Performance of visual inspection, electrical conductance and laser fluorescence in detecting occlusal caries in vitro

Kordic, Alen; Lussi, Adrian; Luder, Hans-Ulrich
Performance of visual inspection, electrical conductance and laser fluorescence in detecting occlusal caries in vitro

Abstract

The aim of this study was to compare visual inspection (VI) and electrical conductance (EC) and laser fluorescence (LF) measurements in detecting occlusal caries. VI was based on fissure discoloration and performed with the naked eye. EC was measured with the ECM device (Lode Diagnostic, Groningen, The Netherlands), and LF was assessed with the DIAGNOdent apparatus (KaVo, Biberach, Germany). In extracted human premolars and molars, clinically sound sites (D0-/D1-lesions), enamel caries (D2-lesions), and dentinal caries (D3-/D4-lesions) were identified using recommended cut-off values. Thereafter, the teeth were cut longitudinally and analyzed by scanning electron microscopy for verification of caries depth. Reproducibility of VI was good, that of EC and LF excellent. In identifying caries at both the enamel and dentin level, the sensitivities of VI and LF were significantly (p < 0.05) higher than that of EC, while EC was significantly (p < 0.05) more specific. The positive predictive values, however, did not exceed 43%. Improved diagnoses at the dentinal level were obtained, when EC and LF were used as an adjunct to VI and when cut-off values were raised. Thus, visual inspection relying exclusively on fissure discoloration seems to allow only proper identification of sound occlusal surfaces. In cases of discolored fissures, the appliance-based methods help to avoid false positive identification of dentinal caries. However, attainable reliabilities of diagnoses do not seem to exceed about 50% to 60%.
Performance of visual inspection, electrical conductance and laser fluorescence in detecting occlusal caries in vitro

Summary

The aim of this study was to compare visual inspection (VI) and electrical conductance (EC) and laser fluorescence (LF) measurements in detecting occlusal caries. VI was based on fissure discoloration and performed with the naked eye. EC was measured with the ECM device (Lode Diagnostic, Groningen, The Netherlands), and LF was assessed with the DIAGNOdent apparatus (KaVo, Biberach, Germany). In extracted human premolars and molars, clinically sound sites (D0-/D1-lesions), enamel caries (D2-lesions), and dentinal caries (D3-/D4-lesions) were identified using recommended cut-off values. Thereafter, the teeth were cut longitudinally and analyzed by scanning electron microscopy for verification of caries depth. Reproducibility of VI was good, that of EC and LF excellent. In identifying caries at both the enamel and dentin level, the sensitivities of VI and LF were significantly (p<0.05) higher than that of EC, while EC was significantly (p<0.05) more specific. The positive predictive values, however, did not exceed 43%. Improved diagnoses at the dentinal level were obtained, when EC and LF were used as an adjunct to VI and when cut-off values were raised. Thus, visual inspection relying exclusively on fissure discoloration seems to allow only proper identification of sound occlusal surfaces. In cases of discolored fissures, the appliance-based methods help to avoid false positive identification of dentinal caries. However, attainable reliabilities of diagnoses do not seem to exceed about 50% to 60%.


Key Words: Occlusal caries, Diagnosis, Visual inspection, Electrical conductance, Laser fluorescence

