Diagnostic performance of radiovisiography in combination with a diagnosis assisting program versus conventional radiography and radiovisiography in basic mode and with magnification

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Abstract

Objective. To evaluate and compare the diagnostic efficiency of a digital radiographic system (RadioVisioGraphy –RVG-) in combination with a diagnostic assisting program (Logicon) with RVG in basic mode, magnification and conventional radiography (Kodak).

Study design. A study was made of 384 proximal surfaces corresponding to 192 posterior teeth. The diagnostic techniques employed comprised Kodak DF-58 Ultraspeed X-rays and a Trophy RVG system used in normal mode, magnification, combination with a caries diagnosis assisting program by Logicon; Kodak DF-58 Ultraspeed radiographs were used. The same X-ray source was used in all cases. The images obtained were compared to histological sections of the teeth used. These were brewed by abrasion and observed using a light microscope. A single operator made all observations. Sensitivity, specificity, the positive and negative predictive values, and the probability ratio were calculated.

Results. Application of the Logicon program increased sensitivity, specially in lesions with caries extending into the dentin. In contrast, conventional radiography yielded a higher specificity and positive predictive value. The negative predictive values were similar for both tecniques.

Conclusions. The RVG digital radiography and the Logicon assistance program was effective in diagnosing caries.

Key words: Digital radiology, caries diagnosis.

Introduction

Radiography is considered essential in the diagnosis of approximal dental caries, though its diagnostic efficacy is dependent upon good image quality. Radiographs have limitations and are unable to reveal the earliest stages of dental caries, and moreover underestimate the extent of demineralization (1), an important consideration when developing a treatment plan. Radiographs have additional limitations, with risk of false positive and false negative diagnoses with diminishing lesion size. Inter-observer variations in the interpretation of the same image also poses a limitation; consequently, adequate training and calibration measures are required when conducting experimental or epidemiological studies involving a number of observers. Another major difficulty arises when attempting to diagnose occlusal caries - though in contrast the early diagnosis of proximal superficial caries is relatively simple. The morphological and structural features of the occlusal

surface make it more difficult to detect incipient carious lesions - of which only a third are correctly diagnosed in practice. Even lesions with minimal dentinal advance are only detected in two-thirds of cases (2).

Digital radiology involving image processing techniques commenced with the introduction of RadioVisioGraphy (RVG) -Trophy Radiologie. Marne-La Vallée, France- (3). Computed radiology with scanning laser stimulated luminescence was introduced in the early eighties (4), and in future, light-induced fluorescence may prove useful for the diagnosis of occlusal caries. The specificity of this technique is less than that of direct visualization, as confirmed from sections of theeth, though the sensitivity of the technique is higher than that of clinical examination/ inspection in determining lesion depth (5). In this study validation was performed with confocal microscopy. Computing procedures have been added to all these innovations to assist the decision taking process, with the aim of optimizing the use of modern imaging diagnostic systems (6). Digital radiology has been found to be useful in diagnosing incipient carious lesions in vitro (7).

The present study compares the diagnostic efficacy of conventional bitewing radiographs, RVG together with a diagnosis assistance program (Logicon Caries Detector™; Logicon, Inc., Los Angeles, CA, USA), RVG in basic mode and with magnification, and conventional radiographs - the findings being contrasted with the histologic observations of the corresponding dental sections.

Material and Methods

The study sample comprised 192 teeth removed for orthodontic or periodontal reasons with or without carious lesions, and with the crown intact. The exclusion criteria were: dental fractures, consumptive processes (wear or abrasion), teeth with developmental alterations causing morphological and/or structural anomalies, teeth exhibiting extensive carious destruction of the pulp chamber or canal invasion, and cases of severe coronal morphological and structural alterations. In the latter case selection was made visually in some instances and radiographically in others.

