

# Subjectivity and examiner experience in diagnosis of residual caries – an in vitro study

## Summary

The aim was to evaluate subjectivity (using inter- and intra-examiner repeatability), the effect of examiner experience, and residual caries diagnostic accuracy with visual tactile (VT) criteria and using a caries disclosing agent (CD).

Thirty teeth with occlusal caries were excavated by a single operator not involved in the diagnostic part of the study. A test area was marked in each cavity. Four dentists with more than five and five dentists with less than five years' experience rated the marked area twice (a week apart) using VT criteria. A week later, the samples were stained using Caries Detector®. The same examiners rated the presence or absence of stain in the marked area twice (a week apart). Undecalcified thin slices were examined for bacteria using light microscopy.

Overall kappa for inter-examiner repeatability was higher for CD (0.45) than VT (0.31). In the less experienced group the kappa value was higher for CD (0.41) than for VT (0.23). In the experienced group kappa was lower for CD (0.43) than for VT (0.46). Median kappa for intra-examiner repeatability was higher for caries detector (0.77, 0.53) compared to visual tactile (0.52, 0.34) for the more and less experienced examiners respectively. There was no significant difference between the experienced and the inexperienced group in combined sensitivity and specificity (mean) for VT (0.52, 0.53) or CD (0.60, 0.58).

In conclusion: VT was more subjective than CD, except for experienced examiners who had a higher inter-examiner repeatability for VT than CD. Diagnostic accuracy for residual caries does not increase with experience.

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Corresponding author:

Dr. Áine M. Lennon

Zentrum für Zahn-, Mund- und Kieferheilkunde  
Klinik für Präventivzahnmedizin, Parodontologie und  
Kariologie, Plattenstrasse 11, CH-8032 Zürich  
Tel. +41 44 634 3483, Fax +41 44 634 4308  
Email: aine.lennon@zzmk.unizh.ch

ÁINE M. LENNON<sup>1</sup>, ANNETTE WIEGAND<sup>1</sup>,  
WOLFGANG BUCHALLA<sup>1</sup>, BRITTA WAHL<sup>2</sup>,  
CAROLA WERNER<sup>3</sup>, HERBERT BETKE<sup>2</sup>,  
CHRISTIAN HANNIG<sup>4</sup>, TINA RÖDIG<sup>2</sup> and  
THOMAS ATTIN<sup>1</sup>

<sup>1</sup> Clinic for Preventive Dentistry, Periodontology and  
Cariology, University of Zürich, Switzerland

<sup>2</sup> Department of Operative Dentistry, Preventive Dentistry  
and Periodontology, Georg August University Göttingen,  
Germany

<sup>3</sup> Department of Medical Statistics, Georg August University  
Göttingen, Germany

<sup>4</sup> Department of Operative Dentistry and Periodontology,  
Dental Clinic and Dental School, Albert Ludwigs University,  
Freiburg, Germany

## Introduction

Although it has been questioned (MERTZ-FAIRHURST et al. 1998), the concept that infected dentin needs to be removed before placing a dental restoration is still generally accepted (TYAS et al. 2000, WEERHEIJM et al. 1999). Therefore, accurate diagnosis of residual caries in a cavity is still important for the clinical dentist. Conventionally the decision is based on an assessment of visual and tactile criteria and is thought to be highly subjective. Caries

detector dyes designed to stain "infected tissue" red have been developed to help the dentist with this decision. There is, however, concern that these dyes which are specific for demineralised dentine rather than for bacteria may mislead the operator into removing non-infected hypomineralised tissue (e.g. circumpulpal dentine) therefore leading to unnecessary over-excitation (KIDD et al. 1993, MCCOMB 2000).

Much has been written about the performance of different caries removal techniques and aids for residual caries detection including caries disclosing agents (SATO & FUSAYAMA 1976, BANERJEE et al. 2000, BEELEY et al. 2000, KIELBASSA et al. 2000, MUNSHI et al. 2001). However, other factors such as the degree of subjectivity and individual clinical experience may play an important role in how well a particular method works in practice for a broad range of operators. Although examiner repeatability has been widely investigated for the diagnosis of caries at the tooth surface or on radiographs, very little has been reported about the effect of subjectivity on diagnosis of residual caries during caries excavation. The accuracy of caries detector dye has been examined in the past (LENNON et al. 2002, YAZICI et al. 2005), but the inter- and intra-examiner repeatability has not yet been looked at.

When teaching dental students how to employ visual tactile criteria and also caries disclosing agents in the diagnosis of residual caries it appears that the level of experience might play a role in the decision to excavate further or not and the length of time needed by the student to reach a decision.