Accepted for publication: 11 April 2003

Introduction

Several developments of the past decades have led to a new interest in the diagnosis of occlusal caries. Firstly, the proportion of fissure lesions has increased as a result of the decline in proximal caries due to prophylaxis (MENGHINI et al. 1998). Secondly, the identification of incipient occlusal lesions by clinical means has become difficult, because the wide-spread use of fluorides seems to delay cavitation (SAWLE & ANDLAW 1988). Thirdly, the classical bite-wing radiography hardly detects occlusal caries, before it has progressed well into dentin (WENZEL et al. 1990). For these reasons, appliances for measuring electrical conductance (EC) and laser fluorescence (LF) have been intro-
duced and recommended as diagnostic aids to identify both ini-
tial enamel lesions and dentinal caries requiring operative treat-
ment.
Irrespective of the availability of appliances, the identification of
fissure caries in daily practice still relies largely on the classical
visual inspection (VI), although its performance seems to vary.
Whereas some validation studies (LUSI 1991, 1993, VERDON-
schot et al. 1993, IE et al. 1995, RICKETS et al. 1995, HUSYMANS et
al. 1998, ASHLEY et al. 1998, PEREIRA et al. 2001) revealed high
specificity, but low sensitivity values and only moderate repro-
ducibility, other investigations (VERDONSCHOT et al. 1992,
EKSTRAND et al. 1997) indicated a moderate to good repro-
ducibility and high sensitivity, but low specificity.
The evaluation of commercially available instruments for EC
measurements, that were carried out in vitro (VERDONSCHOT et
ANS et al. 1998, ASHLEY et al. 1998) and in vivo (VERDONSCHOT et
al. 1992, IE et al. 1995, LUSI et al. 1995), revealed high sensi-
tivity and specificity values as well as excellent reproducibility.
This suggested that the technique was not only suited to reli-
ably detect enamel and dentinal caries, but could also be used for
longitudinal monitoring of lesions.
A recently introduced commercial product for LF mea-
urements makes use of the fact that upon excitation with red laser
light of 655 nm wave length, carious enamel and particularly
dentin fluoresce more brightly than sound dental hard sub-
stances (HIBST 1999). First studies carried out with this method
indicated a reproducibility comparable to that of EC measure-
et al. 2001), whereas reported sensitivity values varied marked-
ly, ranging from 0.17–0.2 (PEREIRA et al. 2001) to 0.78–0.82 (SHI
et al. 2000).
Several of the previous studies evaluating EC and LF used cut-
off values for the identification of enamel or dentinal caries, that
were not predetermined, but chosen deliberately based on the
measurements in the sample of examined teeth (HUSYMANS et
a result, the sensitivities and specificities may not correspond to
the values achievable in daily practice. It was the aim of the pre-
sent investigation to compare the performance of VI, EC, and LF
in one sample of extracted teeth, applying established, recom-
mented cut-off values for the detection of caries.

Materials and Methods
Sample: Sixty-one extracted human teeth, 25 premolars and
36 molars, from 33 females and 28 males ranging from 10 to
38 years of age were used (Table I). The molars were mostly wis-
tdom teeth which had been fully erupted and exposed to the oral
environment for some time. From both types of teeth, speci-
mens were selected to ensure that no apparent cavitation was
present and all three grades of fissure discoloration described
were assumed to correspond to D0 or D1, to D2, and to D3 or
D4, respectively.

Laser Fluorescence (LF) Measurements: The DIAGNodent device
(KaVo, Biberach, Germany) equipped with probe A was used at
room temperature (22 °C). The teeth were examined after drying
and remoistening with an artificial saliva preparation (Glandosan®, Fresenius, Stans, Switzerland). As in the case of EC mea-
urements, two recordings of laser fluorescence were made and
averaged, and the assessment was also repeated after an inter-
val of six weeks. Caries degrees were assigned to readings
according to recommendations by LUSI et al. (1999) for in vitro
tests. Thus, measurements of 0–4 units, 5–10 units, and >10 units
were assumed to correspond to D0 or D1, to D2, and to D3 or
D4, respectively.

Histological Validation: After completion of the diagnostic tests,
teeth were cut axially along the occlusal markings using a bandsaw (Exakt, Norderstedt, Germany). The two halves of each
specimen were then dehydrated in graded series of alcohol, in-
filtred in Technovit 7200 VLC (Kulzer, Wehrheim, Germany)
for 2–3 weeks, and finally embedded in the same resin. Follow-
ning polymerization of the blocks, their surfaces were polished
with silicon carbide grinding paper followed by a polishing cloth

