values for sensitivity (0.97) and lowest specificity (0.82). However, this device showed the lowest PPV (0.86) and lowest value of LR (4.11) among the other diagnostic techniques.

Repeatability values are represented in Table 3. Cohen’s kappa coefficient values were calculated for checking intra- and inter-examiner repeatability. Visual examination and CarieScan PRO showed the highest values for both the repeatability tests.

DISCUSSION
The sensitivity of visual examination according to present study was 0.60. Previously conducted studies confirm that occlusal

| Methods                  | Se   | Sp   | PPV  | NPV  | LR   |
|--------------------------|------|------|------|------|------|
| Visual inspection        | 0.60 | 0.93 | 0.93 | 0.60 | 8.57 |
| Bitewing radiography     | 0.37 | 0.91 | 0.87 | 0.50 | 6.06 |
| CarieScan PRO            | 0.97 | 0.82 | 0.86 | 0.95 | 4.11 |

\(^{1}\)Sensitivity, \(^{2}\)Specificity, \(^{3}\)Positive predictive value, \(^{4}\)Negative predictive value, \(^{5}\)Likelihood ratio

Figure 1: Scores for visual inspection: (a) Score 0 (no caries), (b) Score 1 (caries confined to enamel), (c) Score 2 (caries extending to dentin)

Figure 2: Scores for bitewing radiography: (a) Score 0 seen with left mandibular second molar. (b) arrow showing Score 1 with a right mandibular second molar. (c) arrow showing Score 2 with right mandibular second molar

Figure 3: CarieScan PRO kit

Figure 4: Detection of caries using CarieScan PRO
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Table 3: Cohen’s kappa value of inter- and intra-examiner repeatability for each diagnostic system (95% confidence interval)

| Cohen’s kappa coefficient | Visual Inspection | Bitewing radiography | CarieScan PRO |
|---------------------------|-------------------|-----------------------|---------------|
| Examiner 1                | 0.834 (0.767-0.887) | 0.814 (0.765-0.863) | 0.889 (0.821-0.924) |
| Examiner 2                | 0.815 (0.697-0.828) | 0.801 (0.759-0.831) | 0.924 (0.903-0.952) |
| Examiner 1 versus 2       | 0.822 (0.761-0.883) | 0.778 (0.703-0.853) | 0.912 (0.861-0.964) |

caries is difficult to diagnose using only the visual exam as it is a subjective method.\[11\]-\[13\]. The specificity was substantial for visual inspection, which is in accordance with several studies.\[11\]-\[16\] This study shows similar result for sensitivity and specificity of visual examination as earlier conducted studies.\[11\]-\[16\]

Bitewing radiography obtained low sensitivity, although the specificity was high. The findings support the conclusions from other studies conducted previously.\[14\]-\[16\]

The limitation of the radiographic examination for occlusal caries diagnosis is related to the superposition of sound enamel that masks the evidence of radiolucency, mainly when there is caries lesion confined to enamel or superficial dentinal caries. In addition, dentin caries can only be visualized radiographically when it is 0.5 mm beyond the dentinoenamel junction.\[4\]

CarieScan PRO showed higher values for both sensitivity and specificity. The sensitivity and specificity showed 0.97 and 0.82, respectively. The CarieScan PRO is the best method to detect occlusal caries because it presented acceptable values of both sensitivity and specificity and showed a good repeatability. This method showed a moderate PPV, which is responsible for a higher number of false positive diagnoses as a result unnecessary treatment may occur. The possibility of false positive results with the CarieScan PRO method, the visual inspection must be conducted initially, following the recommendations of cleaning and drying the fissure. Thereafter, if there is any doubt at a site, the CarieScan PRO can be used to help the decision on how to treat the fissure. According to the study conducted by Teo TK et al., the results with CarieScan PRO were not efficient as compared with International Caries Detection and Assessment System.\[17\] The limitation of this in vivo study may have been that 52 teeth could not be validated. Thus, for ethical reasons, these teeth were not opened. In addition, 60 teeth exhibiting no signs of caries were not opened based on the assumption that they were not carious.

Longitudinal studies that could follow-up the patients for several years would be more appropriate to ensure reliable results and to neutralize the possible biases of in vivo cross-sectional research.

CONCLUSION

This study showed low sensitivity but substantial specificity with visual inspection. Bitewing radiography can be excluded from this comparison as it performed poorly overall when compared with the other two systems. The CarieScan PRO technique gave the highest overall combination of sensitivity and specificity. Therefore, it is advisable to use CarieScan PRO system in association with visual inspection to reduce the possibility of false positive results. Longitudinal studies of occlusal caries diagnosis and patient follow-up using the CarieScan PRO method are suggested.

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Conflicts of interest
There are no conflicts of interest.

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