

In Vivo Comparative Enactment of CarieScanPRO™ with Conventional Methods to Detect Occlusal Carious Lesions in the Mandibular Primary Molars

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ABSTRACT

Aim: To assess the performance of CarieScanPRO™ with radiovisiography (RVG) and international caries detection and assessment system II (ICDAS-II) to detect the occlusal carious lesions in the mandibular primary molars.

Methods: Fifty healthy children of age 5–7 years were involved and evaluated for caries using visual ICDAS-II, RVG, and CarieScanPRO™. Operative intervention pit and fissure opening served as a gold standard for comparison of the three methods of examination. The sensitivity, specificity, accuracy, and area under the receiver operating characteristic (ROC) curve (Az) of the methods were calculated at enamel (D1), dentinoenamel junction (DEJ) (D2), and dentine (D3, D4).

Results: At D1 threshold, CarieScanPRO™ showed higher values of sensitivity and accuracy (0.97 and 0.88) and RVG specificity (0.92). At D2 threshold, visual examination showed higher values of sensitivity (0.80) whereas CarieScanPRO™ showed specificity and accuracy of 0.98 and 0.87. At D3, D4 threshold, CarieScanPRO™ showed higher values of sensitivity, specificity, and accuracy (0.1, 0.98, and 0.99). Higher positive predictive value (PPV), negative predictive value (NPV) and lower false discovery rate (FDR), false-positive rate (FPR) were shown by CarieScanPRO™. The intraexaminer repeatability for CarieScanPRO™ was good with kappa at D1 (0.77) and D3, D4 (0.98).

Conclusion: CarieScanPRO™ showed higher reproducibility compared to visual examination and RVG for the detection of enamel and dentinal caries. Higher accuracy of CarieScanPRO™ can be used for longitudinal monitoring of occlusal caries in primary teeth with low sensitivity at DEJ.

Keywords: Caries detection, CarieScanPRO™, Occlusal caries, Radiovisiography, Visual International caries detection and assessment system II. *International Journal of Clinical Pediatric Dentistry* (2019): 10.5005/jp-journals-10005-1649

INTRODUCTION

Dental caries is an important public dental health problem and the most prevalent oral disease among children in the world.¹ It remains a ubiquitous, global, dynamic disease process and represents a considerable burden for many children while providing challenge for pediatric dentists.² It is well established that caries levels in industrialized nations have been declined over the last few decades with available data indicating greater reductions occurring on the smooth and approximal surfaces. Occlusal surfaces are at greatest risk of carious attack and a minimal intervention approach is effective if caries is diagnosed at an early stage.³

Occlusal surfaces are the most caries-affected sites in children and adults due to the unique morphology of the pits and fissures and the difficulty in plaque removal; hence, early occlusal caries detection has become a topic of interest in the last few years.^{4,5} Incipient occlusal lesions are difficult to detect because of the widespread use of fluorides and their superficial remineralization potential that seems to delay cavitation.⁵ Additionally, the changes in lesion morphology could lead to the presence of occlusal dentine caries under a fissure which seems intact to the naked eye.⁶ A new visual method, the ICDAS, was devised by an international group of researchers with the goal of designing an internationally accepted caries detection system that would also allow assessment of caries activity.^{7,8}

The reproducibility and accuracy of ICDAS-II has already shown to be promising for occlusal caries detection⁹ and a potential aid to treatment planning as the preferred care options might be tilted toward preventive or operative treatment depending on the visual assessment, activity of a lesion, and patients' risk status.

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Probing, visual examination, intraoral film, and digital sensors are the ones most commonly used among various contemporary methods in the diagnosis of caries. Several studies have shown that nearly 25–42% of caries lesions remain undetected by

the clinical examination.^{10–12} Digital acquisition of radiographs enables digital image contrast enhancement and filtering may increase diagnostic accuracy. Radiovisiography is higher than that of clinical examination in determining the lesion depth and is useful in diagnosing incipient carious lesions. Consequently, various novel methods have been developed and recommended as diagnostic aids to identify and quantify early caries lesions. CarieScanPRO™ which works on the principle of “alternating current (AC) impedance spectroscopy” was developed recently.² However, only limited data are available in the literature and the performance of this device, which is already on the market, has not been evaluated. Hence, the present study was conducted to evaluate the efficacy of CarieScanPRO™ compared to visual examinations and RVG in detecting occlusal carious lesions.

METHODS

Ethical approval for the study was obtained from the Institutional Ethical Committee (IEC), and the study was carried out from January 2011 to June 2012. In this study, 150 children with the age range of 5–7 years were selected from the outpatients attending the Department of Pedodontics and Preventive Dentistry. Age group selected was according to the World Health Organization’s basic oral health survey methods.¹³ The children included in the study were with occlusal carious lesions with no obvious cavitations on primary mandibular molars and parents were willing for consent. Medically compromised children, teeth with occlusal restorations, attrition, pit, and fissure sealants, frank occlusal cavitations approaching the pulp, hypoplastic teeth, approximal caries, and parents who were not willing for consent were excluded. Before visual examination, the occlusal surfaces of the selected teeth were thoroughly cleaned with a rotating bristle brush and with pumice or water slurry, after which all the three methods of examinations were carried out.

