

DIAGNOSTIC METHODS IN CONSERVATIVE DENTISTRY AND CURRENT APPROACHES

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ABSTRACT

The detection of the electrostatic connection, by 'H' ions, between the inorganic calcium phosphate crystals and the organic matrix which form hard tissues of the tooth and the series of events starting with the destruction of calcium phosphate crystals, then causing the loss of substance in the tissue result in tooth decay. Streptococcus mutans, lactobacillus and actinomyces species plays an important role in the formation of cavities.¹ In individuals at risk of caries, the provision of re-mineralization of dentin tissues and demineralized enamel without any cavity by stopping infection may come into question when it is possible to diagnose the lesions before the formation of cavities. For this purpose, there are many new emerging and diagnostic methods used today. Minimally invasive procedures are becoming increasingly important in today's dentistry. The way to achieve this is through the early diagnosis. In dentistry, a timely, precise and accurate diagnosis is the first step of a successful treatment. In this review, diagnostic methods one of which is QLF and DIAGNO dent based on the principle of laser fluorescence, the ECM and a newly developed technology are mentioned. Several studies and results which are related to these systems are presented comparatively.

KEYWORDS: Diagnostic Methods, Conservative Dentistry, Caries, New Developed Technology

INTRODUCTION

Despite the presence demineralisation which are wide enough to be determined radiographically, intact or minimally damaged tooth surface and the covered dentin caries are defined as hidden caries.²

Minimally invasive procedures are becoming increasingly important in today's dentistry. This approach is based on the principle of demineralized enamel with non-cavitated caries and maximum protection of dentin tissues. For this purpose, in individuals under risk of decay, demineralized lesions should be checked and necessary measures should taken in

time. Thus, before lesions create cavity, it is important to diagnose. Clinically, diagnosis of caries is a step or is the key which include concepts such as the identification of caries, risk identification, identification of preventive strategy. 3

In dentistry, a timely, precise and accurate diagnosis is the first step of a successful treatment. Pitts reported that ideal method for caries diagnosis should be non-invasive, simple, reliable, valid, sensitive (able to diagnose the disease correctly) and specific (to detect healthy right) in 1997.4

Today, within the framework of a minimally invasive approach, it is intended provide the remineralization of demineralized enamel and dentin tissues by stopping infection in individuals that have caries potential, and to prevent those issues by controlling them periodically. This situation can happen, however, whenever the diagnosis of lesions is possible before the cavities form. In caries diagnosis, the lesion may be seen as active, fast or passive, slow or stalled. Without this information it is not possible to make an ideal treatment planning.5

Diagnostic methods can be listed as follows:

Diagnostic methods:

A. Conventional Method:

- Visual Method
- Tactile and Intra-oral Mirror Application
- Radiography Method

B. Technologies In Use:

- Electrical conductivity (ECM)
- Digital Radiography,
- Fiber Optic Transillumination
- Laser Fluorescence (QLF, Diagnodent)

C. Newly Developed Technologies:

- Alternating current impedance spectroscopy,
- Tuned aperture computed tomography
- Digital imaging fiber-optic transillumination
- Ultrasonic imaging system (sonography),
- Vistaproof Fluorescence Technique,
- Intraoral PH measurement technique of carious lesions,
- Identifying occlusal caries with thermal imaging,

Conventional Methods

Visual Method

Clinical visual examination is examination which is done after the surface of the tooth is cleaned and dried with the help of light and the mirror.⁶ Although it is the most widely used method in dentistry in daily clinical practice, it can't determine many lesions until wide cavities form.⁷ While the free surface cavity caries, dentinal caries in the approximal area, secondary caries, root caries are determined with this method, posterior approximal and occlusal caries may remain undetected.⁷

Examination with Sond (Tactile Method)

Most dentists have determined tactile examination as the diagnostic methods as well as examination done with light and mirror.⁸ Today, most European countries do not find examination with sond ethical. The examination done by using sond can create iatrogenic harm by accelerating progress of occlusal caries in the initial phase. Ekstrand et al. about 20 years ago, demonstrated that the caries in the enamel and dentin with non-cavitated forms, but can be remineralized, may be traumatized irreversible by using sond. However, in addition to this, as a result of examination with sond, caries-causing bacteria from the infected area advance into other areas.⁹

