Early diagnosis of initial carious lesions

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ABSTRACT

Dental caries (tooth decay) remains one of the most prevalent diseases worldwide. Caries begins with deficiency in essential minerals of the enamel surface which may be reversed at this stage by following rigorous hygiene practices and fluoridation. Caries diagnosis is an important part of the dentist's daily work. Clinical diagnosis is currently based on two methods of detection, most commonly on visual inspection and dental explorer. X-ray dental exam can only detect lesions with a depth of at least 500 microns. This article provides an overview of various techniques available for the diagnosis of initial enamel carious lesions.

Keywords: dental caries diagnosis, DIAGNOdent, soprolife, dexis Carivu and the Canary system.

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INTRODUCTION

A precise diagnosis of the presence or absence of a disease is a fundamental requirement for the provision of health care. However, diagnosis of hidden occlusal caries is a complex and highly subjective task with associated inherent uncertainties that may result in very different treatment decisions. The development of specific diagnostic tools related to occlusal surfaces which can be more sensitive and may give reproducible results, contributing to a further increase the accuracy of both preventive and curative treatments.[1] In oral cavity, teeth are constantly exposed to demineralization and re-mineralization cycles. As long as re-mineralization predominates, teeth do not only remain intact but, during alternating cycles, they lose their porosity, and thus, become more resistant to acid. However, when demineralization predominates, due to the ionic composition and oral fluid saturation levels surrounding the teeth, we observe an expansion of water-filled pores located between the apatite crystals[2] which weaken the teeth.

In fact, initial lesions (Fig.1),

which correspond to early stages of dental caries occurring in the enamel, usually pass unnoticed in clinical examination, while their diagnosis at this stage allows the initiation of a noninvasive method of treatment, ensuring the reversibility of the lesion. In this context, the development of new diagnostic tools turned out to be essential since it helps the practitioner to meet the requirements of modern dentistry based upon the concept of prevention.[3]

DIAGNOSTIC METHODS OF INITIAL LESIONS

Diagnosis of initial enamel carious lesions is more or less difficult depending on the situation of the lesion (anterior or posterior teeth, occlusal lesions, cervical or proximal). In order to facilitate the diagnosis, a number of methods have been developed. These methods are more or less reliable according to their sensitivity values and specificity which allow the practitioners to choose one rather than the other.[3,4] Sensitivity is defined as the ability of a system to detect an entity (person, tissue, etc.) with a given disease while specificity is the ability to correctly identify an entity that does not have this pathology.[5,6] Similarly, the caries risk linked to a set of personal and environmental criteria guide the practitioner and the assessment of this risk is the first step towards the diagnosis.[5]

1. Clinical examination

It should be performed on clean, brushed and dried teeth, by using a good light source and a dental mirror. The objective of this examination is to detect any opacity, coloring (Fig.1) or change in the translucency with or without extended drying.[1,3,4,7]

- The clinical examination has the following advantages:
- Dentist familiarisation
- Ability to follow up injuries over time
- Facility
- Rapidity
- Limited resources for implementation

However, some problems persist, such as:

- Access difficulty to some areas especially, the proximal ones, where the direct examination is difficult by simple examination/inspection
- Difficulty to obtain good visibility of posterior areas

The use of optical aids such as magnifying glasses has been proposed by some authors in order to facilitate the clinical detection of initial lesions.[3]

2. Probing

It requires the use of dental explorer (dental explorer 6, 17 and 23) (Fig 2a, b). The reliability of this technique relies on the resistance felt by the operator to remove a dental explorer inserted by force in a crevice.[3,7] The use of a dental explorer does not seem to improve significantly the accuracy of the diagnosis. A sticking probe does not prejudge the decomposition and can be fully attributed to local anatomical features.[1]

Over the past few years, dental probing has been called into question. Indeed, the pressure exerted during a rigorous probing can produce trauma that may occur on the enamel surface corresponding to subsurface lesions and crevice/fissure can become more susceptible to the progression of the lesion.[3]

Fig 1. initial lesion

Fig 2a. dental explorer 6

Fig2b. exploration of caries

3. Bite-wing radiographic exam

Bite-wing radiograph exam is classified amongst the techniques that can provide the practitioner with as much information as possible. The accuracy and

orientation of an incident X-ray, makes Bite-wing, the X-ray imaging chosen for early caries detection, particularly for the proximal surfaces.

Upon reading the image, you must:

- Seek a possible solution for the continuity of the area around the enamel
- Seek the presence of a radiolucent area at the DEJ
- Observe at the pulp chamber a possible response image, possible response of dentin-pulp defense to an injury.