Visual Examination

Visual examination was performed with child positioned in a dental unit with operating light illumination, 3-in-1 air syringe, a plane mirror, and a ball-end probe. The teeth were initially examined wet and then after drying for 5 seconds with oil-free compressed air by a single examiner for the presence or absence of occlusal caries using the ICDAS-II criteria.¹⁴

RVG Examination

The teeth deemed fit for the study were assessed using RVG and were scored according to Ekstrand et al.¹⁵ criteria. The X-ray machine was set to 70 kV at 8 mA with exposure time of 0.8 seconds and the sensor was placed intraorally using paralleling technique for exposure. The digitally recorded images were analyzed using Sopro™ imaging software for the diagnosis of caries. In the selected area for diagnosis, this program provides enamel, dentinal densitometric readings that can be correlated to the possible presence of carious lesions. The extent of caries up to enamel, DEJ, and dentine was determined with the help of grids incorporated in the digital radiographic image. After assessment of caries with RVG, the same teeth were assessed using CarieScanPRO™.

Examination with CarieScanPRO™

The cable and collar were sterilized using tissue wipe and the lip-hook cable was connected to the device. Collar was pushed onto the neck of the device and the single-use sensor with the wire tufts

was snapped onto the CarieScanPRO™ collar. Then, cross-infection barrier sleeve was draped over the device and the lip hook was attached to the cable and the metal hook was hung passively over the patient’s lip (or held in the patient’s fingers) to close the Alternating Current Impedance Spectroscopy Technique (ACIST) electrical circuit, according to the product manual.²

The test teeth to be scanned were isolated with cotton rolls on both sides of the quadrant, using suction devices and air-dried for at least 5 seconds with oil-free compressed air to eliminate debris and saliva. The “ENTER” button on the device was pressed to start the measurement and the sensor tip was placed directly at the specific site on the tooth surface to be measured once the blue indicator light flashed after 4 audible beeps, both numeric (0–100) and visual (green colour to red colour) results on LED were displayed on the device. The mean values of three readings of CarieScanPRO™ device were recorded according to manufacturer’s instructions.²

Operative Intervention

After the carious teeth were subjected to visual examination, RVG, and CarieScanPRO™, operative intervention was performed with pit-and-fissure opening (PFO). The caries was removed using arotor with no. 4 round tungsten carbide bur at slow speed. Later, the penetration depth of the carious lesion was validated using Williams’s calibrated probe, and the required preventive or restorative treatment was rendered. Mild-to-moderate preventive therapy for the teeth having caries up to outer one-third of enamel and the teeth which were having dentine caries were restored with Glass Ionomer Cement GC type IX™ (GC Asia).

Statistical Analysis

The data recorded were analyzed statistically using Statistical Package for the Social Sciences (SPSS-16.0 version, Chicago, Illinois, USA), and the performance of visual examination, RVG, and CarieScanPRO™ was compared and validated with PFO. The sensitivity, specificity, accuracy, PPV, NPV, FDR, FPR, and ROC curve were analyzed. Intraexaminer reproducibility of scores was calculated using Cohen’s kappa statistics (κ) with a level of significance at 0.05.

RESULTS

Only 50 children were available for the study of which eighty eight primary molars were selected for the study based on inclusion criteria (Flowchart 1). The true caries scores using visual examination, RVG, and CarieScanPRO™ were 87.5%, 62.5%, and 56.8%, respectively (Fig. 1). CarieScanPRO™ showed better sensitivity (97.4%) and specificity (98%) compared to RVG and visual examination (Table 1) when caries lesions are confined to enamel (D1). In the case of caries lesion in DEJ (D2), visual examination showed higher sensitivity (80%) followed by RVG (66.7%) and CarieScanPRO™ (33.3%), and CarieScanPRO™ showed higher specificity (98.6%) compared with visual examination (67%) and RVG (64.4%) (Table 2). CarieScanPRO™ showed higher specificity (100) and sensitivity (98.1) compared to RVG and visual examination (Table 3). Overall, for D1 and D3 and D4 lesions, CarieScanPRO™ exhibited higher sensitivity while visual examination showed higher sensitivity scores in case of D2 carious lesions (Fig. 2), and results were statistically significant ($p < 0.001$). CarieScanPRO™ scored higher specificity for all D1, D2, and D3 and D4 lesions (Fig. 3) results showed statistically significant for D₁ and D₂ carious lesions ($p < 0.001$), and for D3 and D4 carious lesions, all the three

Flowchart 1: Study design according to Standards for Reporting of Diagnostic Accuracy Studies (STARD) guidelines