Radiographic Examination

When radiography is used in conjunction with other diagnostic methods, it allows the detection of caries lesions. Radiographic diagnosis of dental caries should always be made with the clinical examination of the oral cavity.¹⁰ In order to be seen in radiograph, caries have to be proportional to the amount of X-ray penetrating to the tissue. Also, when tooth structures are decalcified (at least %30), they can be identified radiographically.¹¹ Between the two intense radiopaque area, Cervical burnout can be seen in the form of a radioculent band or wedge. Cervical portion of the teeth are between the parts of bones that enclose crown and root and compared to those tissues, it absorbs less X-ray. As a result, in radiography, a radiolucent band around teeth occurs and it can be unconsidered to be Cementum caries. In such cases, cementum caries should clinically be verified with intraoral examination.^{12,13}

In a former study, it was put forward that more than half of the intraoral films that are used in caries-diagnosis, based on many reasons, were stated not to have enough quality to be accepted.¹⁴ Cervical burnout, optical illusions, mach band effect, radiolucent restorations,

dental anomalies and technical errors (irradiation errors, projection errors) are among the factors that cause misdiagnosis.¹⁵

Technologies in Use

Electrical Conductivity (ECM)

In general, it is based on the electrical conductivity difference of the healthy and carious tooth tissue. Electrical conductivity powered devices with the principle of diversity have been manufactured.¹⁶ These devices measure the electrical conductivity with the help of a sond placed into fissure and gingival having high conductivity or a connector coupled to a region, such as skin.

The electrical conductivity of the tooth tissue is variable even when demineralization is available, but there is not any loss of material on the surface. So while sound enamel surfaces are very limited or has no conductivity, caries and demineralized enamel surface has measurable conductivity and this conductivity is increased with the increase of demineralization. High-value measuring of device is observed. This determines whether lesions are remineralized by being followed over time.¹⁷

Digital Radiography

Two systems are available: the first image on the screen occurs immediately after irradiation, and in the other there is an intermediate phase on the screen after the image is scanned with a laser .¹⁸

First, the direct digital radiography system introduced in dentistry as Radiovisiography (RVG) was invented by Dr.Frances Mouyens and was produced in 1984¹⁹ .By then a lot of digital imaging systems have been released by different companies. These systems that have same principles of operation differentiate by resolution values, sensor type, the matrix size and pixel values.^{20,21} Every day a new one is added to the digital imaging methods.

Fiber Optic Transilluminating, (FOTI)

Fiber Optic Transillumination Technology, based on enamel caries having a lower index in light transmission contrary to healthy enamel, is used in conjunction with clinical examination and radiographs in cutters and premolar region. This is a technique in which a bright optical fiber light is passing through carious lesion. Healthy tooth tissue absorbs very little light, but rotten tissue absorbs more light (Figure 1). Thus bruise area is displayed in bold.²²

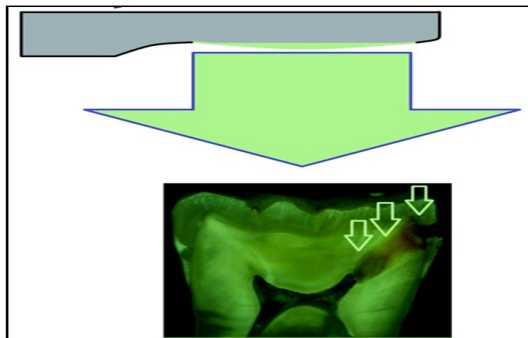


Figure 1: Transillumination Technique

Laser fluorescence (QLF,DIAGNOdent)

Let us examine first the basic principles of fluorescence. Light diffusion coefficient in the carious lesions is quite high compared to healthy enamel. This leads to short path of the light in the lesion and to less absorption and fluorescence in this area. Fluorescence is more due to the dentine tissue. Changes in molecular structure of the chromophore prevents fluorescence formation. Chromophores development remove caries in healthy enamel. First study on this subject was made in 1911, with Stubelhe's application of ultraviolet light to the teeth.²³

Then Eisenberger, in 1933, noted that in teeth which induced by the blue light occurs fluorescence. Benedict was the first who mentioned that the organic components of human teeth have Fluorescence properties. Benedict touches on, in his studies, the differences between the fluorescence properties of sound and carious enamel.²⁴ In this technique, different inserts, probes are available. Probe A is the most widely used at the clinics. It is generally used for caries in the pit and fissure on occlusal surfaces of the teeth. Before using, the device necessarily must be calibrated. (Figure 2). When end of the device is moved over the tooth surface, numbers are observed on the digital display. In Tablo 1, the meanings of this numbers have been told.