Visual Inspection (VI): The specimens were evaluated in random
order by four dentists. For each assessment, they were first dried
thoroughly with a jet of air and then examined with the naked
eye at room illumination. Marked sites were assigned a grade of
fissure discoloration according to the definition of MARTHALER
(1966). No discoloration (grade 0) indicated a caries-free fissure
(D0) or an initial enamel lesion (D1), a yellow to light brown
discoloration (grade 1) was assumed to reflect deep enamel
lesions, a brown discoloration (grade 2) corresponded to dentinal
caries (D2), and a dark brown to black discoloration was consid-
ered to correspond to dentinal caries (D3 or D4).
Electrical Conductance (EC) Measurements: Measurements were
made under moist conditions with Ringer lactate solution as
conducting medium, using the prototype of the ECM I device
(Lode Diagnostic, Groningen, The Netherlands) at room tem-
perature (22 °C) and with 7.2 l/min air flow. Moist teeth were
held in firm contact with the reference electrode in one hand of
the examiner, while the other hand was used to carry the mea-
suring hand-piece. Each specimen was assessed twice and the
average of the two measurements recorded. After an interval of
6 weeks, the examination was repeated. The recordings were
assigned to degrees of caries according to the manufacturer’s rec-
ommendations. Thus, conductance readings of –0.5–3.0 units,
3.1–6.0 units, and >6.0 units corresponded to dentinal caries (D0)
or an initial enamel lesion (D1), to D2, and to D3 or D4, respec-
tively.

Histological Validation: After completion of the diagnostic tests,
teeth were cut axially along the occlusal markings using a bandsaw (Exakt, Norderstedt, Germany). The two halves of each
specimen were then dehydrated in graded series of alcohol, in-
filtred in Technovit 7200 VLC (Kulzer, Wehrheim, Germany)
for 2–3 weeks, and finally embedded in the same resin. Follow-
ning polymerization of the blocks, their surfaces were polished
with silicon carbide grinding paper followed by a polishing cloth

<table>
<thead>
<tr>
<th>Lesions</th>
<th>Sound sites (D0)</th>
<th>Initial enamel caries (D1)</th>
<th>Deep enamel caries (D2)</th>
<th>Dentinal caries (D3 or D4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean; range; years)</td>
<td>13.9; 10–23</td>
<td>24.6; 18–38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fissure discoloration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no discoloration (grade 0)</td>
<td>9</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yellow – light brown (grade 1)</td>
<td>8</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dark brown – black (grade 2)</td>
<td>8</td>
<td>17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tab. I Sources of premolars and molars used and lesions identified.

<table>
<thead>
<tr>
<th>Source</th>
<th>Premolars</th>
<th>Molars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females (N)</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td>Males (N)</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>Age (mean; range; years)</td>
<td>13.9; 10–23</td>
<td>24.6; 18–38</td>
</tr>
<tr>
<td>Fissure discoloration</td>
<td>no discoloration (grade 0)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>yellow – light brown (grade 1)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>dark brown – black (grade 2)</td>
<td>8</td>
</tr>
</tbody>
</table>

Histological Validation: After completion of the diagnostic tests,
teeth were cut axially along the occlusal markings using a bandsaw (Exakt, Norderstedt, Germany). The two halves of each
specimen were then dehydrated in graded series of alcohol, in-
filtred in Technovit 7200 VLC (Kulzer, Wehrheim, Germany)
for 2–3 weeks, and finally embedded in the same resin. Follow-
ning polymerization of the blocks, their surfaces were polished
with silicon carbide grinding paper followed by a polishing cloth

Histological Validation: After completion of the diagnostic tests,
teeth were cut axially along the occlusal markings using a bandsaw (Exakt, Norderstedt, Germany). The two halves of each
specimen were then dehydrated in graded series of alcohol, in-
filtred in Technovit 7200 VLC (Kulzer, Wehrheim, Germany)
for 2–3 weeks, and finally embedded in the same resin. Follow-
ning polymerization of the blocks, their surfaces were polished
with silicon carbide grinding paper followed by a polishing cloth

Histological Validation: After completion of the diagnostic tests,
teeth were cut axially along the occlusal markings using a bandsaw (Exakt, Norderstedt, Germany). The two halves of each
specimen were then dehydrated in graded series of alcohol, in-
...
with diamond paste. Thereafter, blocks were coated with a 10–15 nm thick carbon layer using a MED020/EVM030 electron beam evaporator (BAL-TEC, Balzers, Liechtenstein) and examined with a Stereoscan 180 scanning electron microscope (SEM; Cambridge, Dortmund, Germany) equipped with a four quadrant silicon backscatter detector set-up to show atomic number contrast. Digital micrographs were obtained at 15–20 kV accelerating voltage, a working distance of 15–20 mm, and primary magnifications of 10 to 120, using the scanning and imaging software WinDISS (point electronic, Halle, Germany) and a personal computer connected to the SEM (Figs. 1e–h).

