Araştırma / Original Paper

In Vitro Comparison of Intraoral Films and Four Image Plate Systems in Radiographic Caries Diagnosis

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Kabul tarihi / Date of acceptance: 11 Aralık 2012 / December 11, 2012

ÖZET

Radyografik çürük tanısında intraoral filmler ve dört fosfor plaka sisteminin *in vitro* karşılaştırılması

Amaç: Radyografide çürük tanısının konması bazen kolay olmayabilir. Bu çalışmada aynı şartlar altında değerlendirilen dört adet fosfor plaka sisteminin ve iki film esaslı sistemin çürük tanısındaki yerinin araştırılması amaçlanmıştır.
Yöntem: İki yüz adet diş beşerli gruplar halinde plastik Lego® bloklara yerleştirildi. Her bir bloktan standart şartlarda dental röntgen apareyi ile radyografik görüntü alındı. Fosfor plakalarla (Dentsply DenOptics®, Dürr Vistascan II®, Soredex Digora FMX®, Soredex Digora Optime®) 60 kV ve 7 mA ışınlamayla görüntü elde edildi. Çürük derinliği on bir gözlemci tarafından değerlendirildi. Histolojik bulguları karşılaştırmak için mikroskobik inceleme yapıldı. Mikroskobik ve radyolojik bulgular arasındaki farklar değerlendirilerek çürük derinliği belirlendi.
Bulgular: Çürük tanısında farklı sensörlerin çok az etkisi olduğu görüldü. En büyük farkı DenOptix ve Digora FMX sistemleri gösterdi. Tüm yüzeyler hesaplandığında etkinin istatistiksel olarak anlamlı olmadığı bulundu.
Sonuç: Dört fosfor plaka sistemi de çürük tanısında kabul edilebilir sonuçlar göstermiştir. Mine çürüğündeki histolojik derinlik radyografik ölçümlerle uyumlu bulunmamıştır.
Anahtar sözcükler: Diş çürüğü, diş çürüğü tanısı, fosfor plaka

ABSTRACT

In vitro comparison of intraoral films and four image plate systems in radiographic caries diagnosis

Objectives: Detecting early caries lesion on a radiograph may be a difficult task. The aim of this study was to compare four image plate and two film-based systems by evaluating the accuracy of caries detection under standard conditions.
Methods: Two hundred teeth were attached in groups of five onto plastic Lego®blocks. Radiographs were taken from each block under standard bitewing conditions with an X-ray device. Phosphor plates (Dentsply DenOptics®, Dürr Vistascan II®, Soredex Digora FMX®, Soredex Digora Optime®) were exposed at 60 kV and 7 mA. The caries depths were analyzed by eleven observers and microscopic investigation was used to compare the histological findings. The caries depth was calculated as the difference between microscopic and radiological findings.
Results: Data analysis showed a small impact of different sensors on the diagnostic accuracy. The largest differences between microscopic and radiographic caries ratings were found with DenOptix and Digora FMX. When it was calculated over all surfaces no statistical significance was found.
Conclusion: The results suggest that the performance of the four storage phosphor image plate systems is acceptable for the detection of caries. The increase in histological depth of enamel caries was not significantly correlated with radiographic measurements.
Key words: Dental caries, caries diagnosis, phosphor plate

INTRODUCTION

Over the last century, since the introduction of x-rays in dentistry, radiography has been regularly used to diagnose dental caries particularly on the surfaces which cannot be examined clinically (1,2). It was reported that the sensitivity of caries detection is improved by radiographs in comparison to exclusively clinical examinations. Dental caries is demineralization of the tooth surface caused by bacteria and altogether is a dynamic process which starts at the molecular level and cannot be diagnosed until the occurrence of irreversible loss of tooth structure (1-5). Radiographic

diagnosis of dental caries is based on the fact that the increase in x-ray penetration is correlated with decrease in the mineral content of enamel and dentin. Thus, carious lesions should be more radiolucent than the unaffected parts (1). An initial caries lesion may not have yet caused sufficient demineralization to be visualized on a radiograph. The radiographic appearance of dental caries is not representative of its real size, therefore the caries extension is expected to be larger rather histologically than radiologically. Moreover, measurement of the extent of a carious lesion is difficult to perform accurately (1-9). Generally, it has been pointed out that the lesion depth is underestimated in radiographs by approximately 30% (1,4,7,8).

Radiography is still the method of choice to assess the lesion size, despite its relatively low reproducibility (8). In order to evaluate the presence, location and depth of caries lesions, intraoral films and digital sensors have been compared in many studies in recent years (7-18).