For the radiographic study, the teeth were mounted in groups of 8 teeth (4 maxillary and 4 mandibular, of which two each were premolars and molars). Articulation of the two blocks of teeth was achieved with plastic mini-articulators, to reproduce the anatomical relations among the neighboring and opposing teeth. Once articulated, the teeth were kept stable on a support with the occlusal plane parallel to the floor and the long axis of the tooth perpendicular to this plane. A soft tissue simulator was positioned between these models and the X-ray source, to simulate a realistic reproduction of the actual oral conditions.

An ORIX-AET 65 kV intraoral radiodiagnostic apparatus was used. The selected exposure time was 0.8 seconds. Paralleling was achieved with a plastic Klauser paralleli-

zer - the Hawe-Kwik-Bite (Hawe Neos Dental, Bioggio, Switzerland) - which both fixed the radiographic film and marked the distance between it and the end of the X-ray tube. Conventional radiography was in turn conducted with the Kodak DF-58 Periapical Ultraspeed (size 2) (Kodak, USA). Processing of the exposed film was performed with a Periomat developer (Dürr Dental, Germany). Visualization was carried out with a viewer under conditions of environmental illumination, without opacification or magnification. Digital recording of the same models with teeth was also performed using the same X-ray generating tube, with an exposure time of 0.4 seconds, employing a Trophy RadioVisioGraphy system. The latter consisted of a scintillation sensor that transmits the absorbed radiation via optic fibers to the CCD or couple transfer device that register the image. The associated electronics in turn process the image obtained. Te image was equalized to optimize resolution and enhance diagnostic performance. The image producing unit in turn allows variations in image presentation, offering a series of options such as image equalization and zoom amplification - which might help the observer viewing the image.

Once digitally recorded, the images were analyzed using specific software for the diagnosis of caries (Logicon). In a selected area for diagnosis, this program provides enamel and dentinal densitometric readings that can be correlated to the possible presence of carious lesions through an information based in previous studies made by the manufacturer (fig. 1).

The approximal caries observed with both conventional radiography and standard and magnified RVG were classified according to the following criteria: 0 = no radiotransparency or visible restoration; 1 = enhanced radiotransparent zone in the external half of the enamel; 2 = radiotransparent zone occupying the full thickness of the enamel, though without reaching the amelodentinal junction; 3 = increased radiotransparency involving the enamel, amelodentinal junction and external half of the dentine; 4 = increased radiotransparency penetrating to the internal half of the dentine, either with or without apparent involvement of the pulp (8).

Histopathological verification of the carious lesions was carried out by specimen abrasion and observation under a Nikon SMZ-10A photomacroscope (x32 magnification) equipped with a Nikon FDX-35 camera and its corresponding adapter (Nikon H-III) (Nikon, Japan) with a light source. The histopathological diagnostic criteria were: 0 = no evidence of caries, 1 = presence of a carious lesion (or lesions) in the external half of the enamel only; 2 = presence of a carious lesion (or lesions) in the inner half of the enamel, including the amelodentinal junction but without spread to the dentine; 3 = presence of a carious lesion (or lesions) through the enamel to the external half of the dentine (fig.2); 4 = presence of a carious lesion (or lesions) through the enamel to the inner half of the dentine (9).
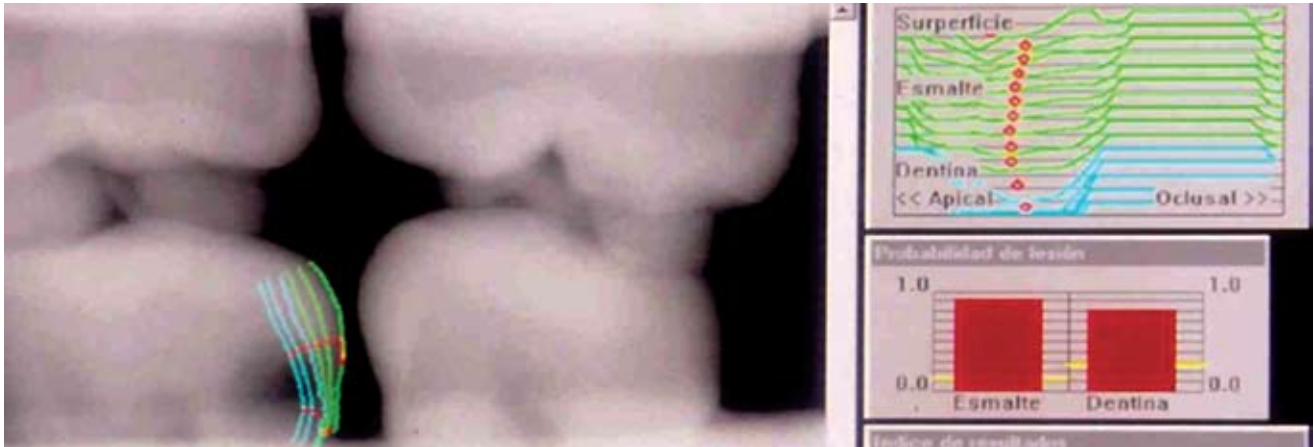
Fig. 1. Logicon densitometric analysis display from an approximal caries lesion.