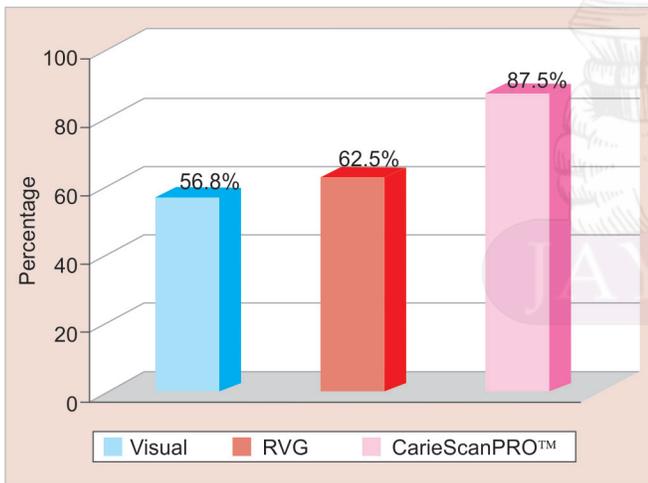
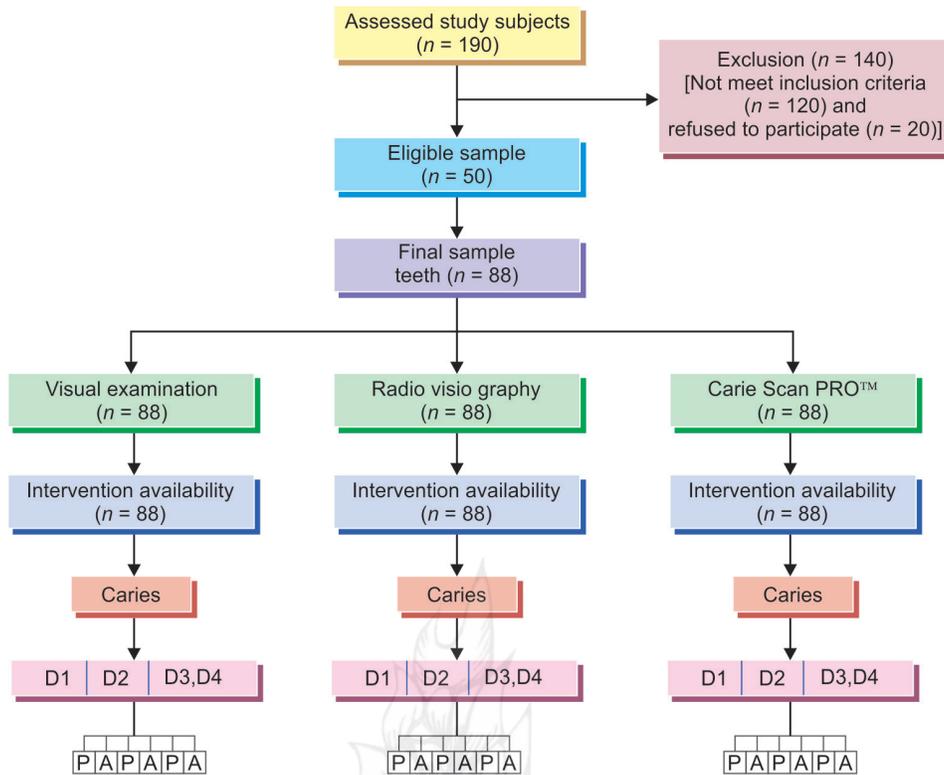


Fig. 1: Percentage of true caries detection with visual examination, radiovisiography (RVG), and CarieScanPRO™

methods scored more than 92% but the results were not statistically significant ($p > 0.05$). CarieScanPRO™ showed highest accuracy (Fig. 4) among three methods in the cases of all D1, D2 and D3, D4 carious lesions, and the results were statistically significant ($p < 0.001$). Receiver operating characteristic curve was analyzed and represented for all three diagnostic methods at various thresholds (D1, D2 and D3, D4) shown in Figure 5. The results show that the CarieScanPRO™ is superior to RVG and visual examination in detecting caries at dentine level. The specificity values at all three cutoff levels were highest for CarieScanPRO™.

Table 1: Comparison of visual examination, radiovisiography (RVG), and CarieScanPRO™ in the diagnosis of caries at enamel cutoff level (D1) compared with pit and fissure opening (PFO)

Evaluation D1	Visual examination	RVG	CarieScanPRO™	p value
Sensitivity (%)	42.1	63.2	97.4	<0.001*
Specificity (%)	82.0	92.0	82.0	0.07
Positive predictive value (%)	64.0	85.7	80.4	<0.001*
Negative predictive value (%)	65.1	76.7	97.6	<0.001*
Accuracy (%)	64.8	79.6	88.6	<0.001*

*Significant ($p < 0.05$)

Table 2: Comparison of visual examination, radiovisiography (RVG), and CarieScanPRO™ in the diagnosis of caries at DEJ cutoff level (D2) with pit and fissure opening (PFO)

Evaluation D2	Visual examination	RVG	CarieScanPRO™	p value
Sensitivity (%)	80.0	66.7	33.3	<0.001*
Specificity (%)	67.1	64.4	98.6	<0.001*
Positive predictive value (%)	33.3	27.8	83.3	<0.001*
Negative predictive value (%)	94.2	90.4	87.8	0.29
Accuracy (%)	69.3	64.8	87.5	<0.001*

*Significant ($p < 0.05$)

Table 3: Comparison of visual examination, radiovisiography (RVG), and CarieScanPRO™ in diagnosis of abnormalities of middle and lower third of dentine (D3 and D4) cutoff level compared with pit and fissure opening (PFO)

Evaluation D3, D4	Visual examination	RVG	CarieScan-PRO™	p value
Sensitivity (%)	62.9	60	100.0	<0.001*
Specificity (%)	92.5	96.22	98.1	0.14
Positive predictive value (%)	84.6	91.3	97.2	0.002*
Negative predictive value (%)	79.0	78.46	100.0	< 0.001*
Accuracy (%)	80.7	81.81	98.9	<0.001*

*Significant ($p < 0.05$)