Figure 2: Device of Diagnodent

0 - 10	Healthy Tooth Structure
11-20	Outer Half Enamel Caries
21-30	Inner Half Enamel Caries
30+	Dentin Caries

Table 1: Digital Numbers on DiagnoDent

Wireless indicator working with new-generation DIAGNOdent Pen allows the obtained values from the patient's mouth while working to be observed more easily and quickly by both dentist and patient (Figure 3).



Figure 3: New Generation Caries Detection Device

The detection device which provides quantitative assessment of in-vivo and in-vitro in regard to dental caries, dental plaque, bacterial activity, tartar, discoloration and tooth whitening is widely used in the assessment of caries lesions.²⁵

NEW DEVELOPED TECHNOLOGIES

Alternating Current Impedance Spectroscopy

It is a complex approach in identifying lesions. It performs measurement taking advantage of the electrical properties of dental tissues by scanning a plurality of frequency. When operation of the system, the movement of ions are determined with electrical impedance spectroscopy, the gaps formed in the tooth tissue in ionic size are characterized and the sizes of these gaps are measured. Such gaps in the carious lesion are larger than healthy tissue. At different times the size of the spaces can be determined at regular intervals by controlling them.^{26, 27, 28}

Tuned Aperture Computed Tomography

It is a system of three-dimensional display of Dento-alveolar system. In the studies done, it was observed that more reliable results are obtained with Local CT in approximal caries and in the examinations of dento-alveolar system.

Digital Fiber-Optic Transillumination Images

DIFOTI is a new method combining Fotia and digital camera in order to reduce the shortcomings of the FOTIA method. In the system of DIFOPTI, the images are provided with CCD Camera.²⁹ Because CCD usage enables the projection of the snapshots, it helps to compare changes in different examinations over time.³⁰

Ultrasonic Imaging System (Sonography)

The basic principle of the ultrasound is to apply high-frequency waves (1-20MHz) generated by probe to tested material or to the biological tissue, or to convert the returning waves absorbed by a probe into the electrical impulses and to determine them ecological.^{31,32}

It is necessary for the reflected waves coming from material or tissue to create an electrical signal (radio frequency signal) and sending it to the monitor by putting through process. This signal can be obtained in various imaging modes. Mode A is graphical representation of the perceived eco. This mode is mostly used in industry and medicine (neurosurgery, ophthalmology). The examined fractions in this mode is not visible and quantitative assessment is made. With the B Mode, tissue sections are seen in that kind of images composed of points in the different brightness located in the reflected echo of the cathode ray tubes. It is used in diagnostic radiology. M-mode shows the amplitude of the contents in function. It is a method to examine heart. Generally, it is used in Laser Dropper ECG.^{33,34}

An ultrasonic imaging device used in practice during the operation of the system draws electricity generators from the screen and produce electrical impulses that are translated into ultra-high frequency sound waves by pulses used for sonography. Converter (transducer) is a device converting a form of energy into another. Here it translates ultrasonic energy to electrical energy (ultra-high-energy sound waves), then transmits to the tissue/material.³⁵

Vistaproof Fluorescence Technique

Vista proof contains a fluorescent camera. In this system, the image of the teeth is taken and analyzes putting it into the computer

Vistaproof values are within the range of 0-3. When values are above 2, it indicates dentin caries and changes into orange (Figure 4). Vistaproof is a method working with fluorescence techniques, but is not sufficient for diagnosis. They are used only to help

diagnose. Even though so far, vistaproof has disadvantages, blue fluorescent gives more accurate results than red fluorescent in the storing the images and also can detect the caries.

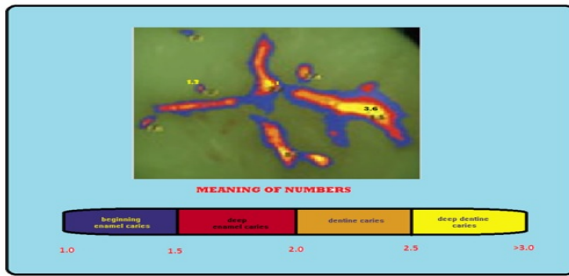


Figure 4: Vistaproof Scale

Intraoral PH Measurement Technique Of Carious Lesions

In this technique, the pH of carious lesions is measured by micro pH sensor and also the DNA of acid-producing karyogenesis is measured by using qPGR. Intraoral pH measurement clinically provides benefit in terms of caries activity of carious lesions. The determined caries are measured using micro-pH sensor. Micro pH sensor can be applied to all surfaces. In order to complete the circuit, 1 mm diameter (reference electrode) was placed on the patient's mucosa. In 1 min, the pH value is automatically reflected to the pH meter monitor.*PH values have been determined in table 2.