For the quantitative evaluation of the micrographs, the program SigmaScan Pro (Jandel Scientific, San Rafael, CA) was used. Enamel thickness, dentin thickness, and caries depth were measured along a line running from the ground of the fissure through the deepest point of an eventual carious decalcification to the limit of the pulp cavity (Figs. 1f, g). In order to standardize the data, caries depth was expressed as percentage of the enamel and dentin thickness. As a result, values of relative lesion depth were obtained that ranged from >0% to 100% for enamel and from >100% to 200% for dentinal caries. These values were averaged across the two halves of each tooth. For comparison with the diagnostic outcomes, fissures lacking any decalcification were classified as sound (D0), while relative caries depths of 1–50%, 51–100%, 101–150%, and 151–200% were taken as D1-, D2-, D3-, and D4-lesions, respectively. In accordance with the diagnostic abilities of VI, EC, and LF, D0- and D1-lesions were combined and considered clinically sound. Likewise, D3- and D4-lesions were pooled, because there were only very few specimens with deep dentinal caries.

Statistical evaluation: In order to test the reproducibility and repeatability of the detection methods, the values of unweighted Cohen’s Kappa (K) were calculated for duplicate diagnoses and Pearson’s correlation coefficients for repeated EC- and LF-measurements. Values of K above 0.75 were interpreted to indicate excellent, values of 0.4–0.75 moderate to good agreement. For further analyses, the ratings of different examiners and the repeated measurements were averaged. For establishing average VI-diagnoses, mean discoloration grades of 0.5 or 1.5 were rounded up.

The determination of accuracy, sensitivity, specificity, and predictive values as well as a ROC-analysis served to estimate the performance of VI, EC, and LF. The accuracy was calculated as the proportion of correct identifications of clinically sound sites and D2- and D3/D4-lesions. Sensitivity, specificity, and predictive values were determined for the detection of caries in general and dentinal caries in particular. In the first case, caries-free sites and D1-lesions were regarded as sound, while D2/D3/D4-lesions were considered diseased, in the second case, the cut-off between non-diseased and diseased was assumed between D2- and D3-lesions. Differences between the three diagnostic procedures were analysed using Pearson’s Chi²-test, and when this
Detection of occlusal caries

Schweiz Monatsschr Zahnmed, Vol 113: 8/2003

Suggested a significant difference, pairwise using Fisher’s exact test. For calculating positive and negative predictive values, the prevalence of occlusal caries in molars and upper premolars was adjusted on the basis of data obtained from an epidemiologic survey in 168 15-year-old school children living in the canton of Zurich, Switzerland (MENGHINI et al. 1998). Thus, the population prevalence of caries deeper than D1-lesions was estimated at about 20% and that of dentinal caries at about 15%.

On the same assumptions as for the calculation of sensitivities and specificities, ROC-analyses were made for the identification of caries at the enamel and dentinal level. In an attempt to evaluate the performance of EC and LF, when these were used in combination with VI, readings obtained from specimens disclosing dark fissure discoloration (grade 2) were taken to calculate sensitivity, specificity, and predictive values in detecting dentinal caries. For these analyses, both the predetermined cut-off values and higher thresholds derived from the ROC-curves were applied.

All statistical analyses were performed with the program Systat (SPSS, Chicago, IL), and the program Axum (MathSoft, Seattle, WA) served to make the graphical plots.

Results

The outcomes of the visual inspection varied considerably between pairs of examiners, K-values ranging from 0.6 to 0.75. In contrast, duplicate EC- and LF-measurements exhibited highly significant correlations (p<0.001), and K-values for the derived diagnoses were 0.81 and 0.78, respectively.