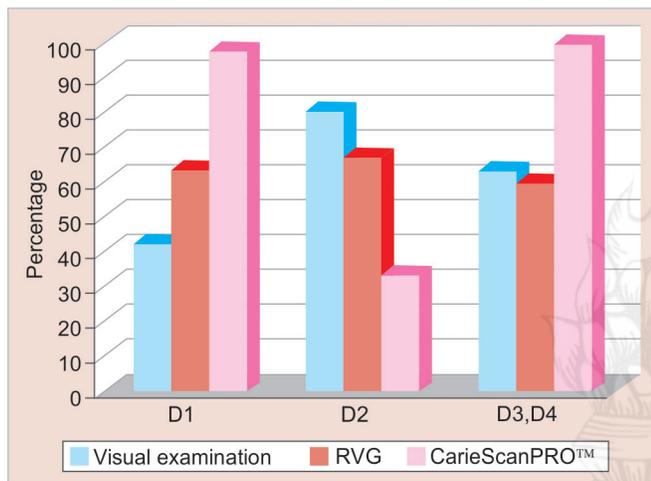


Fig. 2: Sensitivity values for visual examination, radiovisiography (RVG), and CarieScanPRO™ at D1, D2 and D3, D4 levels (D1 = enamel; D2 = DEJ; D3 = outer half of dentin; D4 = inner half of the dentin)

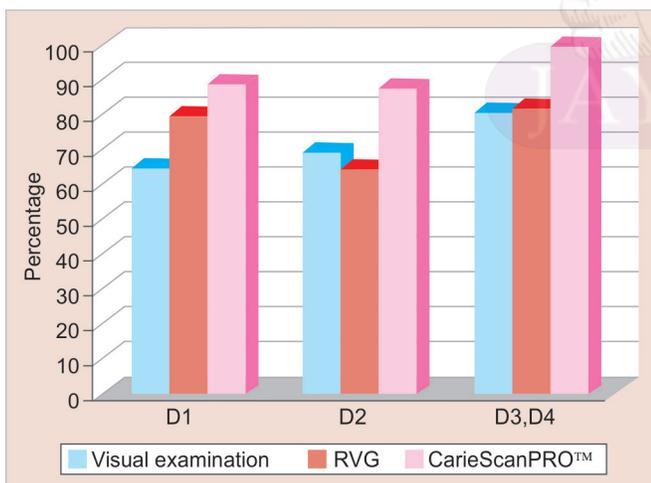


Fig. 4: Accuracy values for visual examination, radiovisiography (RVG), and CarieScanPRO™ at D1, D2 and D3, D4 levels (D1 = enamel; D2 = DEJ; D3 = outer half of dentin; D4 = inner half of the dentin)

DISCUSSION

To our knowledge, this is the first *in vivo* study to test the new device CarieScanPRO™ in detecting occlusal caries lesions. This is an ideal study design with exceptional combinations of visual ICDAS-II, RVG,

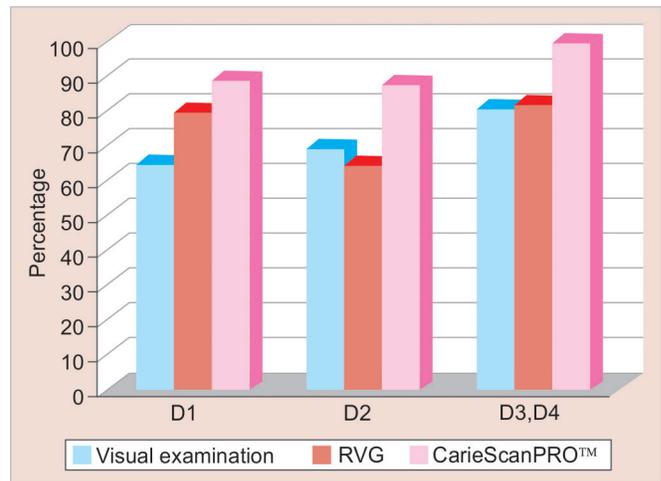
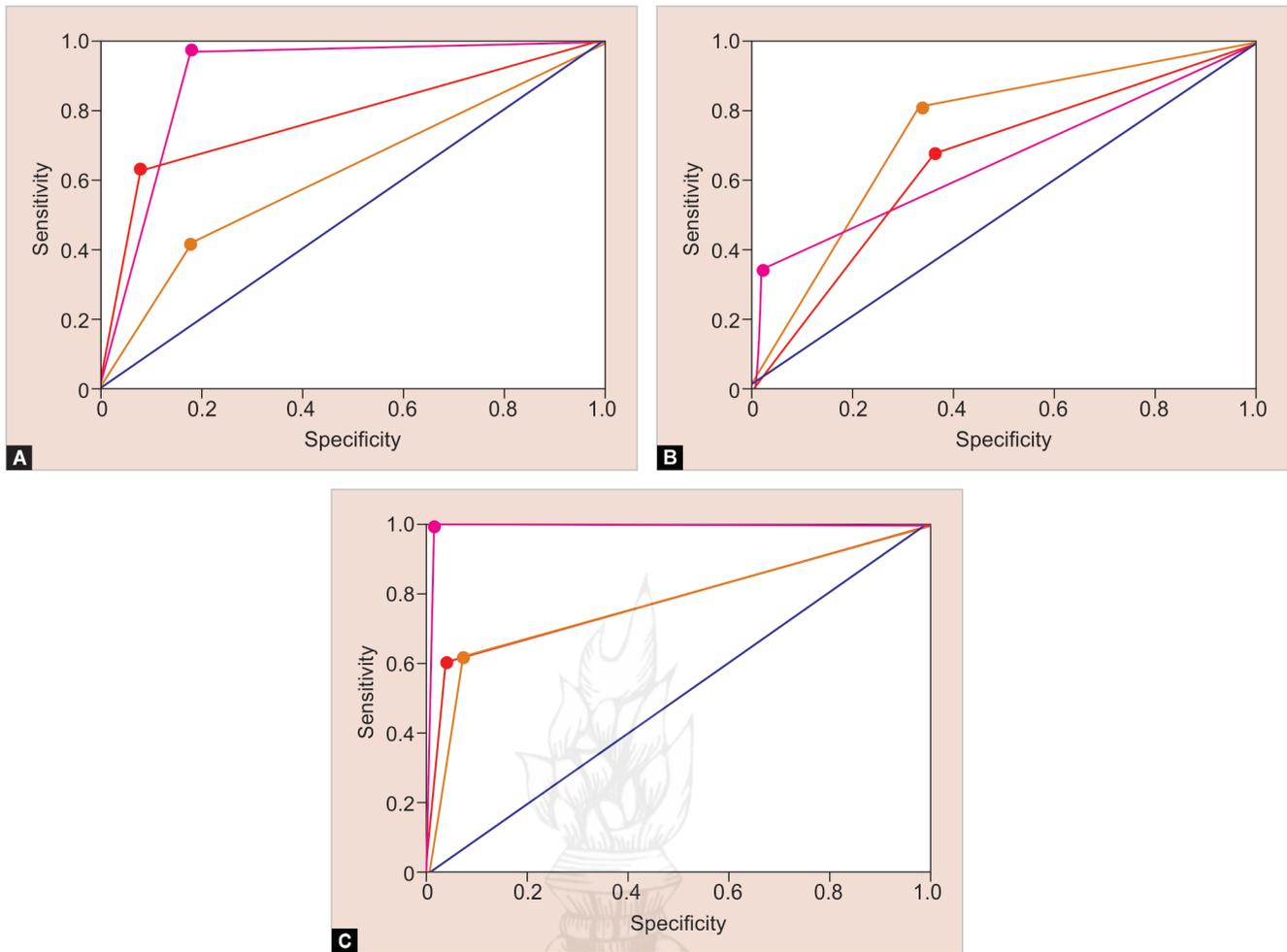