We hypothesised that

1. Repeatability would be better for Caries Detector (CD) compared to Visual Tactile (VT).
2. Experienced examiners would achieve higher accuracy with VT compared to less experienced examiners.

Therefore, the aim of this investigation was to evaluate subjectivity (using inter- and intra-examiner repeatability), the effect of examiner experience, and accuracy in residual caries diagnosis using conventional visual tactile criteria and a caries disclosing agent.

## Materials and Methods

### Sample selection and caries removal

Thirty extracted human molars and premolars with dentine caries were chosen and stored in 0.5% thymol solution before use and also between examinations. On visual examination the teeth all had small cavities in the enamel. Caries was removed from all 30 sample teeth by one operator who was not involved in the diagnostic part of the study. 15 samples were thoroughly excavated with a tendency towards over-excitation while the other 15 were less thoroughly excavated with a tendency to under-excitation. The samples were randomly numbered and a test area was marked in each cavity using a felt tipped pen as follows: Four dots were made in the enamel edge of the cavity and the point at which lines through the dots would cross was the test area. In this way no marks were made directly on the test area obscuring the area in question. 20 of the test areas were entirely confined to dentine and 10 were at the enamel-dentin junction.

### Clinical evaluations

The examiners were nine clinical dentists from the Department of Operative Dentistry of Göttingen University whose experience ranged from under one year to over 15 years in clinical practice. For each exam the examiners were blinded as to how the teeth were rated by their colleagues and also how they themselves had scored the same sample teeth in other exams. All exams were

carried out without magnification and under standard dental unit lighting conditions.

The examiners independently rated a marked test area in the cavity of each specimen as carious or caries free using visual tactile criteria as follows:

Examiners used a sharp probe (Aesculap, Tuttlingen, Germany) and a visual assessment to rate each sample. The criteria for the diagnosis of residual caries were that soft and stained tissue in dentine would be rated as carious while hard and stained dentine would be rated caries free. At the enamel-dentine junction both soft and stained, and hard and stained tissue was rated as carious. The same examiners re-examined the same teeth again using visual tactile criteria a week later.

Then the cavities were stained using Caries Detector® (Kuraray, Osaka, Japan), containing acid red and propylene glycol, according to the manufacturer's instructions. A cotton pellet soaked in Caries Detector® was applied to the cavity for 10 s then the cavity was rinsed with water for 1 min. For this exam the examiners were asked to rate tissue which retained the red stain after rinsing as carious. Again, the same group of examiners repeated this exam independently in a blind study using the same criteria a week later.

### Histology

All chemicals used in the embedding, deplasticisation and staining process were obtained from Merck (Darmstadt, Germany). The sample teeth were dehydrated in graded ethanol and then infiltrated with a specially designed methylmethacrylate resin embedding material (methylmethacrylate 100 ml, nonylphenolpolyglycolether 20 ml, dibutylphthalate 2 ml, benzoylperoxide 5 ml) at 4 °C. Polymerisation was completed at 32 °C over 48 hours.

A thin slice (8 µm) was prepared from the centre of the marked test area in the cavity using a rotary microtome (Leica Microsystems, Bensheim, Germany). For deplasticisation, the sections were placed in three changes of 2-methoxyethylacetate for 20 min each, two changes of acetone for 5 min each, and two changes of deionised water for 5 min each. The sections were stained with 2% Giemsa for 45 min and then rinsed extensively with water.

The sections were evaluated for presence of bacteria in the dentine-tubules using light microscopy at a total magnification of 1000×. The section was scanned from the cavity surface to the pulp along the entire cavity outline from one dentine-enamel junction to the other. Sections with more than one infected tubule along the cavity outline were scored positive for residual caries. Sections with only single isolated bacteria present were scored negative as reported previously (LENNON et al. 2006).

### Statistical analyses

For statistical analyses the examiners were split into an experienced (5–15 years clinical experience) and an inexperienced group (0–4 years clinical experience). Inter- and intra-examiner repeatabilities were calculated for each method and experience group using Cohen's kappa. For intra-examiner repeatability, the scores for the first and second exam using each method were used. For inter-examiner repeatability we compared only the scores given by the examiners for the first exam using each method.

Sensitivity and specificity were calculated for each method and experience group based on the answers given by the examiners for the first exam for each method.

Differences between the groups for sensitivity and specificity were tested for significance using a one-way ANOVA test.

**Results**

Median kappa (Tab. I) for intra-examiner repeatability was higher for caries detector (0.77 and 0.53) compared to visual tactile (0.52 and 0.34) for the more and less experienced examiners respectively.

