VALUATION OF MODERN DIAGNOSTIC METHODS IN DETECTING INITIAL CARIOUS LESIONS

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Abstract

Introduction: Modern investigation methods used in the diagnosis of dental caries may bring substantial improvements to the classic ones. However, their implementation requires specific knowledge, appropriate endowment and prior assessment. It is the aim of this research to replace the classic concepts of early dental caries diagnosis by modern methods. *Material and methods*: Studies are focused on the testing of various diagnosis methods in order to compare them, as well as to validate them histologically by the means of stereomicroscopy to develop applications for teaching and basic research purposes. Quantitative light-induced fluorescence (QLF) and Diagnodent will be assessed so as to optimise these methods. As the present diagnosis systems are very diverse, the choice of one or another in practice needs to be estimated beforehand. In vitro analysis is therefore mandatory. Computer-assisted diagnosis is employed to get additional data by using the related softwares that will enable the clinician to store information, as well as to subsequently assess and monitor. *Results*: Following this research, we expect the new computerised work methods to may be optimised, customised, multiplied and implemented in practice as regards both the design, and the execution technology. *Conclusions*: Computer-assissted work methods in the early diagnosis of caries lesions are laborious; they involve a series of work phases and specific knowledge.

Key words: dental caries, diagnosis methods.

Introduction

Modern management of dental caries comprises three major components: prevention, control and treatment. It is based on the adequate diagnosis of the disease and on the detection of pathological changes of the lesion in the initial stages. A great drawback for the clinician regarding the caries management strategies based on the risk assessment is the lack of methods to certainly determine the degree of profound dental tissues decay. It is possible to detect the lesions in an early phase, before the emergence of cavity lesion by using the modern methods. This is of particular importance in order to take adequate preventive measures in due time [1, 2]. If the modern diagnosis methods are not used, the risk of caries lesions is increased, as the classic methods do not allow for the detection of early carious lesions that are still in the reversible stage of remineralisation. Besides the visual examination, the most widespread exam to improve the initial carious lesion diagnosis and also the only one used in most dental offices is the radiographic examination [3, 4]. Although the bite-wing radiographic examination is thought to be important in the detection of proximal caries, this type of exam shows poor results in the detection of enamel occlusal caries [5, 6]. Several new methods were introduced in the early 1990's, some of them as research tools, while others were used in the dental offices. These were intended to increase the reliability of occlusal caries detection besides the visual examination and the radiographic methods. FOTI, DIFOTI, ECM, QLF, DIAGNOdent and D-Carie are some of them. [7, 8, 9,10]. In the case of **optical based methods for detecting carious lesions**, the light interacts with hard dental tissues in different ways: it can be reflected, scattered, transmitted or absorbed. Fluorescence, in which the electrons having a lower energy level move to a higher level, is a possible consequence of absorption. When they reach back the initial level, the energy is emitted as light, which is known as fluorescence. In other words, fluorescence is the result of interaction between the electromagnetic radiation and molecules in the tissue. It is still not clear what causes the enamel fluorescence. The most part of fluorescence is induced by organic components, protein chromophores, but a portion is probably due apatite. Dentine fluorescence has been suggested to be caused by inorganic complexes, as well as by organic components. In healthy enamel wave lengths are large, with a high probability that photons will hit a chromophore. Thus, fluorescence is relatively intense. Demineralisation of dental hard tissue, enamel or dentine leads to the loss of auto-fluorescence, the natural fluorescence. Several factors may contribute to the decreased fluorescence of early carious lesions. Four possible mechanisms have been proposed: the light scattering in the lesion causes the light path to be much shorter than in the healthy enamel: light absorption per volume is much lower in the lesion, so the fluorescence is weaker; light scattering within the lesion acts as a barrier for excitation light to reach the underlying fluorescent dentine and for fluorescent light in the dentine to reach the surface; fluorescence is ended by a switch in molecular environment of chromophores; protein chromophores are removed by dental caries evolution. **The QLF method – light-induced quantitative fluorescence** (fig.1) measures the fluorescence induced after use of green-blue laser light at approximately 488 nm wavelength, quantifying demineralisation and severity of lesion. It is used for *in vitro, in vivo* and *in situ* studies in the diagnosis of early lesions, both for deciduous and permanent teeth [11]. Effects are higher *in vitro* than *in vivo*, were a humid environment exists [12]. The QLF method has been tested in several *in vitro*, *in situ* and *in vivo* studies for caries lesions of tooth surfaces [13, 14, 15, 16]. This method has high *in vivo* repeatability and reproducibility, which means it can monitor the effects of preventive programmes [16]. Examples of factors that may influence in different ways the measurements results include: presence of bacterial plaque, dental calculus and/or stains on tooth surface, ambient light, daylight or artificial light and dehydration de degree of dental tissue [17, 18].