Although the selection of teeth intended to ensure similar frequencies of fissure discoloration in premolars and molars, the histological examination revealed that with the exception of one specimen, all premolars were caries-free or exhibited D1-lesions. In molars, however, the degrees of caries were distributed more evenly (Table I). Overall, 40 specimens were clinically sound, 10 teeth exhibited deep enamel caries, and 11 specimens disclosed dentinal caries. Hence, the prevalence of caries in the sample examined was about 34%, that of dentinal caries about 18%.

From the plots of caries depth against the diagnostic measurements (Fig. 2), it was evident that none of the regression lines predicted dentinal caries. With the predetermined cut-off values, the accuracy of VI, EC, and LF in detecting clinically sound sites was about 37%, 78%, and 53%, respectively (Table II). From the D2-lesions, about 30–40% were correctly identified by all three procedures, whereas dentinal caries was recognized most accurately by VI and LF. With respect to the detection of lesions deeper than D1, VI and LF exhibited significantly higher sensitivity, but lower specificity than EC (Table II). A similar pattern was also evident regarding the identification of dentinal caries.

> Fig. 2 Scattergrams and non-parametric regression lines of relative caries depth as a function of fissure discoloration (a), electrical conductance (b), and laser fluorescence (c). Ranges of diagnostic measurements corresponding to clinically sound sites, enamel caries, and dentinal caries are labeled D0/D1, D2, and D3/D4, respectively; ranges of relative caries depth corresponding to the respective true diagnoses are marked as "sound", E’Caries, and D’Caries, respectively. Note that due to averaging across examiners, fissure discoloration grades (a) could assume non-integer values.
Tab. II  Accuracy and diagnostic performance of visual inspection (VI) as well as electrical conductance (EC) and laser fluorescence (LF) measurements in identifying caries (cut-off at D2) and dentinal caries (cut-off at D3). Significant (p<0.05) differences are marked by bars.

<table>
<thead>
<tr>
<th></th>
<th>VI</th>
<th>EC</th>
<th>LF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinically sound sites</td>
<td>37.5%</td>
<td>77.5%</td>
<td>52.5%</td>
</tr>
<tr>
<td>D2-lesions</td>
<td>40.0%</td>
<td>40.0%</td>
<td>30.0%</td>
</tr>
<tr>
<td>D3/D4-lesions</td>
<td>81.8%</td>
<td>36.4%</td>
<td>90.9%</td>
</tr>
<tr>
<td><strong>Performance (caries)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>100.0%</td>
<td>66.7%</td>
<td>95.2%</td>
</tr>
<tr>
<td>Specificity</td>
<td>37.5%</td>
<td>77.5%</td>
<td>52.5%</td>
</tr>
<tr>
<td>PPVa</td>
<td>28.6%</td>
<td>42.6%</td>
<td>33.4%</td>
</tr>
<tr>
<td>NPVa</td>
<td>100.0%</td>
<td>90.3%</td>
<td>97.8%</td>
</tr>
<tr>
<td>ROC-area</td>
<td>0.764</td>
<td>0.785</td>
<td>0.811</td>
</tr>
<tr>
<td><strong>Performance (dentinal caries)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>81.8%</td>
<td>36.4%</td>
<td>90.9%</td>
</tr>
<tr>
<td>Specificity</td>
<td>68.0%</td>
<td>90.0%</td>
<td>76.0%</td>
</tr>
<tr>
<td>PPVa</td>
<td>31.1%</td>
<td>39.1%</td>
<td>40.1%</td>
</tr>
<tr>
<td>NPVa</td>
<td>95.5%</td>
<td>88.9%</td>
<td>97.9%</td>
</tr>
<tr>
<td>ROC-area</td>
<td>0.745</td>
<td>0.727</td>
<td>0.727</td>
</tr>
</tbody>
</table>

* Adjusted to an estimated prevalence of 20%  
* Adjusted to an estimated prevalence of 15%

Discussion

Although the teeth used for validation were chosen to obtain an even distribution of all grades of fissure discoloration, only 11 out of the 61 specimens exhibited dentinal caries. This rather low frequency renders estimates of diagnostic performance susceptible to confounding effects of e.g. staining, deposits, or irregular enamel structure in the fissures and may account for part of the discrepancies between the present and previous findings. On the other hand, the caries prevalence found in our experimental teeth was about two to three times higher than that observed in randomly selected individuals of a comparable age (Steiner M. personal communication). Therefore, the prevalence of caries was adjusted for obtaining clinically relevant estimates of positive and negative predictive values.

