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ORIGINAL ARTICLE

Comparison of the Accuracy of Digital Radiography with Conventional Radiography and Visual Examination in the Detection of Permanent Teeth Interproximal Caries

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Abstract

Objective: To compared the accuracy of digital radiography in the diagnosis of interproximal caries in permanent teeth with conventional radiography and visual examination. **Material and Methods:** In this descriptive-analytical study, 78 human premolars, which seem normal in primary examination, are mounted on the plaster in a pair-wise manner and their caries are visually evaluated. Conventional and digital radiographic images are taken under the same conditions and their caries are graded with Confidence Score. To determine the golden standard, after mesiodistal incision, the teeth are examined using stereomicroscopy. Finally, the results obtained by visual observation and conventional radiography as well as digital images were compared with those obtained from the stereomicroscopy to determine their accuracy in detecting the interproximal caries. **Results:** The consistencies between the visual, digital, and conventional methods with the standard method (microscopic histology) are 53%, 78%, and 50% respectively - all of them are significant ($p<0.05$). The highest and the lowest sensitivities are related to the digital (96%) and visual (88%) methods respectively, while the highest and lowest specificities are related to the digital (79%) and conventional (50%) methods respectively. The highest and lowest positive predictive value is related to the digital (79%) and conventional (80%) methods respectively. The highest and lowest negative predictive values are related to the digital (90%) and visual (71%) methods respectively. Compared with the standard methodology, the most accurate diagnostic accuracy can be seen for the digital method (91%). **Conclusion:** There is no significant difference in the diagnosis of interproximal caries by different methods, and the only advantage of digital radiography, compared with the conventional one, is storing radiographs without losing important information and the lower dose of radiation for the patient.

Keywords: Dental Caries; Radiography, Dental, Digital; Radiography, Bitewing.

Introduction

Dental caries is one of the world's most common chronic diseases [1]. It is identified by observable changes in surface consistency and tooth color, sensation when applying the catheter, radiography, and passing light through the tissues. Usually, it is not enough to use a single method for precise diagnosis [1,2]. Identification of caries is a key to their prevention and treatment [3]. Without doubt, early identification of initial caries and their prevention should be made before any clear degradation occurs. The correct diagnosis of dental structures relates precisely to the quality of oral radiography. Using low-quality radiographs would distort the diagnostic information and affect the treatment plan. On the other hand, if all the information and useful diagnostic details are obscured or eliminated in low-quality radiography, it may lead to repetitive radiography and unnecessary exposure for the patient. Visual examination can detect only 22.9%-32.9% of interproximal caries and more than two- thirds of these lesions remain undetected [4].

The most commonly used method for detecting interproximal caries is radiography, with its most useful version being bitewing imaging. Since the proximal surfaces of the posterior teeth are usually wide, it is difficult to detect the loss of just a small amount of minerals in primary lesions and the progression toward an active lesion in these images [5]. The actual rate of decay penetration is often more than what is observed in the radiography, and there is no clear relation between the depth of real decay and the radiographic images [6].

Conventional radiography is commonly used in clinical cases; it displays the details with high-contrast resolution. However, film-handling artifacts and the noises created in the processing and fixing may affect the radiography image. It is also not possible to enhance the image after processing [7]. Digital radiography allows instant display of the images, image enhancement, and image storage; it includes digital rulers and densitometers [8]. However, radiography resolution in this case is less than that of conventional radiography. Moreover, digital radiography requires equipment like computers and specific receptors that may not always be available [8].

To eliminate the disadvantages of conventional radiography, such as film-processing techniques and radiation, direct digital radiography has become commercially available since 1987 [9]. In its oral version, radiation is 20%-50% less than that in the conventional method [10]. There is no agreement on whether the digital approach is superior to conventional radiography in detecting surface enamel caries. Considering that primary caries can be re-mineralized again and may return to the primary histological stages, it is very important to detect these caries in the prevention of their progress and to encourage remineralization [1].

Considering the need for an auxiliary diagnostic method for the interproximal area and the lack of consensus on whether conventional radiographic images is more preferred or digital radiography, as well as the differences in dental types and ages in previous studies regarding the lack of any previous literature on this issue in the Tabriz Faculty of Dentistry, this paper aims to compare the power and accuracy of digital images taken by the Phosphore Storage Plate (PSP) and Optim

Digora (Soredex, Tunsula, Finland) with conventional radiographic images for accurate diagnosis of interproximal dental caries of permanent teeth.