Fig. 3: Specificity values for visual, radiovisiography (RVG), and CarieScanPRO™ at D1, D2 and D3, D4 levels (D1 = enamel; D2 = DEJ; D3 = outer half of dentin; D4 = inner half of the dentin)

and CarieScanPRO™ with age constrained to 5–7 years. Most of the studies conducted on primary molars were *in vitro*^{2,16–20} with very few studies *in vivo*.^{18,21} All *in vitro* studies were of limited value since they do not reflect the difficulties encountered in the clinical setting. Sample size of teeth ($n = 88$) in the present study is comparable to that of the prior *in vivo* study.²¹ The age group 5–7 years was selected for the study as it is the age group of second caries risk according to the previous studies.^{22,23} In the clinical setting, dark, discolored fissures that are associated with dentin decay in primary molars can go undetected or misdiagnosed as enamel caries by visual examination and RVG, allowing underlying dentine caries to progress unchecked.²⁴ The CarieScanPRO™ has a higher sensitivity for lesions into dentin as compared to the visual examination and can be a valuable addition to the visual examination for occlusal dentin caries detection in the primary teeth.

Among various diagnostic techniques traditionally employed for caries detection in the field of preventive dentistry, visual examination is the easiest, simple, and economical method of caries detection. Till now, minimal data have been published on the visual ICDAS-II system¹⁴ in the primary molars. Literature states that the reproducibility and diagnostic accuracy of it was excellent for the detection of occlusal caries at varying stages of the disease process in both the permanent and primary molars.^{5,7,14,17,25–27} Hence, in the present study, ICDAS-II system¹⁴ was selected for visual examination. The main advantages of digital intraoral radiography are that they result in fewer errors in the image and fewer environmental problems, as there is no use of chemicals. They also save time and reduce radiation dose to the patient because the receptors are more sensitive. These advantages are significant when dealing with children.¹⁸

The radiographic examination of this study relied on the ranked scoring system developed by Ekstrand et al.¹⁵ which is the basis of the ICDAS-II criteria, with higher values for diagnostic parameters. The radiographic image size was fixed to a display ratio of 1:1 for higher diagnostic validity according to the study conducted by Haak et al.²⁸ which specified that excessive magnification could result in poor caries detection rate. An ideal diagnostic method should offer high sensitivity and specificity as well as other characteristics such as ease of use and reliability.¹⁴ In terms of sensitivity and specificity, the present study showed that the visual examination was less accurate than radiographic method which is contradicting with the previous *in vitro* study²⁹ at D1 and D3, D4 cutoff levels.



Figs 5A to C: Receiver operating characteristic (ROC) curves for visual examination (orange), radiovisiograph (blue), and CarieScanPRO™ (pink) at D1 threshold (A), D2 threshold (B), and D3, D4 threshold (C). X-axis: specificity; Y-axis: sensitivity

This could be due to the difference in examiner's experiences that differ from this study. In the present study, CarieScanPRO™ showed significantly higher sensitivity value than visual examination and RVG at D1 and D3, D4 cutoff levels, whereas at D2 threshold, visual examination showed higher sensitivity value. The poor performance of CarieScanPRO™ at DEJ may be due to narrow cut-off readings as mentioned by the manufacturer. Also, it is well known that DEJ is less mineralized than either enamel or dentine which contains a higher organic matrix.³⁰ Consequently, the AC-impedance reading of CarieScanPRO™ was much lower than what was expected.