The technique of VI applied in this study has been introduced by Marthaler (1966). Although it has been refined in various ways since then, the method has been and still is widely used in numerous epidemiologic surveys (Menghini et al. 1998). However, it has never been validated histologically so far.

In order to simulate the clinical circumstances of LF measurements, the saliva substitute Glandosan® was used as a fluid in the fissure. However, it has never been validated histologically so far.

Although significant differences were found only between EC and LF with respect to sensitivity and between VI and EC with respect to specificity (Table II), positive predictive values for the presence of enamel and dentinal caries ranged from about 29% to 43% and from about 31% to 40%, respectively (Table II). Thus, compared to predictions by chance alone (which would yield hit rates corresponding to prevalence values) diagnoses of caries were improved by about 9-25%. In contrast, predictions of the absence of caries (NPV) varied between about 89% and 100% (Table II).

The ROC-areas characterizing the three diagnostic procedures in detecting either caries deeper than D1-lesions or dentinal caries were similar (Table II). The respective ROC-curves also disclosed only slight differences regarding the identification of enamel caries (Fig. 3a).

With respect to the identification of dentinal caries (Fig. 3b), however, the performance of the procedures differed. In the high sensitivity/low specificity range, VI and LF performed somewhat better than EC. In the low sensitivity/ high specificity range, where the ROC-curve characterizing the performance of VI is theoretical, because this method did not offer any cut-off points beyond discoloration grade 2, EC yielded higher specificities than LF. The inferior performance of LF was mainly due to a marked drop in sensitivity without a proportionate gain in specificity above the threshold of 10 LF-units. As a result, the corresponding positive predictive values revealed a maximum of about 0.35 at 10 LF-units and decreased rapidly at higher cut-off values (Fig. 3d). In contrast, the positive predictive values produced by EC increased almost continuously and attained levels around 0.45 for the prediction of caries at the dentinal level (Fig. 3c).

When EC was used as an adjunct to VI for the identification of dentinal caries, the high sensitivity attained with VI alone dropped to about 36%, i.e. the value produced by EC alone. Conversely, the specificity increased to 96% at a cut-off value of 8 units, yielding positive and negative predictive values of about 62% and 90%, respectively. With the complementary use of LF, optimal performance was achieved at a threshold of 10 units with a sensitivity of about 82%, a specificity of 84%, and positive and negative predictive values of about 47% and 96%, respectively.

In accordance with the findings from previous studies (Verdonscot et al. 1992, Ie et al. 1995, Ricketts et al. 1995, Huymans et al. 1998, Pereira et al. 2001), VI exhibited a better reproducibility and sensitivity, but a lower specificity. This discrepancy seems to be related to the way caries is graded visually. When the examiners (Lussi 1991, 1993, 2000, Verdonscot et al. 1993, Ie et al. 1995, Ricketts et al. 1995, Huymans et al. 1998, Pereira et al. 2001) were asked to identify the degree of caries on the basis of their own, mostly not further specified criteria and experience, reproducibility and sensitivity were low, while specificity was high. Conversely, reproducibility was good and sensitivity higher than specificity, when the examiners, as in our study, had to indicate only the degree of fissure discoloration (Verdonscot et al. 1992, Ekstrand et al. 1997). Therefore, when VI based on fissure discoloration is used as the sole technique, it is associated with a risk of false positive diagnoses and, hence, unnecessary treatments of about 70%.

In accordance with the findings from previous studies (Verdonscot et al. 1992, Ie et al. 1995, Lussi et al. 1995, Ricketts et al. 1995, Ekstrand et al. 1997, Lussi et al. 1999, Lussi 2000), both EC and LF exhibited good to excellent repeatability, which renders them suitable for longitudinal monitoring. At the predetermined cut-off values used in our evaluation, EC was generally more specific, but less sensitive than LF. In fact, the sensitivities obtained with EC are among the lowest and vice versa the specificity values among the highest observed so far. It would
Detection of occlusal caries

Schweiz Monatsschr Zahnmed, Vol 113: 8/2003

appear, therefore, that recommendations for the usage of the ECM are well adjusted to a situation of low caries prevalence, where specificity is more important than sensitivity.

