Diagnosis of Occlusal Caries: Part II. Recent Diagnostic Technologies

(Diagnostic de la carie occlusale : Partie II. Nouvelles techniques de dignostic)

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Sommaire

Le diagnostic précis de la présence ou de l'absence d'une maladie est une exigence fondamentale de la prestation des soins de santé. Le diagnostic de la carie occlusale non apparente est toutefois une tâche complexe qui peut être hautement subjective, et les incertitudes inhérentes qui y sont associées peuvent donner lieu à des décisions très différentes en matière de traitement. Cet article en 2 volets fait une synthèse des connaissances actuelles sur les méthodes classiques et nouvelles de diagnostic de la carie occlusale. Dans la Partie I, nous avons examiné les méthodes de diagnostic établies, lesquelles comportent plusieurs limites notamment quant à leur capacité de déceler les caries débutantes. La Partie II est consacrée aux techniques nouvelles et émergentes qui sont mises au point pour le diagnostic de la carie occlusale. Les mesures de conductance électrique et la fluorescence quantitative induite par laser représentent des améliorations appréciables par rapport aux méthodes de diagnostic classiques, en particulier pour les applications in vitro et, surtout, sur le plan de la sensibilité et de la reproductibilité. Selon les promoteurs du système de fluorescence laser DIAGNOdent, cet appareil mesure la fluorescence qui se crée lorsque la lumière laser frappe des zones de déminéralisation; il s'agit d'un appareil non invasif, simple à utiliser, qui fournit des données quantitatives. Les études corroborant son efficacité sont toutefois limitées, mais elles semblent indiquer une bonne sensibilité et une excellente reproductibilité. L'appareil DIAGNOdent doit toutefois faire l'objet d'un examen scientifique plus exhaustif car, même s'il permet de déceler un taux élevé de lésions, il offre peu de possibilités pour ce qui est de déterminer l'étendue de la carie. Il est important que les cliniciens soient bien informés des limites des méthodes de diagnostic sur lesquelles ils appuient toutes leurs décisions en matière de traitement. Le jugement clinique — basé sur les antécédents du patient, les signes visuels, l'examen des radiographies et l'évaluation de la probabilité de lésions — demeure le critère le plus important dans la prestation de soins optimums. Les nouvelles technologies offrent peut-être des renseignements supplémentaires, mais elles ne peuvent pas encore remplacer les méthodes établies pour le diagnostic de la carie occlusale.

Mots clés MeSH : *dental caries/diagnosis; fluorescence; human lasers/diagnostic use*

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Accurate diagnosis of occlusal caries is difficult. The established diagnostic methods of visual and radiographic examination were discussed in Part I of this 2-part article. New diagnostic technologies are now emerging to meet the challenge of diagnosing occlusal decay. Each must be thoroughly investigated and evaluated before clinical use. Such new techniques include measurements of the scattering of light, fibre optic transillumination, ultrasound imaging, measurement of endoscopically viewed fluorescence, electrical conductance measurements and quantitative laser- or light-induced fluorescence.[1] These new technologies quantify changes in the physical characteristics of enamel related to demineralization.

Some of the above-mentioned technologies are suitable only for interproximal or smooth-surface lesions, and others are unsuitable for clinical application. Electrical conductance measurements and laser fluorescence methods (including the DIAGNOdent laser fluorescence device [KaVo, Biberach, Germany]) are 2 distinct technologies with applications in the diagnosis of occlusal caries. The reported sensitivity and

Table 1 **Reported sensitivity (Sens) and specificity (Spec) for the diagnosis of occlusal enamel decay**

	Visual Examination		Radiography		EC		QLF		DIAGNOdent	
	Sens	Spec	Sens	Spec	Sens	Spec	Sens	Spec	Sens	Spec
Ferreira Zandoná and others[2]	0.12-0.80	0.66-0.97	0.18-0.73	0.66-0.98	0.67-0.96	0.71-0.82	0.50-0.63	0.27-0.33		
Ferreira Zandoná and others[3]	0.03	1.00					0.49	0.67		
Lussi and others [4]					0.87	0.64			0.83-0.87	0.72-0.78
Lussi and others[5]	0.62								0.96	
Shi and others[6]									0.42-0.46	0.95

EC = electrical conductance measurements, QLF = typical quantitative laser fluorescence method.

