Utilization of Laser Fluorescence to Monitor Caries Lesions Development in Primary Teeth

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ABSTRACT

Purpose: The objective of this study was to analyze and evaluate laser fluorescence (LF) performance in monitoring and quantifying smooth-surface incipient caries lesions in primary teeth. **Methods:** Artificial caries lesions were produced in 2 delimited windows on the buccal surface of 24 primary incisors using a pH-cycling procedure. LF (DIAGNOdent) readings were collected on the windows on each tooth surface before (sound enamel) and after (artificial caries lesions) the demineralization process. The left lesion of each tooth was used for the polarized light microscopy analysis. Statistical tests were performed to observe the performance of the method and correlation between LF readings and caries lesions depth. **Results:** There was a significant increase in the LF readings after demineralization ($P<.0001$). The area under receiver operating characteristic curve was 0.956, showing a good result of the method. The best cut off LF value to detect incipient caries was 5, and with this value, sensitivity, specificity, and accuracy was 0.78, 1, and 0.89, respectively. Pearson's correlation coefficient between DIAGNOdent values and caries lesion depth was 0.68. **Conclusions:** Although LF was good at detecting artificial caries lesions in primary teeth, the quantification of mineral loss was undesirable. (*J Dent Child*. 2004;71:139-142)

KEYWORDS: ENAMEL, DEMINERALIZATION, LASER FLUORESCENCE, SMOOTH-SURFACE CARIES, PRIMARY TEETH

Early detection of smooth-surface caries lesions provides more efficient management of caries, avoiding operative treatment.[1,2] Quantitative detection methods would allow monitoring of changes in mineral content of caries lesions.[1-5] Short-term clinical tests of foodstuff's cariogenicity and patient's caries activity have been performed using the quantitative laser fluorescence (QLF) method of caries detection.[6] QLF uses an argon-ion laser (λ=488 nm) and provides early detection of mineral loss.[7-9] The QLF's feasibility for monitoring mineral changes in the demineralization and remineralization process has been proposed by some authors.[10,11]

The diode laser fluorescence (LF) device uses fluorescence quantification induced by a diode laser (λ=655 nm) for caries detection in smooth and occlusal caries lesions. The laser light is absorbed by dental substance and is partially re-emitted as near-infrared fluorescent light. The system provides quantitative measures of caries lesions on a scale from 0 to 99. The higher the number, the deeper the lesion.[1,12-14]

Good results have been observed in detecting occlusal caries.[5,12,15-20] Some authors suggested that LF could be useful in monitoring the caries process due to excellent reproducibility obtained in previous studies.[5,12,19,21] The possibility of early detection and capability of monitoring enamel demineralization by the LF, however, remains unclear.

The aim of this in vitro study was to evaluate LF's feasibility in monitoring caries development in primary teeth using an artificial caries method.

METHODS

TEETH SELECTION

Twenty-four exfoliated primary upper central incisor teeth were selected, polished with pumice/water slurry and rinsed with tap water. Two windows of 1 mm 3 2 mm were delimited in the buccal surface of each primary tooth to create the artificial caries lesions.

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LF MEASUREMENTS

LF (DIAGNOdent, KaVo, Biberach, Germany) readings were performed following the manufacturer's instructions. Probe tip B (for smooth surfaces) was selected. The laser device was calibrated against a porcelain reference object prior to the examination and recalibrated after the readings of 10 teeth. Calibration on the sound surface of each tooth was not performed. After the initial calibration, teeth were removed from the solution, wiped with a paper tissue and submitted for LF readings by an operator.

The teeth's LF readings submitted to artificial incipient caries lesion formation were carried out on each of the delimited smooth surfaces before (sound enamel) and after (artificial incipient caries lesions) the demineralization process. Three readings of each site were performed, and the mean value was calculated.

ARTIFICIAL CARIES LESIONS EXPERIMENT

A pH-cycling procedure to create artificial incipient caries lesions was used, according to the protocol described in previous reports,[22,23] for 14 days. The demineralizing solution contained 2.2 mM $CaCl_2$, 2.2 mM NaH_2PO_4, and 50 mM acetic acid adjusted to a pH of 4.8. The remineralizing solution contained 1.5 mM $CaCl_2$, 0.9 mM NaH_2PO_4, and 0.15 M KCl adjusted to a pH of 7. After the first LF reading, the teeth were covered with nail varnish, except in 2 windows of 1 mm 3 2 mm dimensions. Each specimen was cycled in 10 ml of both solutions for 8 hours in the demineralizing solution and 16 hours in the remineralizing solution. This procedure was carried out at room temperature and without shaking.