Regarding specificity, CarieScanPRO™ showed significantly higher value at DEJ and dentine compared to other two modalities. Thus, it indicates that CarieScanPRO™ performed better in ruling out the correct level of caries extension at deeper layers, and the performance is partially dependent on the cutoff points used to classify the numerical output into sound, enamel caries or dentine caries scores. Regarding accuracy, the key factor for predicting the efficiency of diagnosis, CarieScanPRO™ showed significance in accurate diagnosis of caries at all the levels of caries at D1, D2, and D3, D4 cutoff levels, respectively. Thus, it elucidates that the overall performance of CarieScanPRO™ is best when compared to visual examination and RVG. The result in the present study is in agreement with Pitts et al.³¹

In terms of PPV, the overall performance of CarieScanPRO™ was superior to the visual examination and RVG at D2 and D3, D4

cut-off levels, whereas RVG showed higher PPV at D1 cut-off level followed by CarieScanPRO™. A higher value of PPV demonstrates the excellent reliability of the CarieScanPRO™ in making correct positive diagnosis of caries. At D1 and D3 threshold levels, the PPV of RVG was lower than the results of *in vitro* study by Shoaib et al.¹⁴ which can be attributed to the inclusion of advanced carious lesion in the previous study that was detected easily in the radiograph and also due to the fact that the radiograph was unable to detect initially demineralized occlusal enamel and dentin lesions.²⁹

Regarding NPV, the performance of CarieScanPRO™ was superior to other diagnostic modalities at D1 and D3, D4 threshold levels, whereas it showed least performance at D2 threshold level as the advanced caries detection device is sensitive enough to detect initial demineralization of enamel and dentine caries. With respect to DEJ, caries progression will be in a lateral direction followed by demineralization into the superficial layer of dentine³² that might have affected the performance of the device in some cases.

The FDR and FPR were assessed exceptionally only in this study, which proved that overall performance of CarieScanPRO™ was best with its low FDR (16.67%, 2.78%) and FPR (1.369%, 1.886%) at D2 and D3, D4 threshold levels, whereas RVG showed low values of FDR (14.28%) and FPR (8%) at D1 threshold. The moderate performance of CarieScanPRO™ at enamel cutoff level may be due to its ability in detecting demineralized tissue which is not perceptible with

conventional examinations and also operative intervention (gold standard). It can be credited that the CarieScanPRO™ is an accurate diagnostic modality in the detection of deeper levels of caries and also good at the detection of enamel caries. These findings showed that overall performance of CarieScanPRO™ is good. The relationship between the sensitivity and specificity illustrated by ROC curve analysis was used to evaluate the diagnostic accuracy of visual examination, RVG, and CarieScanPRO™ at D1, D2, and D3, D4 threshold levels of occlusal caries are shown in Figure 5.

Receiver operating characteristic curve analysis was used to evaluate the diagnostic accuracy of visual examination, RVG, and CarieScanPRO™ at D1, D2 and D3, D4 threshold levels of occlusal caries. Receiver operating characteristic curve reflects the diagnostic performance more comprehensively than sensitivity and specificity, which were determined by only one cut-off point. In this study, the diagnostic performance of the three caries diagnostic aids showed statistical significance ($p < 0.05$). The closer a result to the upper left corner, the better it predicts, but the distance from the random guess line in either direction is the best indicator of how much predictive power a method has either best or worst.³³ The result was above the random guess line located at the left top corner of the ROC graph, indicating that CarieScanPRO™ has the best predictive power of caries.

The area under the curve (AUC) value for ROC curve of the CarieScanPRO™ was 0.97 at D1 and 1 at D3, D4 present at the upper left corner of the graph which occupied larger ROC area predicted that the device is a high-precisional tool for the diagnosis of occlusal caries in primary molars. The intraexaminer reproducibility was excellent for CarieScanPRO™ at enamel, and dentine (0.77, 0.98, respectively), as expressed by Cohen's kappa values. This suggested that the better results produced by the CarieScanPRO™ can be reliably repeated which is a necessary feature of the diagnostic method. The kappa values were moderate for RVG (0.57, 0.20, 0.59) and poor for visual examination (0.25, 0.30, 0.58) at enamel, DEJ, dentine threshold levels, respectively.

Overall visual examination (ICDAS-II criteria) in this study showed lower kappa value which is in concordance with the previous *in vitro* studies.^{5,14,25,27,34} The kappa value of RVG in this study at D2 threshold level was lower than that of study conducted by Dias et al.,¹⁸ while the CarieScanPRO™ showed moderate-to-excellent kappa values at D1 to D3, D4 threshold levels. Thus, it can be attributed that the previous studies were *in vitro* and there may not be any influence of oral environment on the examination of caries with the exception of CarieScanPRO™ which has given high intraexaminer reliability as it does not require examiner's experience. The Pearson correlation between CarieScanPRO™ and PFO (gold standard) was found to be in almost perfect positive correlation (0.95) than that of the visual examination and RVG. Thus, it can be noted that the CarieScanPRO™ is a comparatively better diagnostic method.

False positive reading in case of arrested caries by CarieScanPRO™ can be explained by the device principle AC-impedance spectroscopy (resistance), which effectively measures the porosity of the enamel, dentine, and pulp (negligible) along the path of least electrical resistance indirectly. If the active lesion extends into dentine but arrests, the pulp reaction will be the laying down of reactionary dentine, which will have the effect of reducing the overall porosity of the dentine along the electrical pathway of the lesion, thereby increasing the measured electrical impedance of the tooth along that pathway. Reactionary dentine is more like enamel in structure than dentine, and as the impedance of enamel is much

greater (by a ratio of 10:1) than that of dentine, the AC-impedance measurements will increase when a lesion arrests in dentine.³⁵

In the present investigation, the comparison among visual examination, RVG, and CarieScanPRO™ was found to be statistically significant for the detection of occlusal caries. In case of stained occlusal surface, only the CarieScanPRO™ was able to detect the extent of caries, whereas visual and RVG failed to detect. In such cases, the treatment decision is solely dependent on CarieScanPRO™.