The DIAGNOdent device (fig.2). Sundstrom and co-workers performed in 1985 a comparative study on the fluorescence of healthy tooth surface for different excitation wavelengths and reported the absence of fluorescence in the visible area for red light illumination (633 nm) . Studies by Hibst and Gall showed the red light induced fluorescence (638–655 nm) could differentiate between healthy and carious tooth tissue [19, 20]..The DIAGNOdent device has been assessed in several *in vitro* and *in vivo* studies [21, 22, 23, 24].

Fig.1 QLF sistem - Inspektor™ Pro.

Fig. 2. DIAGNOdent device and DIAGNOdent – pen device.

In a study by Lussi and co-workers that compares traditional examination and treatment to concurrent use of DIAGNOdent device, good to excellent sensitivity and excellent reproducibility were reported [21]. Reproducibility is high, the device is therefore used for the longitudinal monitoring of caries, for the differentiation between active and inactive lesions and for establishing the treatment plan [25]. Stained dental materials might affect DIAGNOdent readings and consequently result in false-positive diagnoses of secondary caries. Dental fillings should be polished prior to DIAGNOdent measurement [26]. As the DIAGNOdent accuracy concerns, it is influenced by the presence of bacterial plaque and dental calculus; thus the professional hygiene prior to measurements is required. A prolonged drying will also modify the reading [27]. DIAGNOdent accuracy is superior to that of radiography, while its specificity is higher than that of ECM [28, 29]. The factors that can influence in different ways measurement results are: presence of plaque, dental calculus and/or stains on tooth surface, dehydration degree of dental tissue, the presence of sealing materials or professional hygiene [27,30,31]. For measurements performed on occlusal surfaces it is important the tip to be tilted, so all the surfaces to be scanned.

Aim

The main purpose of this study is to investigate if correlations between data from the **modern methods of early carious lesion detection** (QLF, Diagnodent) and **histological validation** exist. This study aims to test fidelity, reproducibility and validity of the methods designed to detect and quantify the caries in terms of statistical analysis; this study investigate if data from the diagnostic methods may improve the performance of investigator in the diagnosis caries as compared with the visual inspection, and to examine the way in which they may influence treatment decisions.

Materials and methods

The study material was formed by 192 human extracted teeth: premolars extracted for orthodontic purposes and impacted molars with macroscopically intact occlusal surface- without any loss of tooth substance, extemporaneous stains, hypoplasias, or other enamel abnormalities or restorations. In order to perform the extractions, the written and verbal consent of the patient was previously obtained. Clinical diagnosis, clinical inspection was performed by three calibrated investigators which individually assessed each dental piece, establishing the treatment indication: monitoring - absence of treatment, non-invasive treatment (topical applications with de fluoride, sealing) or invasive treatment (tooth restorations). Indications will be recorded in an individual file of each tooth piece; these will be lately compared to the results obtained after measurements by modern methods of detecting early carious lesion, as well as to the anatomo-pathological exam of the lesion. One week after the visual examination QLF examinations were conducted by the same three examiners. Four weeks following the initial visual examination/treatment decision, all examiners were requested to re-evaluate the designated examination sites, this time having available to them the results from the other detection methods, to make another decision regarding their recommended treatment.

Visual examination was carried out using only a dental operating light and air-drying up to 5 s. No explorer was used during the examination. Each predetermined site on the occlusal surfaces was scored using the criteria described by Ekstrand et al. [32], as presented in Table 1. The tooth selection included scores 0–3, but not score 4 (Table1).

Table 1. Criteria for visual examination.

Score	Criteria
0	No or only a slight change in enamel translucency after prolonged air drying (>5s)
1	Opacity or discoloration hardly visible on the wet surface, but distinctly visible after air drying
2	Opacity or discoloration distinctly visible without air drying
3	Localized enamel breakdown in opaque or discoloured enamel and/or grayish discoloured from underlying dentine
4	Cavitation in opaque or discoloured enamel exposing the dentine beneath

Laser fluorescence measurements were made using the DIAGNOdent device (Kavo, Biberach, Germany). The device was calibrated before use with a porcelain standard provided by the manufacturer. The probe tip A was adjusted to each tooth separately by holding the tip against a sound smooth surface and pressing the ring button until calibration was complete. The tooth surface was dried, then the conical probe tip was positioned perpendicularly over each selected site, as indicated in the photographs, and rotated around its long axis. A score of 5 or higher was considered to indicate the presence of caries. Each site was measured three times using the above-mentioned procedures and the average of these readings (0–99 range) was considered as the definitive score.