Ph Values	Means
5.5 ±0.3	active caries
6.1±0.2	passive caries.

Table 2: pH values on pH meter monitor

Identifying Occlusal Caries with Thermal Imaging

In this method, infrared imaging device is employed for the detection of early occlusal surface caries. Thanks to the vaporized liquid in the pores of the teeth, a thermodynamic mechanism forms on the teeth. Infrared photothermal radiometry (PTR) device was used for the detection of dental caries. **

PT device uses an optical and save thermal changes on the tooth surface. This technique allows the detection of pit and fissure caries and can provide information about 5 mm down from the surface. Color code is ΔQ. and is more approaching to red in the areas with more demineralization. ** (Figure 5)

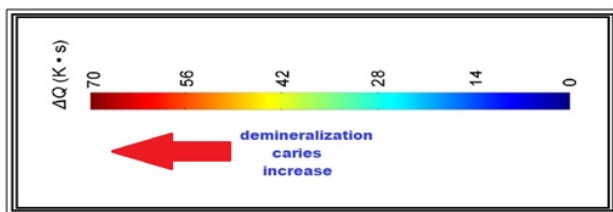


Figure 5: PTR Device Color Code

As seen in the color scale, color dramatically changes from yellow to red in the case of deep dentin caries on occlusal surfaces of the teeth. The more dentine caries proceed, the more color code increases.

DISCUSSION

Bab and his colleagues and Ziv and his colleagues stated that ultrasonic system can detect the proximal enamel and dentin caries. Bab and his colleagues introduced (1997)' Ultrasonic Caries Scanning System '(UCD). When doing this, they used surface waves and tried it on proximal caries. However, success has only been achieved in deep dentin lesions.³⁶

The same device was used by Ziv and his colleagues and Gazit and his colleagues with 100% sensitivity and 91.9% specificity, then they stated that they found it successful using histology as the gold standard in a deep enamel, dentin shallow and deep dentin lesions. The UCD system researchers introduced still has not been presented to the dental markets.^{37,38}

In the diagnosis of occlusal and approximal caries, ECM have shown very good results in vivo and in vitro studies. Asley have stated that ECM gives more accurate results in in-vitro diagnosis of occlusal lesions that have no cavitation on posterior teeth when compared to the visual examination, FOTIA, conventional and digital bitewing radiographs.³⁹

Although in this study ECM was partially found successful on occlusal surface, in general it is considered to be limited in capacity on occlusal surfaces. ECM is mostly found to be successful in a very smooth surface and approximal surfaces. Moreover, when ECM measurements are compared to clinical image methods, despite its high sensitivity, specificity was reported to be low.⁴⁰

Lussi et al examined the occlusal surfaces of teeth 322 in their study in 2001. They determined the values of DIAGNOdent as : 0-13: No caries, 14-20: enamel caries, and > 20: dentine caries. They have set these values as gold standart. 100 of 322 occlusal surfaces, the dentin caries have been determined using the visual examination, bite-wing radiographs and DIAGNOdent. Of 100 tooth, 29 of them were determined only by visual

inspection. When the bite-wing radiographs was used as the second method, the determined number rose to 71. But while DIAGNOdent was used, the 92 dentin lesions were determined.⁴¹

Schneiderman et al reported that in the studies they used DIFOTI for approximal and occlusal surfaces caries, they achieved excellent results.⁴² O'Brien et al examined the paints leaving a trace and discovered that Zyglo22, a fluorescent dye which is not suitable for intraoral use, penetrates to previously undetermined lesions. In addition, 10% Brilliant blue, another mark-leaving dye and used with FOTIA method, was observed to reveal the incipient caries lesions of FCF.⁴³

As a result of research, the direct digital radiographs are shown to have a number of advantages and disadvantages while compared to conventional radiographs.^{44,45}

Quantitative light -effective fluorescence method (QLF), in the diagnosis of caries lesions with white light distribution technique, starting-threshold value could not be found. But in-vitro studies, lesions having only 25 microns depth was measured.⁴⁶ In Smooth surface caries, it is a major disadvantage of light reflection technique because the use of this technique is limited. However, for the development of occlusal caries diagnosis with QLF system is currently under research.⁴⁷