All observations were made by a single operator, with the repetition of 10% for intra-observer validation purposes based on percentage concordance and the Cohen Kappa test. In order to analyze the results of the three diagnostic modalities tested versus the histopathological findings, measurements were made of the corresponding sensitivity, specificity, positive and negative predictive values (PPV and NPV), and likelihood ratio.

Results

The results corresponding to intra-observer concordance are shown in Table 1 (range, 84-95%), along with the Cohen Kappa values (over 0.9 in all cases). As suggested by the data analysis afforded by both tests, intra-observer reliability was found to be very high - thus contributing to ensure consistency of the results obtained.

Comparison of the sensitivity, specificity, PPV and NPV and likelihood ratio for each of the diagnostic procedures studied (i.e., conventional radiology, standard RVG, RVG with magnification and diagnosis assisted by the Logicon program) with a standard (in our case, the associated histopathological findings) showed the highest sensitivity in enamel to correspond to the Logicon program on the mesial surfaces. In the case of the distal surfaces, maximum sensitivity was afforded by RVG with magnification. As regards dentine, the Logicon program likewise yielded the highest sensitivity values. In contrast, the highest specificity was afforded by conventional radiography for all surfaces studied. In the case of PPV, the best results were obtained with conventional radiography, while NPV showed coincident values for mesial enamel assessment between radiography and the Logicon program - with very similar values among all the diagnostic modalities and for all surfaces. The likelihood ratios for a positive reading of the diagnostic techniques showed values equal to unity for standard RVG in relation to mesial dentine and distal

Fig. 2. Example of a histopathologic image from a caries lesion (score 3).

Table 1. Intra-observer concordance values.

	Percentage concordance	Kappa test
Conventional X-rays	95	0.98
Standard RVG	89	0.98
RVG with magnification	89	0.98
Logicon software	92	0.97
Histopathology	84	0.98

RVG: radiovisiography

Table 2. Performance parameters for each of the diagnostic methods studied.

	Sensitivity				Specificity				PPV				NPV				Probability ratio			
	Mesial		Distal		Mesial		Distal		Mesial		Distal		Mesial		Distal		Mesial		Distal	
	E	D	E	D	E	D	E	D	E	D	E	D	E	D	E	D	E	D	E	D
Rx	14	5	18	3	98	100	91	96	81	100	45	25	70	83	74	86	7	∞	2	0.7
RVGst	17	5	20	7	85	95	80	90	36	22	28	11	67	82	72	86	1.1	1	1	0.7
RVGmag	19	14	32	19	79	94	71	87	30	35	29	17	66	83	73	87	0.9	2.3	1.1	1.4
Logicon	39	20	26	34	68	81	61	76	38	18	20	18	70	82	68	88	1.2	1	0.6	1.4

Rx: conventional radiography, RVGst: standard radiovisiography, RVGmag: radiovisiography with magnification, PPV: positive predictive value, NPV: negative predictive value, E: enamel, D: dentine

enamel, and for the Logicon program in mesial dentine. This indicates that positive readings with these explorations do not increase the probability of caries affecting the surfaces studied. In the rest of cases, the likelihood ratios ranged from 0.6 to 7, reflecting the different increments in the probability that a given carious tooth will yield a positive reading with the corresponding diagnostic technique (Table 2).