When all nine examiners were taken into account, kappa for inter-examiner repeatability (Tab. II) was higher for CD (0.45) than VT (0.31).

In the less experienced group the kappa value was higher for CD (0.41) than for VT (0.23) in contrast to the experienced group where kappa was lower for CD (0.43) than for VT (0.46). Our first hypothesis (that repeatability would be better for CD compared to VT) was correct except for inter-examiner repeatability among experienced examiners.

Sensitivity (Fig. 1) was higher for the caries detector method compared to the visual tactile diagnosis. However, this was only statistically significant for the more experienced group. Specificity (Fig. 2) was higher for the visual tactile method compared to caries detector, but this difference was not statistically significant for either experience group. There was no significant difference between the experienced and inexperienced groups in combined sensitivity and specificity (unweighted mean) for VT (0.52 and 0.53) or CD (0.60 and 0.58).

Our second hypothesis (that experienced examiners would achieve higher accuracy with VT compared to less experienced examiners) was not proved, as there were no significant differences between the experience groups as regards sensitivity and specificity.

**Discussion**

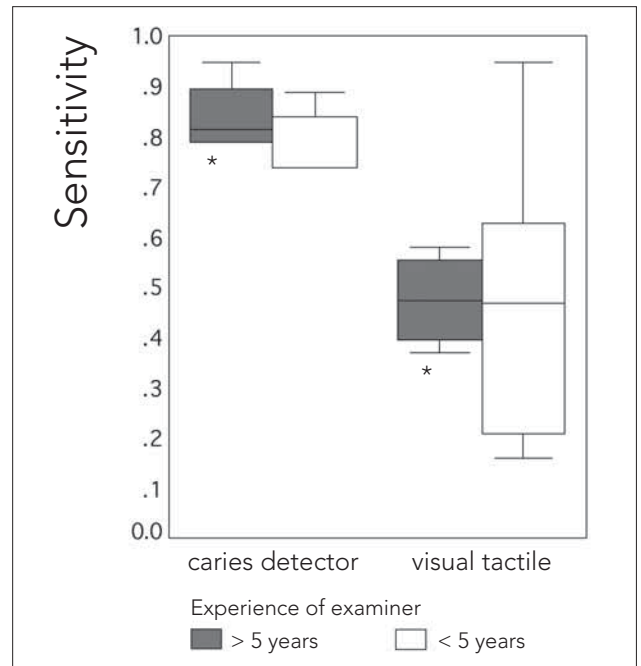
In this study we looked at the effect of examiner experience on two methods for residual caries diagnosis. The conventional visual tactile method is generally presumed to be highly subjective given the need for a two-component assessment of tissue hardness and discolouration (BANERJEE et al. 2000, LENNON et al. 2002, LENNON 2003, KIDD & FEJERSKOV 2004). Tissue discolouration is probably the more easily definable of the two criteria but has a potential for subjectivity due to differences which are sometimes very subtle. Hardness on probing on the other hand is not only difficult to characterise but, because it is felt indirectly using a probe, is open to personal interpretation. A previous

*Tab. I Intra-examiner repeatability (median kappa value) for caries detector and visual tactile methods and for more experienced and less experienced groups.*

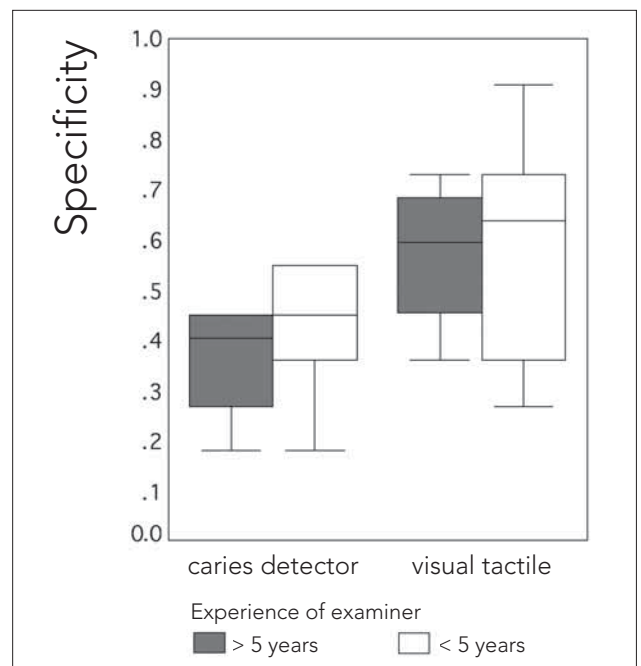
	Intra-examiner repeatability (median kappa value)		
	examiners	visual tactile	caries detector
more experienced	1-4	0.52	0.77
less experienced	5-9	0.34	0.53