Ultrasonic methods that give good results in the diagnosis of early caries has been shown by studies.⁴⁸ In DIFOTI system, the images are provided with digital CCD camera. Because the CCD use enables the projection of snapshots, it allows comparison of variations in different examinations over time.⁴⁹ FOTIA is a practical method for dental imaging.⁵⁰

Shi et al, in 2000, noted that Kavona Diagnodent device is very sensitive to lesion volume rather than to the depth of the lesion. But still, it is more effective in the detection of lesion depth than mineral loss. Therefore they noted that it is inadequate for determining minor caries.⁵¹

Sheehy et al, in their study in the 2001, reported that two of 7 tooth surface of the high DIAGNOdent value had hypomineralization. This data has been shown to be a disadvantage in practical use, because it cannot be distinguished from caries.⁵² In the lesions formed by Fontana and his colleagues with the method of microbial decay as in-vitro with about 20 microns depth, QLF and confocal microscopy were used as controls. However demineralization was only determined by confocal microscopy and QLF and ultrasonic systems gave negative results. On the other hand remineralization was determined by

ultrasonic systems.⁵³ In 1997, Al-Khateeb et al followed mineralization of enamel lesions treated by fluorine. The lesioned enamel samples prepared from buccal maxillary first molar tooth of 12 people were subjected to flora during 35 days and implemented with three different ways. Samples were taken every week for display purposes. And it was stated that the laser fluorescence method enables remineralization to be followed every week, also results were found to match with microradiography.^{54,55}

Bétrisey et al, in their study in 2013, have used two different methods working with DIAGNOdent and vistaproof fluorescent techniques, but both are not sufficient for diagnosis. They are only used to help diagnose. The ends of the Diagnodent device permits to make measurements on the surface of teeth at different and smaller angles. Just because vista proof has larger and thicker ends, it does not allow you to take measurements in each region. However, although vistaproof has disadvantages, for storing the images, blue fluorescent gives more accurate results compare to red fluorescent and can detect rotten places.⁵⁶

In 1999, Stookey et al have done a pilot study on 150 children aged 9-12. Patients used fluoridated toothpaste, oral hygiene instruction was given to them and in 4th, 8th and 12th months, they were examined with QLF, electrical conductance meter (ECM) and conventional methods (clinical examination, digital radiography or bitewing). In the results, it was found that the caries were rising gradually and this was found to be compatible with QLF and DMFs (decayed, missing or filled surfaces) obtained from conventional experiments. Despite the negativity of the results of this study, QLF is important in terms of being the first study on occlusal surfaces for caries diagnosis. On Occlusal surfaces, as well, successful results have been achieved at least as achieved in the buccal and lingual surfaces. Also QLF is stated to be necessarily supported by clinical examinations. Because QLF can determine developmental hypocalcified areas, these parts should be separated from caries lesions.⁵⁷

In 2012, Farida et al evaluated CCD, PSP receptors and E-film radiographs in terms of approximal caries detection in their study. There was no difference between conventional radiography and digital radiography.⁵⁸

CONCLUSION

Caries detection methods enables the detection of caries in the early stages and aims the elimination of steps leading from cavitation to demineralization. But unfortunately, none of the known methods of caries diagnosis is enough to define the dynamic tooth decay which is likely re-emerge. In light of all these studies, ultrasonic system was stated to be reproducible and have a high sensitivity and specificity. In the diagnosis of caries lesions, more clinical studies are thought to be required for the use of ultrasound.^{59,60,61} While QLF is seen to be the most effective method on flat surfaces and interfaces, DIAGNOdent now partially responds to the needs of occlusal surfaces.⁶² If carious lesion can be detected early enough, no matter where localization in teeth is, it is possible to intervene in progress of the lesion. Because carious lesion is localized in different anatomical regions, and because it develops next to new-made restoration, may cause diagnostic error. These differences result from the lack of sufficient sensitivity and specificity of diagnostics model that can detect any decay on all the different surfaces. Numerous implementation of a combination of the diagnostic test is an attempt to increase efficiency in caries diagnosis.⁶²

In this study, the proposed new diagnostic methods for caries diagnosis and their advantages and disadvantages are presented. While hidden caries can not be detected in the radiographs, this system allows early detection of caries when used in conjunction with other clinical examinations. These systems are promising, but their use takes time. No doubt, with the development of more appropriate diagnostic methods, there will be little differences in dental hard tissues. Thanks to preventive and stopping measures, dentistry will move away from restorations.

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