Discussion

Digital radiology detects 70% of deep dentinal lesions, versus only 45% when using other radiological techniques (including conventional X-rays and xeroradiography), without incrementing the proportion of false positive readings (10).

In the initial version of radiovisiography (RVG), the authors acknowledged that the resolution afforded was slightly inferior to that of a conventional radiograph - though images could be magnified. Additional advantages over conventional X-rays are the possibilities of improving brigthness and contrast (3). The radiographic image depends on a number of factors; these include exposure time, geometric parameters such as the distance between the X-ray source and film, or the direction of the tube, the amount and extent of mineral loss in the tooth, the type of film used, the conditions of development, and the conditions of observation. As a result, the apparently simple process of "seeing" and X-ray can lead to important diagnostic errors if the above mentioned influencing factors are not adequately controlled. In this sense, Cederberg & others (11), in relation to the diagnosis of dental lesions, showed background illumination to have no effect upon the diagnostic capacity of the observer. On the other hand, these authors dealt with images processed both digitally (Digora) and conventionally (Ultraspeed and Ektaspeed Plus) - thus suggesting that the processing approach employed is also unlikely to greatly influence the diagnostic decision of an experienced observer in situations of genuine carious pathology.

In the present study a single X-ray source was used with known and stable characteristics, and exposure was controlled for time, focal distance and position. The film and digital detector features likewise remained constant throughout the study. In order to avoid one of the main sources of error in the production of radiographic images, we at all times used an automatic processor to ensure similar conditions for all the X-ray films obtained. On the other hand, and although digital imaging obviates such steps, variability may nevertheless result from the possibility of modifying and improving the images; as a result, the digital images obtained were equalized under constant parameters to ensure the best possible image under known and normalized conditions. In the case of the radiographs, we conducted visualization as uniformly

and simply as possible, i.e., using a viewer without environmental illumination (the only way to control for this factor), without magnification.

Digital radiological systems allow image modification and analysis in an attempt to improve their diagnostic capacity. In this sense, a number of experimental studies have tried to precisely assess the true capacity of these technical options. While modifications in the basic functions of the global digital radiological systems do not seem to afford much improvement over direct digital imaging (12), magnification of the initial image - a function also offered from the early digital radiological techniques - does in effect increase the diagnostic precision of proximal carious lesions versus non-magnified images (13). In our study, slightly higher sensitivity values were obtained for magnified RVG versus the standard RVG technique, while for the rest of the methods the values were either similar or slightly inferior.

A study comparing bitewing radiographs with RVG in basic mode in the analysis of occlusal and proximal surfaces reported results similar to our own in terms of specificity and PPV in application to proximal surfaces (9). The sensitivity results of conventional radiography versus RVG in application to the proximal surfaces were inferior to our own, however.

Heaven & others (14), using a software supported diagnostic system (CariesFinder), reported significant differences between the latter procedure and conventional radiography using D-Speed film. In our study, the highest sensitivity values were obtained with the Logicon program, while maximum specificity was afforded by conventional radiography. Wenzel (15) stablished the consistency of Logicon studying proximal surfaces in patients when the analysis is repeated on the same surface; this work showed that inter-observer agreement caries diagnosis did not improved using the program. A recent study (16) compared clinical and Logicon-assisted RVG diagnosis, showing that dentists were able to detect 20 percent more cases of caries penetrating in dentin with Logicon versus those founded by clinical criteria. When comparing with a similar study (17) we obtained less sensibility and higher specificity.

The results obtained suggest digital radiology to be effective in the diagnosis of dental caries. On the other hand, we consider that although diagnosis assisting software offers a good diagnostic performance, further research is required in this field since such systems furthermore contribute to improve communication with the patient and afford documental support of the diagnosis made.

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