The differences regarding the image quality and diagnostic sufficiency of digital sensors and conventional films have been shown to be almost equal (5,7-14).

The aim of this study conducted in 2005 was to compare four storage phosphor image plate systems (PSP) by evaluating the accuracy of caries detection under standard office conditions.

MATERIALS AND METHODS

Two hundred teeth were attached in groups of five onto plastic Lego® (Billund, Denmark) blocks. A total of forty blocks were prepared. An X-ray device (Heliodent MD X-ray unit, Sirona, Bensheim, Germany) was horizontally positioned, the focus-receptor distance was 31.8 cm. A 10 mm acrylic plate was placed between the tube and the teeth to simulate the soft tissue. Radiographs were taken from each block under standard bitewing conditions. PSPs were exposed at 60 kV and 7 mA. The caries depths were analyzed by eleven observers, for crowns at a-six-point and for roots at a-four-point scale. The caries depth was calculated as the difference between microscopic and radiological findings.

The storage plate systems used in this study were:

- DenOptix (Gendex Dental Systems, Lake Zurich, USA),
- Vistascan II, (Dürr Dental, Bietigheim-Bissingen, Germany),
- Digora FMX (Soredex, Helsinki, Finland),
- Digora Optime (Soredex, Helsinki, Finland).

The film based systems were:

- Agfa Dentus M2 (Agfa-Gevaert N.V. Mortsel, Belgium),
- Kodak Insight (Eastman Kodak, New York, USA).

The exposed PSPs were scanned in their respective scanners using the manufacturer's software and were displayed on 17-inch monitors at 1024x768 pixel resolution. A dedicated Image Evaluation Program was programmed using Delphi 2005® (Borland, Cupertino, CA, USA) by the first co-author.

A total of 11 observers assessed the radiographs obtained by each modality for the presence and depth of caries for the crown and the root.

Scale for approximal and occlusal sites:

0: No defect or other defect (preparation or filling),
1: Superficial enamel caries,
2: Caries deeply in enamel,
3: Caries reaching the dentino-enamel junction,
4: Deep dentin caries,
5: Caries defect at the dentin-pulp border.

Scale for sites at the cemento-enamel junction:

0: No defect or other defect,
1: Superficial root caries,
2: Deep root caries,
3: Caries at the dentin-pulp border.

The tooth blocks were poured in plaster for the microscopic investigation. Each block was grinded by a plaster trimmer with a diamond disk and photographed every 250 micrometer under standardized conditions at a 4.8x magnification under a microscope (OPMI PROergo, Zeiss, Oberkochen, Germany) with a digital camera (Nikon, Tokyo, Japan). Three pre-calibrated examiners analyzed the microscopic images for the deepest caries rating at each location analogue to the radiological evaluation.

In the beginning of the study, 40 teeth-blocks were prepared as 120 test-teeth. In the end, the outcomes of 90 test-teeth were analyzed since 10 teeth-blocks were not used for various reasons: Section damage/loss, artefacts, failure in scoring, etc. Analysis of variance (ANOVA) with

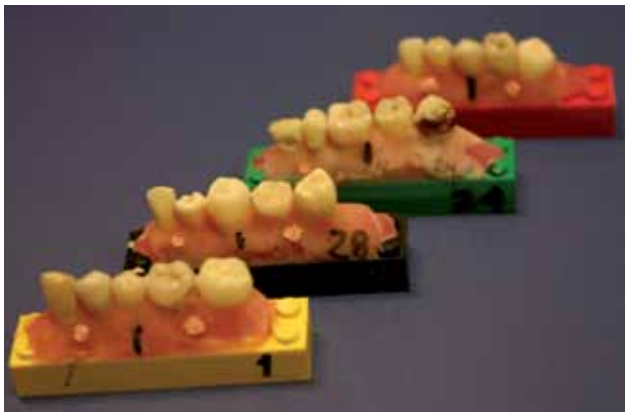

Figure 1: A view of the toothblocks in groups of five

Figure 2: Microscopic image of a cut tooth block

Greenhouse-Geisser correction for repeated measures was used to analyze the statistical interactions between the digital images, tooth position, tooth site and examiners. Further analysis was done by Kruskal-Wallis test. A p-value less than 0.05 was used as condition for statistical significance.