This technique has sensitivity of 45% in itself and 49% when combined with visual examination for occlusal caries lesions without cavity. On the proximal level, the sensitivity of this technique is between 71% and 100% ± 1%, specificity 99% and 100%. Bite-Wing radiography should be performed periodically for all patients before starting treatment decisions-making.[3]

4. Combined visual and radiographic diagnosis

Further investigation of the validity of the diagnosis by using combined pericoronal radiography with visual clinical examination has demonstrated that the majority of caries lesions and almost all healthy teeth can be correctly identified.[1]

5. Digital/computed Radiography

Digital radiography allows a better visualization of caries lesions by increasing the contrast, the detection of superficial enamel injuries and a quantitative assessment of densities by radiometry. The contrast of the observed image can be adjusted so as to reveal the desired anatomical details by the practitioner if existing in the area of dark or light grey of the image.

It seems that for these systems, a great contrast is necessary for the improvement of caries lesions diagnosis.

This technique presents certain disadvantages, such as:

- Sensors can cause discomfort to the patient
- System cost is high[3]

6. Elastic separator/ spacers

These appliances are used in orthodontics to put spaces in between teeth, after placing them for 24 hours, in order to fix orthodontic bands. In the context of the early diagnosis of proximal caries lesions, temporary spacing obtained with these elastics, allow direct examination of proximal surfaces, and thus the detection of initial caries lesions.[3]

7. Fluorescence laser

This method is based upon the measurement on the fluorescence induced by the teeth following light irradiation in order to distinguish caries enamel from healthy enamel. The detection principle is based upon the change in the physical properties induced by the caries lesions. Because there is more water in a caries lesion rather than in healthy enamel, healthy enamel has a yellow fluorescence while the demineralized areas appear dark. We may distinguish:

a. Quantitative laser-induced fluorescence (QLF)

The term quantitative laser-induced fluorescence (QLF) is applied in order to determine the fluorescence of the tooth induced after using a laser light of approximately 400 nm to quantify the demineralization and the severity of the lesion. However, the quantitative laser-induced fluorescence cannot differentiate between the confined lesions to enamel and those having extended into the dentin.

In this respect, a caries detection device has been developed based on this principle.[3,4,6,8] The fluorescent laser is thus better and more objective than radiography.[8] It is also more accurate than radiography. Moreover, it has been proven to be very reliable: the correlation between the values displayed on the device and the demineralization changes observed by microradiography are quite acceptable. However, the decision to treat tooth decay cannot depend only on this machine, because you must evaluate other variables such as the patient's history, caries susceptibility and fluoride exposure.[3,6,9] Therefore, we will present a set of devices that use fluorescent laser in their functioning.

- DIAGNOdent® (Kavo)
- Soprolife®
- The Canary System®
- Dexis Carivu®

DIAGNOdent®

DIAGNOdent® (Kavo) involves fluorescence measurements performed by a laser device. The

development of DIAGNOdent came about thanks to the work of Hibst and Gall who showed in 1998 that exposing a tooth surface to red light (638–655 nm) helps to differentiate between healthy and carious tissues. This is because the fluorescence intensity caused by excitation in caries lesions exceeds that of healthy tissues.[4,6] DIAGNOdents® allows both the detection and quantification of caries. It is a battery-operated device and can be used directly in the dental chair. It emits a fluorescent light having a given wavelength: 650 nm.[4,9] The way in which the irradiated surface of the tooth reflects light that determines the degree of demineralization in the structure. DIAGNOdent device then indicates a value between 0 and 99 on the device, in connection with the change of physical properties of the light.[3,10]

For example, a reading of approximately[10] is associated with caries in enamel remineralizable, while a reading above 60 indicates extensive caries found in enamel and dentin. In addition, the machine emits sounds consistent with readings.[3,8] However, it is found to be effective only in the detection of pits, fissures and surface caries, oral and lingual. Moreover, during its use, the tooth should be cleaned and dried in order to obtain good results. The plaque, tartar, restorations and humidity can change the reflected light.[3,8,9,11]

At all levels, proximal caries detection in primary teeth which is made by DIAGNOdent, have shown low sensitivity but high specificity when you have a point of contact between adjacent teeth.

DIAGNOdent is a simple instrument that is well accepted by children and does not require high cooperation of a child because reading can be made in seconds. In order to produce the highest accuracy, DIAGNOdent should be used along with other diagnostic methods. When caries is indicated by DIAGNOdent, we could perform bite wing X-rays to confirm the result.[6,11]

Soprolife®

SOPROLIFE® enhances effectiveness and efficiency, where it facilitates the process of assessing the risk of caries by highlighting the level of activity in risk-prone areas. Because it can be adapted to the most complex of clinical situations, it enables the practitioner to quickly adjust his treatment options. Remarkable precision in diagnosing damaged areas:

In mode I, the Diagnosis mode, SOPROLIFE makes it possible to detect damage at various clinical stages, without loss of consistency and in very high resolution. In mode II, the Treatment mode, it enables actual spatial mapping of unbroken tissue areas which are suspect, by means of a transparency effect.