In comparison with previous *in vitro* investigations of LF (LUSSI et al. 1999, SHI et al. 2000), which in the absence of pertinent experience relied on cut-off values derived from the examined teeth, our evaluation yielded somewhat higher sensitivities and slightly lower specificities. Using the same predetermined cut-off values as in our study, PRATZIA et al. (2001) obtained considerably higher specificities and markedly lower sensitivities. These authors argued that their deviating findings could possibly be attributed to sampling as well as non-random variability of the DIAGNOdent instruments. Our results do not support such an assumption, although a reason for the discrepancy between our and the close to perfect ROC-curves of SHI et al. (2000) was not readily apparent either.

As indicated by the predictive values, the performance of both EC and LF alone was unsatisfactory, the risks of false positive diagnoses amounting to about 60%. An improvement in reliability was achieved, when these techniques were applied as an adjunct to VI in teeth displaying fissures with a dark discoloration, and when cut-off values were raised. In the case of EC, this produced a more or less continuous increase of positive predictive values to about 60% at the level of dentinal caries. For unknown reasons, the reliability of diagnoses from LF, however, increased only up to a cut-off value of about 10.

---

**Fig. 3** Parametric ROC-curves regarding the identification of caries (a) and dentinal caries (b) with the three diagnostic methods and corresponding positive and negative predictive values regarding the identification of caries (c) and dentinal caries (d) with EC and LF measurements, plotted as a function of the cut-off values.
Zusammenfassung

Das Ziel dieser Studie war, Diagnosen von Fissurenkaries, die mit visueller Inspektion (VI), Messungen der elektrischen Leitfähigkeit (EC) und Laserfluoreszenz-Messungen (LF) gestellt wurden, zu vergleichen. Bei der VI wurde mit bloßem Auge die Grad der Fissurenverfärbung beurteilt. Die elektrische Leitfähigkeit wurde mit dem ECM Gerät (Lode Diagnostic, Groningen, Niederlande) gemessen, und zur Bestimmung der Laserfluoreszenz diente der DIAGNOdent Apparat (KaVo, Biberach, Deutschland). Unter Anwendung etablierter Beurteilungskriterien wurden an extrahierten menschlichen Prämolaren und Molaren klinisch gesunde Stellen (D0-/D1-Läsionen), Schmelzkaries (D2-Läsionen) und Dentinkaries (D3-/D4-Läsionen) identifiziert. Danach wurden die Zähne axial entzwei geschnitten und für die Untersuchung im REM präpariert. Die Reproduzierbarkeit der VI war gut, die von EC und LF hingegen erhöht. Bei der Identifizierung von Schmelz- und Dentinkaries war die Sensitivität der VI und von LF signifikant (p<0,05) höher als die von EC, während EC signifikant (p<0,05) spezifischere Diagnosen ergab. Die positiven Voraussagewerte überstiegen jedoch den Wert von 43% nicht. Zuverlässigere Diagnosen von Dentinkaries ergaben sich, wenn EC und LF als Ergänzung zur VI verwendet oder die diagnostisch massgebenden Schwellewerte erhöht wurden. Die Ergebnisse zeigen, dass mit einer visuellen Beurteilung der Fissurenverfärbung nur gesunde Okklusalflächen zuverlässig identifiziert werden können. In Fällen von verfärbten Fissuren tragen die Messgeräte zwar dazu bei, falsch positive Identifikationen von Dentinkaries zu vermeiden, die damit erreichte Zuverlässigkeit der Diagnosen scheint aber 50% bis 60% nicht zu übersteigen.

Résumé

L’objectif de cette étude était de diagnostiquer des caries occlusales en comparant les méthodes suivantes: inspection visuelle (IV), mesures par conductibilité électrique (CE) et mesures par fluorescence laser (FL). IV pratiquée à l’œil nu ne basait sur le changement de couleur des fissures. CE était mesurée avec l’équipement ECM (Lode Diagnostic, Groningue, Pays-Bas). La détermination par FL s’était faite au moyen de l’appareil DIA-