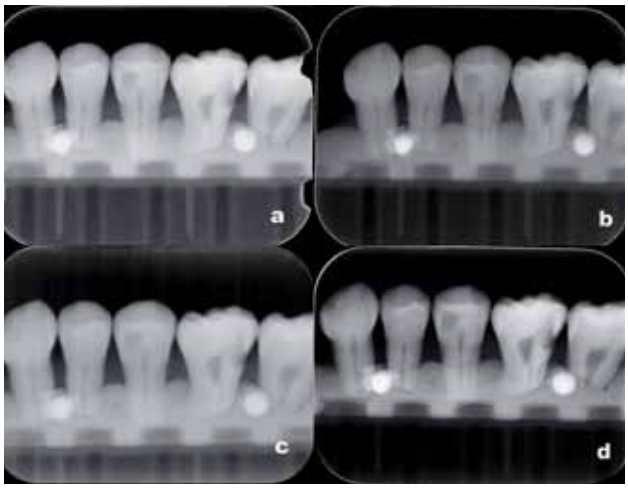

Figure 3: Corresponding images taken with different phosphor plate systems
3a: DenOptix (Gendex Dental Systems, Lake Zurich, USA),
3b: Vistascan II, (Dürr Dental, Bietigheim-Bissingen, Germany),
3c: Digora FMX (Soredex, Helsinki, Finland),
3d: Digora Optime (Soredex, Helsinki, Finland).

RESULTS

Data analysis showed a small impact of different sensors on the diagnostic accuracy. The largest differences between microscopic and radiographic caries ratings were found with Dentsply DenOptix® (1.56±1.73) and Digora FMX® (1.57±1.71, Figures 1-3). Table 1 shows the defect classification and means and standard deviations for each imaging modality. When it was calculated over all surfaces (p = 0.9585) or the following sites; separately for occlusal sites (p=0.9460), proximal sites (p=0.6564) and marginal sites (p=0.2847), no statistical significance was found (Table 2).

Table 1: Differences between the systems

Sensor	Estimation Error			
digital 223,4 µGy	Mean	SD	Mean	SD
Film 923,4 µGy	[Defect classification]		[Procent]	
Agfa Dentus Film	1,34	1,76	26,9%	35,1%
Kodak Insight Film	1,35	1,79	26,9%	35,8%
Agfa Dentus Scanned	1,40	1,77	28,0%	35,4%
Kodak Insight Scanned	1,43	1,74	28,7%	34,7%
Soredex Digora Optime	1,46	1,77	29,2%	35,3%
Vistascan II K1-Filter	1,38	1,72	27,6%	34,3%
Dentsply DenOptix	1,56	1,73	31,1%	34,6%
Trophy RVG FMX	1,57	1,71	31,3%	34,2%

Table 2: Mean and standard deviations versus tooth location and tooth site

	Marginal					Approximal					Central occlusal				
	n	mean	std	min	max	n	mean	std	min	max	n	mean	std	min	max
Dentsply DenOptics®	180	-0.47	0.67	-3.00	0.39	180	-1.19	1.45	-5.00	1.64	90	-2.27	1.39	-5.00	0.00
Dürr Vistascan II®	180	-0.40	0.64	-2.73	1.03	180	-1.03	1.40	-5.00	2.00	90	-2.12	1.29	-5.00	0.45
Soredex Digora FMX®	180	-0.47	0.67	-2.73	0.55	180	-1.21	1.45	-5.00	1.33	90	-2.29	1.40	-5.00	0.00
Soredex Digora Optime®	180	-0.40	0.66	-2.55	0.73	180	-1.10	1.46	-5.00	2.33	90	-2.24	1.40	-5.00	0.00
Agfa Dentus M2® (film)	180	-0.36	0.67	-2.73	0.85	180	-1.05	1.45	-5.00	2.61	90	-2.08	1.39	-5.00	0.36
Kodak Insight® (film)	180	-0.31	0.65	-2.30	1.36	180	-1.00	1.46	-5.00	3.33	90	-2.13	1.43	-5.00	0.27
Agfa Dentus M2® (scanned)	180	-0.37	0.63	-2.36	0.85	180	-1.03	1.44	-5.00	2.15	90	-2.17	1.38	-5.00	0.00
Kodak Insight® (scanned)	180	-0.38	0.66	-2.73	0.85	180	-1.09	1.44	-5.00	1.42	90	-2.22	1.36	-5.00	0.00

DISCUSSION

Digital radiography, both photostimulable storage phosphor and charge-coupled device or complementary metal oxide silicon sensor systems, has been often used by the dentists for intraoral examination in the last decade. Several digital radiographic systems are currently used in dental practice as an alternative to film-based radiography. During the previous years, the accuracy of different digital radiographic systems for caries detection has been compared mutually and with conventional film systems (7,8,11). Several studies have shown that direct digital systems have a number of advantages when compared with conventional film (2,3,5,7,8).