*Tab. II Inter-examiner repeatability (kappa value) for caries detector and visual tactile methods overall and for each experience group.*

	Inter-examiner repeatability (kappa value)		
	examiners	visual tactile	caries detector
overall	1-9	0.31	0.45
more experienced	1-4	0.46	0.43
less experienced	5-9	0.23	0.41



*Fig. 1 Boxplot showing median, 25<sup>th</sup> and 75<sup>th</sup> percentiles (box), maximum and minimum (whiskers) sensitivity achieved using caries detector (CD) and visual tactile (VT) methods by each of the experience groups. Boxes marked with a \* were significantly different statistically.*



*Fig. 2 Boxplot showing median, 25<sup>th</sup> and 75<sup>th</sup> percentiles (box), maximum and minimum (whiskers) specificity achieved using caries detector (CD) and visual tactile (VT) methods by each of the experience groups. None of the differences shown here were significantly different statistically.*

study found that there was considerable variation in the visual tactile diagnosis of residual caries between four different examiners (THOMAS et al. 2000). Whether this interpretation becomes

more consistent or more accurate with increasing clinical experience has not been investigated.

We included the caries detector method because it involves the detection of a dye and should therefore be a more objective method than the conventional visual tactile assessment.

We chose teeth with small cavities through the enamel for this investigation. Based on previous studies (LENNON et al. 2006, LENNON 2003) where teeth were sectioned through the lesion we found that this stage of caries most often resulted in a lesion in dentine not extending into the inner half of the dentine or involving the pulp. This strategy resulted in small to medium sized lesions and no pulp exposures during excavation.

Our examiners ranged from newly qualified dentists in their first year of clinical practice to a professor of conservative dentistry with 15 years of clinical experience. The fact that all of the examiners were members of the same university department might be a limiting factor. But since the nine examiners were trained in four different dental schools and one in a different country we felt that they still presented a relevant range of clinical backgrounds for this investigation.

The sample teeth were excavated by a dentist not involved in the diagnostic part of the study. This dentist was asked to subtly overexcavate half of the samples and underexcavate the other half. This operator was excluded from the diagnostic part of the study so as not to cause bias if the excavator recognised which teeth she had tried to over- and which to under-excavate. This deliberate over- and underexcavation was an attempt to have roughly half of the samples positive on histology (we achieved 19 positive and 11 negative samples) because the analyses using sensitivity and specificity are affected by the distribution of positive and negative samples.

There was some concern that dentine probing could soften the tissue and thereby increase the number of positive diagnoses made by the last few examiners. An earlier study (THOMAS et al. 2000) found that with four examiners the caries rate was not higher for examiners number three and four compared to the first two. Our examiners carried out the exams in random order and not sequentially so that the same examiners did not always carry out the last exams.

The first hypothesis (that repeatability would be better for CD compared to VT) was based on the assumption that the detection of residual caries using a dye might be more objective than a visual tactile assessment. This hypothesis proved correct except for inter-examiner repeatability among experienced examiners. The experienced examiners scored more consistently using the VT exam. This suggests that experience and not method subjectivity has more effect on the outcome of residual caries diagnosis with more experienced examiners.

The second hypothesis was that experienced examiners would achieve higher accuracy with VT compared to less experienced examiners. This hypothesis assumed firstly that the VT method was subjective and secondly that there was a learning effect and accuracy achieved with this method would improve with experience. This was not true.

One explanation for the lack of a learning effect with the visual tactile diagnosis is that the dentist does not immediately discover whether he or she has made a mistake. In the usual course of events a restoration will be placed in the cavity and if over-excavation has taken place no one will be the wiser. If the restoration needs to be replaced due to under-excavation and recurrent caries, this will happen later and may be misdiagnosed as secondary caries (DAHL & ERIKSEN 1978, BURKE et al. 2001, DELIGEORGI et al. 2001).

In conclusion: VT was generally more subjective than CD (higher kappa), except for experienced examiners who had a higher inter examiner kappa for VT than CD. Accuracy in residual caries diagnosis does not necessarily increase with experience.