Quantitative light-induced fluorescence. Images of occlusal surfaces of tooth specimens were captured using a portable intra-oral camera device connected to a computer (QLF; Inspektor Research Systems, Amsterdam, the Netherlands). Each occlusal surface was illuminated with 13 mW cm)2 of violet–blue light (wavelength: 290–450 nm, average 380 nm) from the camera handpiece and the images were captured using a camera fitted with a yellow 520-nm high-pass filter. The images were not analyzed, but were scored subjectively from the stored images displayed on a cathode ray tube (CRT) monitor. The scoring criteria were as follows: 0, no change in enamel fluorescence;1, slight change in enamel fluorescence; 2, loss of fluorescence distinctly visible without broken enamel; 3, loss of fluorescence distinctly visible with enamel broken; and 4, loss of fluorescence distinctly visible with cavitation .

Histological validation. Studies conducted to the date are the result of cooperation with the Department of Technology of Materials within "Politehnica" University Timisoara and with the Department of Histology within UMF Timisoara. They focused on processed extracted dental fragments (polished dried tooth, initially sectioned at 50µm, and later at 15µm thickness; it is fixed between blade and lamella with the luting of edges to prevent the air to permeate) for stereomicroscopic analysis. The stereomicroscopy allows the study of higher quality tridimensional and of laterality images. These interpretative qualities of stereomicroscopy are given by the large examination fields and large work distances ranging between 92 mm and 286 mm, with an increase from 1.95 to 225 x. Basic principles of stereomicroscopy include coaxial, oblique and annular lighting techniques. Optical adjustment of optical and mechanical alignment is required for optimal lighting and micrometry. It allows for the morphological and colour absorption study, as well as for the assessment of the depth of lack of substance, which is very useful in the evaluation of carious lesion progression. Isotropy versus anisotropy and birefringence by Michel Levy phenomenon are determined by using polarised light. Colour interference and quantitative position of particle extinction are also determined. Olympus SZ x 7 and Olympus camera 2.5 x digital zoom and 3 x optical zoom were used to study the specimens in stereomicroscopy and polarised light .

In order to clarify the diagnostic methods,it was by statistical analysis of the results, establishing the sensitivity, specificity and accuracy degree. GraphPad PRISM, prism 5 for Windows, data processing in Excel, EPI and SPSS ver.17

Results

Validity of clinical diagnosis was correlated with the measurements obtained by laser fluorescence device, KaVo DIAGNOdent, QLF device as well as with *the investigation in polarised light and stereomicroscopy – gold standard*, allowing for the histological study of lesion morphology. *Evaluation of the relationship between presence and depth of histologically confirmed carious lesion and diagnosis based on clinical inspection only or clinical inspection combined with QLF, Diagnodent* , as well as *evaluation of relationship between presence and depth of histologically confirmed carious lesion and treatment decision based on clinical inspection only or clinical inspection and examination by QLF, and Diagnodent* has been aimed. Computer-assisted diagnosis has been used for QLF. (fig.3).

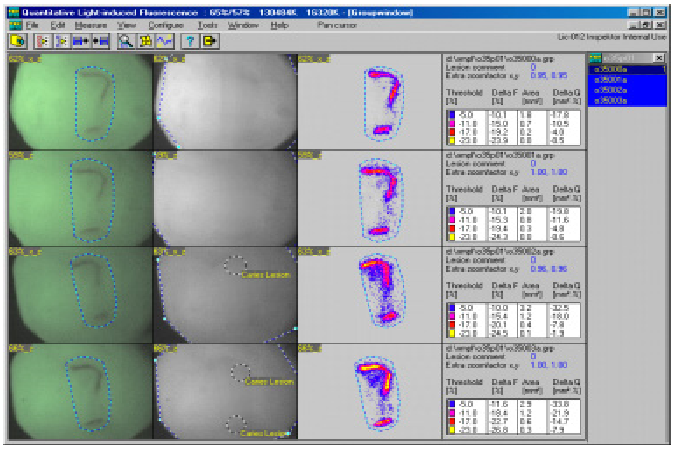

Fig.3. Images interpreted with QLF system software.

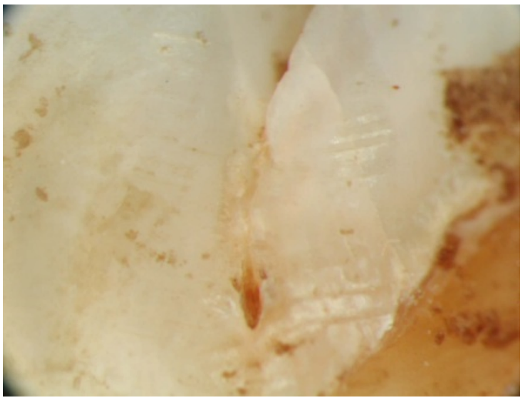

Fig.4. Occlusal surface with deep grooves and plaque deposits, stereomicroscopy aspect of polytopic lysis of enamel and dentine proximal to the carious lesion body,