Two distinct lesions were obtained for each tooth. Next, the nail varnish was removed and second LF measurements were performed.

POLARIZED LIGHT MICROSCOPY EXAMINATION

The incipient caries lesions formed in each tooth's left window side were selected for examination by polarized light microscopy. Sections around 500-µm thick were made using a diamond saw. The teeth slices were then manually ground to about 100-µm thickness. Eight artificial caries lesion specimens were broken and lost during the tooth slice preparation. A Zeiss optic microscope coupled with a Sony camera and Leica Qwin image analysis software (Leica Microsystems, Heildelberg, Germany) was used. The examination was performed with transmitted polarized light (at ×100 magnification) and quartz plate, and the sections were soaked in distilled water. The contrast between sound enamel (negative birefringence) and demineralized enamel (positive birefringence) was detected, and the software determined the depth of the body lesion.

STATISTICAL ANALYSIS

Data were obtained from 32 LF readings of artificial incipient caries lesions, and the histopathological data were collected from 16 artificial incipient caries lesions.

The receiver operating characteristic (ROC) analysis was conducted to assess the LF performance in caries development detection. The area under the ROC curve was calculated (A_Z). Before the formation of incipient caries lesions, the teeth were classified as sound, while after the demineralization procedure, the teeth were considered carious. A diagnostic screening was performed with the best cut off LF value obtained with the ROC analysis (maximum value of the sensitivity plus specificity), and the sensitivity, specificity, and accuracy were calculated.

To compare the LF readings before and after demineralization, the logarithmic values of the data were used to achieve normal distribution. Then, paired student *t* tests were performed. The significance level was chosen as $P<.05$. Pearson's correlation coefficient between the LF readings and depth of the artificial lesion was calculated.

RESULTS

Figure 1 shows the curve obtained with ROC analysis. The area under the ROC curve was 0.956. The best LF cut off point obtained from ROC analysis to distinguish between sound and carious teeth was 5.

At this cut off point, the sensitivity was 0.78, the specificity was 1, and the accuracy was 0.89.

A statistically significant increase in LF measurements of the artificial incipient caries lesions, compared to the readings before demineralization, was observed (Table 1).

Figure 2 shows a significant correlation ($P<.05$) between the LF readings of the artificial incipient caries lesions and the lesions depth determined by histopathological examination (r=0.68).

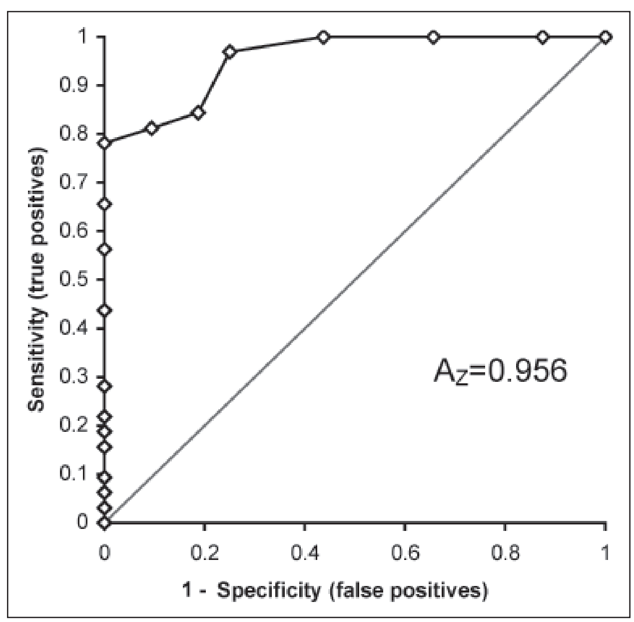

Figure 1. Receiver operating characteristic curve for the analysis of laser fluorescence readings of artificial incipient caries lesions in incisor primary teeth. A_Z indicates the area under the curve.