## Zusammenfassung

Das Ziel der Studie war, die Kariesdiagnose bei der Exkavation mittels visuell/taktilen Kriterien (VT) und Caries Detector® (CD) hinsichtlich deren Genauigkeit, Einfluss der Erfahrung des Zahnarztes und Subjektivität (ermittelt anhand von Inter- und Intra-Untersucher-Reproduzierbarkeit) zu untersuchen. Dreissig Zähne mit okklusaler Dentinkaries wurden von einer Zahnärztin exkaviert, die nicht am diagnostischen Teil der Studie teilnahm. In jedem Zahn wurde ein Testgebiet in der Kavität markiert. Vier Zahnärzte mit mehr als fünf und fünf mit weniger als fünf Jahren Berufserfahrung beurteilten das markierte Gebiet zweimal im Abstand von einer Woche nach VT-Kriterien. Eine Woche später wurden die Proben mit Caries Detector® angefärbt. Dieselben Untersucher beurteilten die Verfärbung der markierten Gebiete ebenfalls zweimal in Abstand von einer Woche. Von den Zähnen wurden Hartgewebsschnitte angefertigt, mit Giemsa angefärbt und unter einem Lichtmikroskop auf die Anwesenheit von Bakterien untersucht.

Über alle Untersucher hinweg war Cohens Kappa-Koeffizient für die Inter-Untersucher-Reproduzierbarkeit für CD (0,45) höher als bei VT (0,31). In der weniger erfahrenen Gruppe war der Kappa-Wert für die CD (0,41) höher als für VT (0,23). In der erfahrenen Gruppe lag der Kappa-Wert für CD (0,43) unter dem Wert für VT (0,46). Für die Intra-Untersucher-Reproduzierbarkeit war der Kappa-Koeffizient (Median) für die mehr bzw. weniger erfahrenen Untersucher für CD höher (0,77 bzw. 0,53) im Vergleich zu VT (0,52 bzw. 0,34). Es gab keinen signifikanten Unterschied zwischen den erfahrenen und unerfahrenen Untersuchern für die kombinierte Sensitivität und Spezifität für VT (Mittelwert 0,52 und 0,53) oder CD (0,60 und 0,58). Schlussfolgerung: Erfahrene Zahnärzte erzielten mit der visuell/taktilen Diagnostik eine höhere Reproduzierbarkeit als mit dem Caries Detector®. Davon abgesehen war die Diagnostik nach visuell/taktilen Kriterien subjektiver als mit Caries Detector®. Bei der Restkaries-Diagnose führt zunehmende Erfahrung nicht zu einer Zunahme der Genauigkeit.

## Résumé

L'objectif de la présente étude était d'évaluer l'influence de l'expérience du dentiste et de la subjectivité (déterminée sur la base de la répétabilité inter- et intra-examineurs) sur la précision de diagnostic de caries résiduelles, en utilisant des critères visuels et tactiles (VT), ainsi que le colorant «Caries Detector» (CD). Trente dents avec caries dentinaires occlusales ont été excavées par une dentiste qui ne participait pas à la partie diagnostique de l'étude. Une zone de test a été marquée dans chaque cavité dentaire. Quatre dentistes avec plus de cinq ans d'expérience à leur actif et cinq dentistes avec moins de cinq ans évaluèrent la zone marquée au moyen des critères VT, deux fois à une semaine d'intervalle. Une semaine plus tard, les échantillons ont été colorés avec le CD. Les mêmes dentistes évaluèrent la coloration des zones marquées, également deux fois avec un intervalle d'une semaine. A partir des dents, des coupes ont été effectuées à travers le tissu dur, colorées au Giemsa et examinées au microscope, à la recherche de bactéries.

Pour la répétabilité inter-examineurs, en prenant en compte la totalité des dentistes, le coefficient kappa de Cohen pour le CD

(0,45) était supérieur à celui pour VT (0,31). Pour le groupe des dentistes moins expérimentés, la valeur kappa pour le CD (0,41) était plus élevée que celle pour VT (0,23). Pour le groupe des dentistes plus expérimentés, la valeur kappa pour le CD (0,43) était moins élevée que celle pour VT (0,46). Pour la répétabilité intra-examineurs, le coefficient kappa (médiane) pour les dentistes respectivement les plus expérimentés et les moins expérimentés était, pour le CD, supérieur (0,77 et 0,53) en comparaison avec VT (0,52 et 0,34). Il n'y avait aucune différence significative entre les dentistes les plus expérimentés et les moins expérimentés pour la combinaison sensibilité et spécificité pour VT (moyenne 0,52 et 0,53) ou le CD (0,60 et 0,58). Conclusions: les dentistes expérimentés obtiennent pour le diagnostic de caries, se basant sur les critères VT, une plus grande répétabilité qu'avec le CD. Pourtant le diagnostic VT est plus subjectif que celui avec le CD. Pour le diagnostic de la carie résiduelle, l'accroissement de l'expérience ne conduit pas à une augmentation de la précision.

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