Many techniques have been used to assess the extent of dental caries from extracted teeth and both their advantages and disadvantages have been discussed (8-18). In the present study, occlusal and approximal surfaces of 90 centrally positioned teeth were evaluated. The surface was the statistical unit, therefore all surfaces were evaluated as independent samples and recorded onto the specific programme. In this study, it was found that there were differences between microscopic evaluation and radiological diagnosis of caries lesions. Yet, the differences in diagnostic accuracy showed no statistical significance.

In a few studies, the accuracy of caries diagnosis was reported to be slightly different among the investigated digital systems. Hintze and Wenzel (7,8,11,18) compared conventional films and ten different digital receptors including CCD (Charge Coupled Device) and PSP, and reported that even though most of them seemed to provide a diagnostic outcome as accurate as with film radiographs, some digital sensors had a significantly lower accuracy than the conventional film.

It has been previously stated that the diagnostic accuracy of digital sensors for caries detection are generally as accurate as the film systems for caries diagnosis (7,8,11,18). Our findings are in accordance with this statement.

Experience with digital imaging had a highly significant impact on the test outcome since experienced observers obtained both higher true positive and lower false positive percentages than the inexperienced observers. The estimation of radiological caries depth can be a difficult procedure for inexperienced observers. A number of

studies have evaluated the influence of observers' experience with diagnosis of caries lesions on digital radiographs. Jacobsen et al. (9) evaluated the observers' performances estimating the caries lesion depth with the use of Digora, DenOptix, Sidexis and Dixi systems. In that study, students underestimated the lesion depth with all aforementioned digital systems while oral radiologists only underestimated caries depth with either DenOptix or Sidexis systems. It was reported that for the experienced observers there was the similar chance for overestimating as for underestimating lesion depth.

Hintze and Wenzel have reported difference between approximal and occlusal caries in many studies based on histological evaluation (7,8,11). The result of this study was proved to be incompliant with the findings of the previous studies.

In a recent study, Pontual et al. showed that there was no significant difference in the diagnostic accuracy among Insight film and Digora and DenOptix digital systems for approximal enamel caries. They stated that the increase in depth of damage to the enamel layer by the carious lesion did not result in the increase in the number of surfaces correctly identified by the radiographic systems (11).

Studies have evaluated the influence of contrast enhancement and filtering on diagnostic accuracy for the detection of caries lesions and for the estimation of lesion depth. It has been shown that enhancement aided to the estimation of lesion depth and resulted in higher accuracy (7-9,15,16). In a questionnaire among general dental practitioners in Norway, 79% stated that digital imaging saved time, which was estimated as 36 min per day for PSP users and 25 min per day for CCD sensor users (19). It was stated that many dentists did not consider that they had enough time to manipulate each image before diagnostic assessment (19,20). Moreover, it was indicated that dentists do not have sufficient time to enhance the images, therefore high quality technology that can be helpful to produce better images should be made available in order to overcome the deficiencies of human factor during the evaluation stage. Observers tend to use one-button filtering in order to achieve image enhancement when provided and dental students are taught and use these facilities where radiography is available (19,20).

Evaluation of recently developed technology on digital sensors had left no doubt about its high quality and performance in obtaining perfect view of the objects (21). In other studies, the accuracy of caries diagnosis was reported to be slightly different among the investigated systems. It was indicated that both CCD and PSP systems produced an accurate diagnosis when compared with the film. Comparisons of digital radiographic systems like this are somehow problematic since new sensors are fast launched and the software of these sensors might even change faster than the sensors themselves.

CONCLUSION

Within the limits of this study, it can be concluded that the performance of the four PSP systems is acceptable for the detection of caries, and the increase in histological depth of enamel caries was not significantly correlated with radiographic measurements.

Acknowledgements

The authors would like to thank Dr. Willers for his great help in statistical analysis and Dr. Mai for the assistance in microscopic evaluation.

This investigation was supported by Dürr Dental Corp. Bietigheim-Bissingen, Germany. Dürr Dental Corp. provided all radiographic systems, was responsible for actuality and correct functioning of the systems. All radiographs were exposed and if necessary scanned or developed at the Dürr Dental laboratories and with the active support by Dürr employees.

This study was presented at the 11th European Congress of Dentomaxillofacial Radiology in June 25-28, 2008, Budapest, Hungary and the first author was supported by Marmara University Scientific Research Project Commission (Project No: SAG-D-050608-0127).

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