Table 2 **Reported sensitivity (Sens) and specificity (Spec) for the diagnosis of occlusal dentinal (or enamel plus dentinal) decay**

	Visual Examination		Radiography		EC		QLF		DIAGNOdent	
	Sens	Spec	Sens	Spec	Sens	Spec	Sens	Spec	Sens	Spec
Ashley and others[7]					0.75	0.78				
Hafström-Björkman and others[8]							0.72-0.76	0.79-0.81		
Huysmans and others[9]	0.27	1.00	0.58	0.87	0.58-0.78	0.79-0.94				
Lussi and others [4]					0.92	0.78			0.76-0.84	0.79-0.87
Lussi and others[5]	0.31		0.63	0.99					0.92	0.86
Shi and others[6]									0.78-0.82	1.00

EC= electrical conductance measurement, QLF = typical quantitative laser fluorescence method.

specificity for electrical conductance measurements and laser fluorescence methods are presented in **Tables 1** and **2**.

Electrical Conductance Measurements (EC)

The electrical conductivity of a tooth changes with demineralization, even when the surface remains apparently intact. Electrical conductance measurements make use of the increased conductivity of carious enamel in pits and fissures.

The entire occlusal surface is first covered with a conducting medium. Conductivity from the occlusal surface to a ground electrode is then measured with a probe. An increase in conductivity is due to the development of microscopic demineralized cavities within enamel, which are filled with saliva. Two early commercial models of devices for measuring electrical conductance are no longer available, but a new instrument, the Electronic Caries Monitor (Lode Diagnostic, Groningen, The Netherlands), is currently being evaluated. No commercial devices are available in Canada.

Generally high sensitivity and specificity have been reported for EC techniques.[4,7,9,10] In one in vivo study, the diagnostic performance of 2 different commercial electronic devices was superior to that of bite-wing radiography, but one device outperformed the other.[9] In another study, the in vitro sensitivity of EC was generally superior to that of previously reported visual or radiographic techniques, but its specificity was lower.[4] Some concern has been expressed about the level of specificity (below 80%) that has been reported for the Electronic Caries Monitor.[4] This translates into a false-positive rate of 20% or a 20% risk of unnecessary operative intervention.

Laser Fluorescence (LF)

The LF method measures the fluorescence of the tooth that is induced after light irradiation to discriminate between carious and sound enamel. It is accepted that the induced fluorescence of enamel is lower in areas of reduced mineral content, and that there is a relation between mineral loss and the radiance of the fluorescence.[11] The term quantitative laser fluorescence (QLF) has been applied to the research method of measuring induced tooth fluorescence after using laser light generally at or near 488 nm range to quantify tooth demineralization and lesion severity. Several studies in which an argon laser light source (488 nm) was used to examine smooth enamel surfaces have shown a strong correlation between a decrease in fluorescence and the degree of enamel demineralization.[12-15] QLF is best suited for longitudinal diagnosis of early lesions of the enamel on accessible smooth surfaces, and many investigations have involved the monitoring of white-spot lesions,[12-15] such as those observed in orthodontic patients during treatment and after debracketing.

Fewer studies have assessed QLF for its ability to detect occlusal pit and fissure caries.[2,3,8] In in vitro studies of artificial and natural decay of occlusal fissure enamel, QLF had better sensitivity but poorer specificity than visual examination alone or radiographic examination alone.[2,3] QLF can be affected to some extent by the wet or dry state of the fissure, by stains in the fissure and by fissure morphology. The use of air-polishing to remove plaque improved diagnosis by QLF.[2]

Some reports suggest that QLF may be limited to measurement of enamel lesions of at most several hundred micrometres depth.[12,13,16] QLF can only discern enamel demineralization and cannot differentiate between decay, hypoplasia or unusual anatomic features. QLF was not designed to discriminate between lesions restricted to the enamel and those extending into the dentin. Furthermore, Banerjee and Boyde[17] showed that the fluorescence from dentin was not related to dentin demineralization, so this method is not suitable for measuring dentin demineralization.