Some molecules in the body give off fluorescence with light excitation as the only external stimulus. This is then known as auto-fluorescence or endogenous fluorescence, unlike induced or exogenous fluorescence which use exogenous fluorophores that can be systemically or topically administered. This is the auto fluorescence process employed by SOPROLIFE. It is based on the stimulation of endogenous fluorophores, which are present in dental tissue. This non-invasive imaging can also be safely conducted and does not require exogenous fluorophores, which can be toxic and require strict regulation.[5]

The Canary System®

The Canary System has a detection potential of inter-dental caries with high sensitivity and specificity by scanning oral and lingual surfaces.

Pulses (2Hz) of laser light (660nm) is emitted from the tooth surface for 5 seconds. The tooth shines (the Luminescence, LUM) and releases heat (radiometry Photo-Thermal, PTR). The Canary algorithm combines the readings to create a Canary number which reflects the state of the mineralization and crystallization of the detected tooth. Dental caries affect PTR-LUM readings. This system detects 50 microns lesion to 5 millimeters below the surface.[12]

DEXIS Carivu®

DEXIS Carivu® is a compact, portable caries detection device that uses trans-illumination technology to support the identification of occlusal, inter-dental and recurrent carious lesions and fissures. CariVu provides easy-to-use diagnostic tools for the dental community.

DEXIS CariVu's trans-illumination

technology makes the enamel appear transparent while porous lesions absorb the light. This allows the clinician to see through the tooth exposing its structure and the actual structure of any carious lesions with very high accuracy.

Similar in appearance, CariVu images read like familiar X-ray images - caries will appear as dark areas. This provides an edge over fluorescent imaging technologies in that there is no need to clean the tooth of bacteria, calibrate the device or become versed in the meaning of multiple color codes or numeric indicators.

Since Carivu uses infrared light, it will not replace X-rays for routine diagnosis. However, the utility of the device is to show things that can't be seen on radiographies. The trans-illumination can show lesions in the beginning stages, using CariVu during routine prophylaxis can help the dentist to identify suspicious areas in the beginning stages sand decide on the preventive care plan. Finally, for patients who refuse to undergo an X-rays exam, Carivu is an alternative diagnostic method with which they can feel more comfortable.[13,14]

b. Experimental dye-enhanced laser fluorescence (DELF) technique

The same principle governs the system except that it relies on the use of a fluorescent dye to enable detection of the initial lesion without improving the quantification. In an in vitro study, the following sensitivity ranges for laser fluorescence were 56-74%, fluorescent dye (DELF) 61-79%, visual examination 58-74% and specificity 67-78% for the laser fluorescence, 86-98% for DELF and 83-97% for visual examination. Thus, with this model DELF compared favorably with laser fluorescence and visual examination in sensitivity, but specificity was better for DELF and visual examination than for laser fluorescence. When reviewing the obtained results, it seems that the quantitative fluorescence laser does not produce the desired results in the diagnosis of the initial lesions.[3]

8. Caries-detector dyes

The validity of these dyes for the detection of enamel caries is more suspicious than for those used for dentinal caries. Their principle is based upon the fact that the fluorescence of the dye varies with the degree of mineral loss caused by caries (Fig.3). This method is behind many false positives; its application to the daily practice could lead to overtreatment.[3]

9. Trans-illumination

Currently, fiber-optic trans-illumination could be based on the original technique or use of digital imaging.[3]

c. Fiber-optic trans-illumination (FOTI)

Through the fibers of a halogen light source positioned at the tooth surface. The specificity of this technique is between 99 and 100% and remains comparable to that of the Bitewing radiography while the sensitivity is lower than that of the X-ray; it is between 50 and 70%.[3,7]

d. Digital Imaging Fiber-Optic Trans-Illumination or DIFOTI

The system uses a visible and non-ionizing light radiation. The transmission of light through the dental tissue is a function of the anisotropic layers with gradient refractive index. Images of the teeth obtained by this technique can indicate the presence of a recurrent caries or at its beginning stage, even when radiographic images fail in their detection.[3,7]

Fig. 3 caries detector dyes

10. Electrical methods

The teeth have a low electrical conductivity due to the presence of the enamel. When the enamel volume is decreased (demineralization or hypo), it will be accompanied by an increase in the electrical conductivity.