Dental caries was found predominantly on the second primary molar when compared to the first primary molar as reported by Saravanan et al.,¹ which might be due to the inaccessibility of the second primary molar to cleansing in younger children and also being more susceptible to caries due to its complex pit and fissure topography. No significant association was found between age, sex, and type of tooth examined. Finally, the results substantiated that CarieScanPRO™ is a better diagnostic modality for caries detection in the primary molars when the protocol was followed appropriately. As this is the first study, more studies are advocated to establish the reliability and accuracy of CarieScanPRO™.

LIMITATIONS OF THE STUDY

- As the study included mandibular molars, proper isolation will be difficult to achieve dry field for the detection of caries.
- Presence of saliva on the carious lesion influences the readings of the CarieScanPRO™, which showed in the increased level of reading and the higher level caries.
- Battery levels of the device had an effect on the detection of caries. Low battery levels showed false negative readings, i.e., lower readings than expected.
- The CarieScanPRO™ was unable to give any score when the sensor tip was improperly inserted over the collar. So, it is obligatory to check whether the sensor is properly inserted or not.
- The CarieScanPRO™ has given lower readings than expected when the sensor tip was placed leaning on the carious lesion. As the pathway of AC can influence the readings, it is mandatory to place the sensor tip perpendicularly over the caries lesion to measure the maximum extension of the caries.
- Even though CarieScanPRO™ has excellent sensitivity and specificity, it has overscored in some teeth with arrested caries.

From the results of the study, it can be concluded that the CarieScanPRO™ is a reproducible and accurate diagnostic tool that may be a valuable adjunct to the visual examination for occlusal caries detection in mandibular primary molars.

CONCLUSION

- The CarieScanPRO™ has shown superior results in diagnosing the caries which is almost close to that of gold standard (PFO).
- The CarieScanPRO™ has shown highest sensitivity and specificity in diagnosing the enamel and dentine caries.
- Though the CarieScanPRO™ performed poorly at D2 cut-off level, and the high accuracy values of CarieScanPRO™ proved that it a very good caries diagnostic tool.
- Visual examination and CarieScanPRO™ have shown similar performance in terms of specificity at the enamel threshold level.
- Visual examination and RVG have shown least results of PPV.

- Both the visual and RVG examinations had a tendency to underscore enamel carious lesions as sound (i.e., false-negative results).
- The CarieScanPRO™ can be used as a valuable and preventive diagnostic tool as an adjunct to the visual examination.

RECOMMENDATIONS

- In routine clinical practice, CarieScanPRO™ can be used as an adjunct to visual examination of primary molars. This device avoids the problem of false negative findings, which are common in visual examination leading to missed or concealed carious lesions.
- Although the results of the present study recommends CarieScanPRO™ as a diagnostic adjunct, further *in vivo* studies are recommended as it is the first *in vivo* study on primary molars.
- In the absence of radiographic examination, this device (CarieScanPRO™) may be a nonharmful additional tool, for occlusal dentine caries detection in the primary teeth.
- Due to its excellent reliability, the device can be used for longitudinal monitoring of occlusal caries in primary teeth.