DIAGNOdent System

A commercial development of LF is the chairside, battery-powered quantitative diode laser fluorescence device (DIAGNOdent). The unit emits light at 655-nm wavelength from a fibre optic bundle directed onto the occlusal surface of a tooth. A second fibre optic bundle receives the reflected fluorescent light beam, and changes caused by demineralization are assigned a numeric value, which is displayed on the monitor. The system is calibrated to a provided standard and to reference (sound) enamel.

The instructions for the DIAGNOdent system specify that the occlusal area to be diagnosed be clean, because plaque, tartar and discolouration may give false values. A laser probe is used to scan over the fissure area in a sweeping motion. Two values are displayed, a current value for the probe position ("moment") and a maximum value for the whole surface examined ("peak"). The instructions suggest that, in general, numeric data between 5 and 25 indicate initial lesions in the enamel and that values greater than this range indicate early dentinal caries. Advanced dentin caries is said to yield values greater than 35.

Shi and others[6] evaluated the DIAGNOdent system in vitro. Surprisingly, the device showed higher diagnostic accuracy in the detection of dentinal caries than enamel caries. The authors suggested that the DIAGNOdent values were dependent on the volume of the caries rather than on the depth of the lesion. With a cut-off of 18 to 22, the sensitivity for diagnosis of dentinal caries in wet teeth was 0.78 to 0.82 (diagnosis confirmed by microradiography of tooth sections). The investigators concluded that overall correlation between DIAGNOdent and microradiography results was moderate but that the device appeared superior to conventional radiography. They reported that the instrument was very sensitive to the presence of stains, deposits and calculus, all of which led to erroneous readings. Similarly, any changes in the physical structure of the enamel, including disturbed tooth development or mineralization, produced erroneous readings. Second (repeated) sets of DIAGNOdent measurements showed better correlation with the microradiography standard, which was construed as revealing operator learning and skill development. Clinical experience was, therefore, a "fundamental prerequisite" to using the device.

In a similar in vitro study with histological measures as the gold standard, the DIAGNOdent device was compared with EC methods.[4] The laser device had sensitivities of 0.76 to 0.84 and specificities of 0.79 to 0.87 whereas the Electronic Caries Monitor had sensitivity of 0.92 and specificity of 0.78 in the measurement of dentinal decay on occlusal surfaces. However, because the DIAGNOdent device had higher specificity than EC and similar sensitivity to EC for the diagnosis of enamel decay, the authors concluded that the DIAGNOdent device had higher diagnostic validity for the detection of the initial carious process. Reproducibility for the DIAGNOdent device was high in this study, but there was also evidence of different degrees of learning for individual dentists, and for 2 of the clinicians reproducibility was poor. The investigators used low cut-off values (10 to 18) for diagnosis and recommended caution in extrapolating their results to the clinical situation. In the end, Lussi and others[4] concluded that, because of its rapidity and very high specificity, visual diagnosis remains the method of first choice and they suggested that this type of examination be carried out before any other technique. The DIAGNOdent device could then be used for sites of clinical uncertainty, as a second opinion or diagnostic adjunct.

The results of Shi and others[6] and Lussi and others,[4] who evaluated the DIAGNOdent device in vitro for the detection of occlusal decay, cannot be directly generalized to clinical practice. The prevalence of caries in those studies was higher than in the typical clinical situation. Furthermore, the extracted posterior teeth were likely cleaner than the true clinical situation because they were stored and/or immersed in a sodium hypochlorite, thymol and/or formalin solution. In clinical practice, therefore, the sensitivity of the DIAGNOdent device will probably be lower.

Lussi and others[5] evaluated the DIAGNOdent system in an in vivo study. Air-dried occlusal surfaces of molars and premolars were examined visually (along with bite-wing radiographs if available) and with the DIAGNOdent device. The extent of decay was determined by means of an explorer during operative intervention. A high sensitivity (0.92) was reported for the DIAGNOdent device in detecting occlusal dentinal decay. However, the calculated sensitivity was based on a population of teeth with a very high prevalence of caries, since only teeth that appeared clinically to require operative intervention were assessed for the presence of decay. There was a wide range of readings for enamel caries (approximately 7 to 100), superficial dentinal caries (approximately 7 to 100) and deep dentinal caries (approximately 12 to 100), and the ranges for each overlapped considerably. The DIAGNOdent device was not able to distinguish clearly between deep dentinal caries and more superficial dentinal caries.