Thus, the principle of this technique is based on the detection of the increase in electrical conductivity that accompanies the reduction of the mineral content of caries lesions. This increase in conductivity is due to the presence of micro-cavities demineralization closed by the saliva which acts as electrolyte for the transmission of electric current.[3]

11. Endoscopic Methods

These methods were tested using either white light or fluorescence. This technique uses the endoscope and a white light source which can be connected to the device by a fiber-optic cable. However, it is a slow method. It requires a rigorous drying and isolation of the teeth. Initial studies on the benefit of the endoscopic examination either by white light or by fluorescence showed a slight increase in sensitivity for detection of occlusal enamel lesions compared to visual inspection.[3]

12. Air abrasion

Goldstein and Parkins, in 1995, have introduced this technique for the diagnosis of initial caries lesions. The principle is the following: if a suspicious groove is observed, the air abrasion system allows the removal of a stain or an organic stopper projection of an alumina powder. If the review suggests that further alumina projection, only very small amounts of tooth structure already infiltrated or demineralised are removed, revealing an underlying lesion which was previously invisible. However, this technique is non-specific for the diagnosis of caries.[3]

13. Ultrasound

The ultrasonic system for detection of enamel demineralization has been studied by various authors. For CALISKAN Yanikoglu (2000), the comparison of this technique with the X-ray and histology as "gold standard" gave a sensitivity of 88% and a specificity of 86%. But, this method is still in the experimental stages.[3]

DISCUSSION

The use of optic aids such as magnifying visual aids was suggested by some authors[15] in order to facilitate clinical detection of initial caries.

However, Haak's in vitro study in 2002 has shown that such aids do not really increase the reliability of a proximal and occlusal caries diagnosis.[15]

But, the use of probing has been subject to questions over the last decades.[1] In fact, pressure exerted during rigorous probing can produce trauma at the enamel surface, leading to subsurface lesions and the fissure can then become more susceptible to lesion progression.[16]

Moreover, probing can promote bacterial transport from one site to another and allow contamination of healthy sites.[17]

Several studies have tried to assess retro-coronal radiographic exam in the detection of initial caries. Lussi stated that this technique has 45% sensitivity by itself, which increases to 49% when combined with a clinical exam in the diagnosis of occlusal carious lesions without cavities. At a proximal level, sensitivity of this technique is included between 71% and 100% ± 1% and specificity between 99% and 100%.[18]

According to Hennequin, carious lesions can be detected by visual radiography as well as traditional films, but it should be noted that edited images on paper are of less diagnostic quality than films, especially if such documents have to be stored.[17,19]

About rubber coins, Rimmer and Pitts have reported a substantial increase of the number of radiographic lesions following dental separation with respect to the clinical and radiographic exam.[20,21]

After the correlation of experimental results and histological controls were observed, several clinical studies have validated QLF for it is used in initial carious lesions diagnosis and for the evaluation of preventive measure. However, QLF cannot differentiate between enamel lesions and those infiltrating the dentin.[1]

In an in vitro study, Eggertsson has observed the following sensitivity values: laser fluorescence 56-74%, DELF 61-79%, visual inspection 58- 74%.

Specificity values were 67-78% for laser fluorescence, 86-98% for DELF and 83-97% for visual inspection.

DELF has thus demonstrated a favorable sensitivity which is close to that seen with fluorescence laser and visual inspection, whereas DELF and visual inspection have a higher specificity than laser fluorescence.

In the light of the obtained results, it seems that quantitative fluorescent laser did not meet the expectations in terms of initial caries diagnosis.

Caries detector dyes lead to an important number of false positive diagnosis, and are not applicable in daily care as their use may lead to over treatment.[22,23]

The study of Schneiderman in 1997 has demonstrated superiority of DIFOTI as compared with radiography, for the detection of initial lesions of proximal, occlusal or smooth surfaces. In a comparative in vitro study with visual inspection and Bitewing radiograph for the diagnosis of occlusal caries, Huysmans has shown that the precision of the electric method and Bitewing radiography is inferior to that of the visual inspection.

Initial studies on the benefits of endoscopic techniques with white light or fluorescence show a slight increase of the sensitivity of this technique with respect to the visual inspection for the diagnosis of enamel occlusal lesions.[20]

For Caliskan Yanikoglu, comparison of ultrasounds with radiography and histology as "gold standards" has yielded 88% sensitivity and 86% specificity. But, this method is still experimental.[24]

CONCLUSION

Early diagnosis of initial enamel lesions is very important in order to be able to create at an optimum time, an appropriate treatment allowing the re-mineralization of these lesions. All diagnostic methods have a margin of error in the detection of true positives and true negatives. Conventional tools have high specificity with few false positives but have a problem in sensitivity with a lot of false negatives. The new techniques could increase the diagnostic capabilities of the practitioners.

The effectiveness of each of these new systems is based primarily on in vitro studies. In addition, there is not enough stepping back and analyses in order to evaluate the performance of these systems. In the mean time, physical examination completed by bitewing radiographs, will provide substantial assistance provided that the practitioner must be well trained. Finally, we must recognize that there are few studies that have evaluated the benefit of the combination of several diagnostic tools on the values of sensitivity and specificity.[3] It remains to say that personal judgment of the practitioner stays an important factor of diagnosis.

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