REFERENCES

1. Saravanan S, Madivanan I, et al. Prevalence pattern of dental caries in the primary dentition among school children. *Indian J Dent Res* 2006;17:10.
2. Pitts NB. How Electrical Caries Detection And Monitoring With Cariescan Can Help Deliver Modern Caries Management. *Oral Health* 2010;34–43.
3. Attrill DC, Ashley PF. Occlusal caries detection in primary teeth: a comparison of DIAGNOdent with conventional methods. *Br Dent J* 2001;190:440–443. DOI: 10.1038/sj.bdj.4800998.
4. Sheehy EC, Brailsford SR, et al. Comparison between visual examination and a laser fluorescence system for *in vivo* diagnosis of occlusal caries. *Caries Res* 2001;35:421–426. DOI: 10.1159/000047485.
5. Rodrigues JA, Hug I, et al. Performance of fluorescence methods, radiographic examination and ICDAS II on occlusal surfaces *in vitro*. *Caries Res* 2008;42:297–304. DOI: 10.1159/000148162.
6. Lussi A, Imwinkelried S, et al. Performance and Reproducibility of a Laser Fluorescence System for Detection of Occlusal Caries *in vitro*. *Caries Res* 1999;33:261–266. DOI: 10.1159/000016527.
7. Jablonski-Momeni A, Stachniss V, et al. Reproducibility and accuracy of the ICDAS-II for detection of occlusal caries *in vitro*. *Caries Res* 2008;42:79–87. DOI: 10.1159/000113160.
8. Ricketts DN, Ekstrand KR, et al. Relating visual and radiographic ranked scoring system for occlusal caries detection to histological and microbiological evidence. *Oper Dent* 2002;27:231–237.
9. Ismail AI. Visual and visuo-tactile detection of dental caries. *J Dent Res* 2004;83:C56–C66. DOI: 10.1177/154405910408301s12.
10. Rocha RO, Ardenghi TM, et al. *In vivo* Effectiveness of Laser Fluorescence Compared to Visual Inspection and Radiography for the Detection of Occlusal Caries in Primary Teeth. *Caries Res* 2003;37:437–441. DOI: 10.1159/000073396.
11. Neuhaus KW, Rodrigues JA, et al. Performance of laser fluorescence devices, visual and radiographic examination for the detection of occlusal caries in primary molars. *Clin Oral Investig* 2011;15:635–641. DOI: 10.1007/s00784-010-0427-5.
12. Ekstrand KR, Martignon S, et al. Detection and activity assessment of primary coronal caries lesions: a methodologic study. *Oper Dent* 2007;32:225–235. DOI: 10.2341/06-63.
13. World Health Organisation. Oral health surveys - Basic methods, 4th ed., Geneva: WHO; 1997.
14. Shoaib L, Deery C, et al. Validity and Reproducibility of ICDAS II in Primary Teeth. *Caries Res* 2009;43:442–448. DOI: 10.1159/000258551.
15. Ekstrand KR, Ricketts DN, et al. Reproducibility and accuracy of three methods for assessment of demineralization depth of the occlusal surface: an *in vitro* examination. *Caries Res* 1997;31:224–231. DOI: 10.1159/000262404.
16. Francescut P, Lussi A. Correlation between fissure discoloration, DIAGNOdent measurements, and caries depth: an *in vitro* study. *Pediatr Dent* 2003;25:559–564.
17. Dunkley S, Ashley P. Use of a ranked scoring system to detect occlusal caries in primary molars. *Int J Paediatr Dent* 2007;17:267–273. DOI: 10.1111/j.1365-263X.2006.00807.x.
18. Dias da Silva PR, Martins Marques M, et al. Accuracy of direct digital radiography for detecting occlusal caries in primary teeth compared with conventional radiography and visual inspection: an *in vitro* study. *Dentomaxillofac Radiol* 2010;39:362–367. DOI: 10.1259/dmfr/22865872.
19. da Silva RP, Assaf AV, et al. Reproducibility of Adjunct Techniques for Diagnosis of Dental Caries in an Epidemiological Situation. *Oral Health Prev Dent* 2011;9:251–259.
20. Kouchaji C. Comparison between a laser fluorescence device and visual examination in the detection of occlusal caries in children. *Saudi Dent J* 2012;24:169–174. DOI: 10.1016/j.sdentj.2012.07.002.
21. Goel A, Chawla HS, et al. Comparison of validity of DIAGNOdent with conventional methods for detection of occlusal caries in primary molars using the histological gold standard: An *in vivo* study. *J Indian Soc Pedod Prev Dent* 2009;27:227–234. DOI: 10.4103/0970-4388.57658.
22. Huysmans MC, Longbottom C, et al. Impedance spectroscopy of teeth with and without approximal caries lesions – an *in vitro* study. *J Dent Res* 1996;75:1871–1878. DOI: 10.1177/00220345960750110901.
23. Sudha P, Bhasin S, et al. Prevalence of dental caries among 5-13 year old children of Mangalore city. *J Indian Soc Pedod Prev Dent* 2005;23:74–79. DOI: 10.4103/0970-4388.16446.
24. Haak R, Wicht MJ, et al. Conventional, digital and contrast-enhanced bitewing radiographs in the decision to restore proximal carious lesions. *Caries Res* 2001;35:193–199. DOI: 10.1159/000047455.
25. Diniz MB, Rodrigues JA, et al. Reproducibility and accuracy of the ICDAS-II for occlusal caries detection. *Community Dent Oral Epidemiol* 2009;37:399–404. DOI: 10.1111/j.1600-0528.2009.00487.x.
26. Novaes TF, Matos R, et al. Performance of a pen-type laser fluorescence device and conventional methods in detecting approximal caries lesions in primary teeth – *in vivo* study. *Caries Res* 2009;43:36–42. DOI: 10.1159/000189705.
27. Braga MM, Oliveira LB, et al. Feasibility of the International Caries Detection and Assessment System (ICDAS-II) in Epidemiological Surveys and Comparability with Standard World Health Organization Criteria. *Caries Res* 2009;43:245–249. DOI: 10.1159/000217855.
28. Haak R, Wicht MJ, et al. Influence of displayed image size on radiographic detection of approximal caries. *Dentomaxillofac Radiol* 2003;32:242–246. DOI: 10.1259/dmfr/17654484.
29. Zanin L, de Castro Meneghim M, et al. Depth of occlusal caries assessed clinically by fluorescence laser, conventional and digital radiographic methods. *Braz J Oral Sci* April June 2005;14:13.
30. Tencate AR. Oral histology development, structure, and function. 7th ed. Elsevier Publishers; 2017. pp. 192–193.
31. Pitts NB, Longbottom C, et al. Diagnostic Accuracy of an Optimised AC Impedance Device to Aid Caries Detection and Monitoring. *Caries Res* 2008;42:185–238. DOI: 10.1159/000128562.
32. Shafer WG, Hine MK, et al. Text book of oral pathology. 6th ed. Elsevier Publishers; 2009. p. 436.
33. Zhu W, Zeng N, et al. Sensitivity, specificity, accuracy, associated confidence interval and ROC analysis with practical SAS® implementations. NESUG; 2010.
34. Jablonski-Momeni A, Ricketts DN, et al. Occlusal caries: Evaluation of direct microscopy versus digital imaging used for two histological classification systems. *J Dent* 2009;37:204–211. DOI: 10.1016/j.jdent.2008.11.014.
35. Malone WF, Bell C, et al. Physicochemical characteristics of active and arrested carious lesions of dentin. *J Dent Res* 1966;45:16–26. DOI: 10.1177/00220345660450010901.