Unanswered Questions

The DIAGNOdent system is the only LF-related method available commercially for clinical application. However, the available documentation for its use is limited and involves primarily in vitro studies. Whereas the basic research behind the typical QLF technique, which uses lower wavelength light, is relatively plentiful, little documentation exists for the measurement of enamel fluorescence with the red 655-nm diode laser light source used in the DIAGNOdent system.

Many concerns regarding the DIAGNOdent system remain. For example, there is no basic research to show the correlation between DIAGNOdent measurements and the degree of tooth demineralization. The typical QLF methods use a 520-nm high-pass filter to receive the 540-nm autofluorescent light from enamel and to exclude the lower-wavelength light scattered by the teeth. In contrast, the DIAGNOdent system uses a 680-nm filter and detects caries by measuring changes in fluorescence intensity rather than by analyzing spectral differences.[18] The DIAGNOdent system, therefore, is fundamentally different from typical QLF methods, and the basic research for the typical QLF technique cannot be extrapolated to the DIAGNOdent device. It is of considerable concern that scientific evidence showing a direct correlation between the numeric DIAGNOdent reading and the severity of disease is lacking. The absence of such evidence precludes the use of the DIAGNOdent device for monitoring the progression of decay.

Also of concern is how the DIAGNOdent readings relate to the presence of dentinal decay and the need for operative intervention. As stated previously, typical QLF results show a strong correlation with the degree of enamel demineralization only but no correlation with the degree of dentinal decay. Furthermore, correlation with the degree of enamel demineralization is limited in depth.[12,13,16] For the DIAGNOdent device, it has been postulated that the diode laser light does not reach deeper dentinal layers,[5] which would explain the reported inability of the device to distinguish between superficial and dentinal decay in vivo.

Yet other questions relate to the optimal technique for clinical use of the DIAGNOdent device. At this time, in light of the unanswered questions and given the overall reduction in the prevalence of caries in the population, the clinical value of the device requires further investigation.

Conclusions

The development of reliable, accurate quantitative methods to diagnose and monitor early carious lesions is critical. EC and LF demonstrate significant improvements over established diagnostic methods, especially for in vitro applications and particularly with regard to sensitivity and reproducibility. Because of their quantitative nature and high reproducibility, these 2 methods can be used to monitor the progression of a suspected carious lesion and for patient education and motivation. In individual cases, they might also contribute to the decision-making process concerning appropriate preventive and operative strategies in caries management. However, one-time measurements made with EC and LF cannot discriminate between active and inactive lesions, which is also the case with other diagnostic methods. The DIAGNOdent device, a commercial variant of LF technology, is noninvasive and simple to use and provides quantitative measurements. However, more scientific scrutiny is required before it can be recommended for the definitive diagnosis of occlusal decay requiring operative intervention.

No current diagnostic method fulfils all the criteria for optimal caries management. Verdonschot and others[19] conducted a meta-analysis on various diagnostic tests. They determined a D_z value, which they considered representative of the probability above chance that the output from a diagnostic test would be correct (true negative or true positive). For diagnosis of occlusal caries, the EC methods demonstrated the highest D_z value relative to visual and radiographic methods; the D_z of QLF was not reported in that paper. However, true QLF correlated best with histological lesion depth or mineral loss of smooth-surface enamel caries. For occlusal surfaces, visual inspection had the highest correlation with histological observations of demineralization.

Incorrect diagnoses result in incorrect treatment decisions. In the current age of lower overall prevalence of decay and slow disease progression, the potential risk of unnecessary restorations is greater than the risk of missing early decay. The potential risk of missing early decay is also lower in patients who return regularly for recall dental examinations. In all treatment decisions, clinicians must be aware of the limitations of the diagnostic methods that have been used. Knowledgeable clinical judgment based on the patient's case history, visual cues, review of radiographs and probability of disease is a necessity for the provision of optimum care. New technologies may provide supplemental information, but they cannot yet replace established methods for the diagnosis of occlusal caries. ◆

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