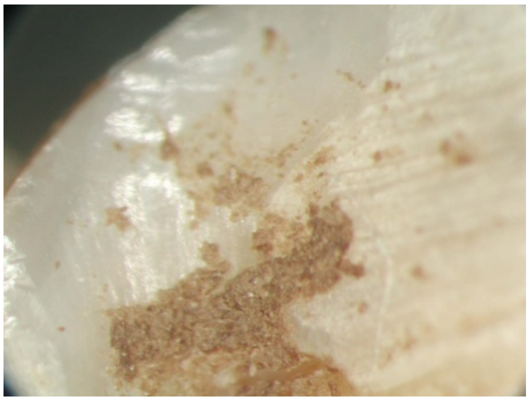

Fig.5. Stereomicroscopic study of a carious lesion bacterial diffused along the amelo-dentinal line presenting an in polarised light, x 32.

Histological examination of the teeth (fig.4,5) revealed that 82 teeth (42.7%) were sound, 62 (32.3%) had demineralization in the enamel, and 48 (25.0%) had demineralization extending into the dentin.

Table 2 presents the sensitivity, specificity, for the visual examination by all three examiners and for the results obtained by combining all diagnostic methods at the D1 diagnostic threshold. The mean sensitivity of visual examination combined with the other methods was significantly higher than that of visual examination alone. Concurrent reduction in specificity was also statistically significant.

Table 2. The examiner´s sensitivity and specificity in detecting oclussal caries using visual examination and combination of visual examination and Diagnodent and QLF.

Type of the examination	examiner	sensitivity	specificity
Visual examination	1	0,73	0,80
	2	0,67	0,83
	3	0,91	0,59
Combination of visual+ other methods	1	0,84	0,73
	2	0,80	0,73
	3	0,91	0,56

Table 3 shows the number and type of treatments indicated by each examiner for occlusal surfaces, based on the visual examination alone, as opposed to visual examination combined with other detection methods.

The weighted kappa agreement between the initial and revised decisions is also shown. An increase was observed in the number of invasive treatments indicated for the occlusal surfaces when the examiners had assessed data from all methods combined, in comparison with treatments indicated after visual examination alone. This increase ranged from 11 to 20% of the teeth. A considerable difference in the number of calls for invasive treatment among the examiners was observe.

Table 3. Number and type of treatments indicated by each examiner for occlusal surfaces, based on visual examination alone and on visual examination combined with Diaagnodent and QLF.

Visual				Visual + other methods			
Examiner	Nothing	Non-invasive treatment	Invasive treatment	Nothing	Non-invasive treatment	Invasive treatment	Weighted Kappa
1	102	68	22	74	58	60	0,50
2	106	82	04	42	82	68	0,59
3	48	96	48	34	86	72	0,61

Discussions

It is obvious that the decision to restore an occlusal tooth surface should not be made solely on the basis of detecting disease by visual examination or with the help of other diagnostic methods, as observed in the present study. In making a decision to place a restoration, the dentist should assess the caries risk and activity of the individual patient, the tooth age and morphology, and rationally interpret the reading of any mechanical device. Various authors have suggested that if visual examination was followed by the use of an additional method, the accuracy of occlusal caries diagnosis would be improved [31,33]. This theory is corroborated by data from studies that indicated that detection technologies,as such ECM and DIAGNOdent, performed better in detecting early carious lesions in occlusal surfaces than traditional visual examination. By using visual criteria developed more recently this advantage of the detection technologies has greatly diminished; the detection methods mainly improve sensitivity, but by compromising on the specificity side of the equation. According to Lussi [31], when high values of both sensitivity and specificity cannot be achieved, the test providing high-specificity values is to be preferred. This study failed to find any improvement in the overal accuracy of the detection, although shifts in sensitivity and specificity reached statistical significance. Those shifts would lead to an increase in the number of false positive diagnoses and may have affected the decision of the examiners towards invasive treatment.

From the data presented in Table 4, it was observed that examiners showed a tendency towards more invasive treatment when more data were available. This occurred even though the examiners were well aware of the danger involved in the situation. Future studies should focus on defining and improving the diagnostic process resulting from data from diagnostic methods, under in vivo clinical conditions, and need to take into consideration variables of patient and dentist factors, with the aim of finding the best combination to assist dentists in their treatment decision-making.

Conclusion

Having data available from multiple methods did not improve the accuracy of examiners in detecting early occlusal caries lesions, but it had a great influence on the number of surfaces indicated for operative treatment. The potential decrease in overall specificity while using multiple methods may be of concern in populations with a low prevalence of occlusal caries lesions.

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