Table 1. Logarithmic Values of Laser Fluorescence Readings Before (Baseline) and After (AD) Formation of Artificial Incipient Caries Lesions in the Buccal Surfaces of Primary Incisor Teeth*

Group	N	DIAGNOdent readings
Baseline	32	0.546±0.085
AD	32	0.788±0.127
		P<.0001

***Mean±SD N indicates the number of samples.**

DISCUSSION

This study's aim was to investigate whether LF is able to monitor development of artificial caries lesions of primary teeth. Few investigations have been performed to evaluate LF's effectiveness with smooth-surfaces of permanent teeth.[1,2,14] To the best of the authors' knowledge, no studies of smooth-surface lesion detection in primary teeth have been published.

The development of methods providing an incipient caries lesion detection would allow application of preventive measures rather than restorative treatment.[15] The possibility of monitoring caries activity in children would be a valuable tool in dental caries prevention and treatment.

The artificial caries induction method is adequate for enamel caries studies.[24] Conflicting results have been reported in early studies using LF in artificial caries lesions in permanent teeth. While some authors reported no alterations in fluorescence before and after demineralization[13], others described high LF values of artificial lesions in permanent teeth.[25] In the authors' work with primary incisor teeth, a statistically significant increase in the LF readings after demineralization, compared with the readings before demineralization, was observed.

The increase in LF readings, albeit statistically significant, was relatively small (only 3 units), while the full capacity of the LF is to 99. The device reportedly does not adequately measure small changes in mineral content.[1,13,14,26] Despite these facts, this study's results suggest that a minor portion of the fluorescence increase with laser fluorescence could be due to the porosity increase.

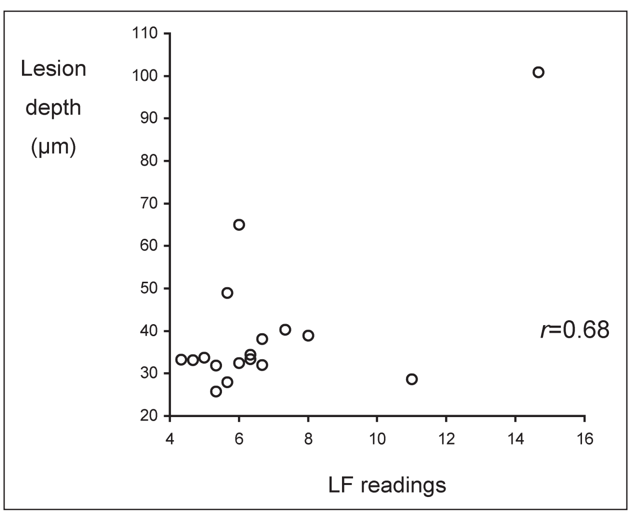

Figure 2. Correlation coefficient between the depth, as measured by polarized light microscopy image, and the laser fluorescence readings carried out in artificial incipient caries lesions.

Other statistical tests were used to evaluate the performance of the device for mineral loss detection. A ROC analysis was performed, and the area under the ROC curve was calculated. In this sort of analysis, the performance is better when the area value is near 1.[27,28] In this study, good performance of LF detection on incipient caries lesions was observed, since the area under ROC curve was 0.956. Moreover, the best cut off LF point for detection of the incipient enamel lesions, obtained by ROC analysis, was 5. With this cut off point, the sensitivity, specificity, and accuracy values were high.

To evaluate the device's accuracy, the LF readings of the artificial incipient caries lesions were correlated with the lesion depth, as determined by polarized light microscopy examination. Albeit significant, the Pearson's correlation coefficient was not so high (r=0.68). Other authors observed a higher coefficient correlation between LF readings and depth of natural smooth-surface caries lesions in permanent teeth.[1,14] The QLF method, however, was preferable for monitoring demineralization or remineralization, since it showed a closer correlation with the mineral changes than with LF.[14] The LF device was not adequate for measuring in vitro remineralization in natural incipient caries lesions.[26]

A good performance in detecting smooth-surface incipient caries lesions was achieved in the present study. The LF could be helpful in evaluating caries activity in short-term studies, since the method is quantitative and has an excellent reproducibility. This was suggested by others authors.[5] The QLF method proved to be useful for this purpose.[6]

CONCLUSIONS

LF showed good performance in detecting artificial caries lesions in primary teeth, and could be useful in monitoring caries development.

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