Material and Methods

Study Design and Sample

This descriptive-analytical study was carried out to investigate the human premolar teeth pulled for orthodontic purposes. It should be noted that in order to simulate soft tissue, our acrylic block with a thickness of 2cm was posited between the dental blocks and the collimator. Considering the results of the pilot study and by considering the decay rate of 41.6% in the visual comparison and 8.3% in the conventional radiography, as well as by considering alpha = 0.05 and the power of 80%, the sample size included 64 samples. To increase the validity of the study, 20% was added to this number and thus 78 samples were selected.

Visual Examination of the Teeth and Recording 0f Ekstrand Criteria (in Dental Caries Detection)

At this stage, the extracted premolar teeth were studied. The teeth were kept in distilled water at 4°C during the study period. Next, the teeth were mounted on the plaster in a pair-wise manner, and at the first stage, the teeth were visually examined in terms of appearance and color change by using a weather spray.

Visual examination was performed by considering the criteria presented previously [11]. After that, the teeth with fractures and pitting were excluded from the study. Then, a score was assigned to each tooth for a statistical analysis. These criteria included: 0: No color change; 1: Blur or discoloration hardly seen at the wet level; 2: Stain or discoloration in dry conditions; 3: Topical fracture of the enamel or grayish color of tooth dentin base and 4: Cavitation of the enamel or discoloration of the dentin.

Determination of Confidence Score in Conventional Images (in Decay Diagnosis)

At this stage, a conventional radiography of the mounted teeth in the same repeatable situations was performed by a dens-o-mat (Philips, Italy) device with a flash exposure of 0.32 seconds and E-speed films (Eastman Kodak Co., Rochester, NY, USA) with 65kW and 7.5mA, a spacing of 30cm, and a vertical tube on the film. After processing and fixing the films in an automatic Velopex (Medivance Instruments Limited, London, UK) device, the images were observed by the student and two faculty members of the maxillofacial radiology department in standard dark room conditions on the negatoscope and at a distance 50cm. To assess the inter-observer agreement, the Kappa agreement coefficient was calculated. In case the coefficient was excellent, the observed agreement was continued by one of the observers. Afterward, an interpretation was made for the caries and every tooth was categorized based on the five-point Confidence Score method: 0: Definitely no caries; 1: Probably no caries; 2: Uncertain; 3: Probably there is caries; and 4: Definitely there is caries.

Determination of Confidence Score in Digital Images (in Caries Diagnosis)

To obtain digital radiography, at first, one site in each tooth was chosen for radiography from among the most susceptible sites to caries. For digital radiography, a Phosohore Storage Plate (PSP) receiver in the holder and the Optim Digora (Soredex, Tunsula, Finland) device were used with an exposure of 0.25 seconds, 65kW and 7.5mAh and a spacing of 30cm, and a vertical tube on the film. The obtained digital radiography was stored in the Scanora 4.3.1 Software (Soredex Corporation, Helsinki, Finland) and analyzed in a dark room on a 19" Samsung monitor calibrated for a good contrast by two maxillofacial professors. The Kappa agreement coefficient was calculated to observe the agreement between the observers. In case the coefficient was excellent, the observed agreement was continued by one of the observers. Then, for every tooth, the caries detections were categorized by the five-point Confidence Score: 0: Definitely no caries; 1: Probably no caries; 2: Uncertain; 3: Probably there is caries; and 4: Definitely there is caries.

Grading Histologic Analysis with Stereomicroscope for Detection of Caries

At the gold standard, the teeth were placed in an acrylic resin and mesiodistal incisions were made by a cutting machine and a diamond disk (D&Z Diamant GmbH, Berlin, Germany) at a low speed. To determine the precise extent of the decay, the incision surfaces were verified by a maxillofacial pathologist using stereomicroscope (Nikon, SMZ1000, Tokyo, Japan) with a magnification of 10*. A three-point scale was used for the histological analysis of decay: 0: Healthy; and 1: Decay in the enamel or dentin.

Comparing the Accuracy of Radiographic and Stereomicroscopic Results

The results of conventional and digital radiography were compared with the results obtained by the stereomicroscopy of the incised teeth; the findings of the above-mentioned methods were recorded in the checklist. Finally, the accuracy of both types of radiography in detecting interproximal caries was obtained in this study.

Statistical Analysis

Data was analyzed by descriptive statistics and Chi-square test. Moreover, the values of sensitivity and specificity as well as positive and negative predictive values were calculated by considering alpha = 0.05 and the power of 80%.

Results

The results of visual examination are presented in Table 1. The results of decay diagnosis by using conventional and digital radiography images are presented in Table 2 and Table 3 respectively.

According to the classification of histological analysis by the stereomicroscope, the teeth were classified into normal and decayed. As many as 54 of the teeth definitely had decayed, while 24

of them had no caries at all. The results of conventional and digital radiographies were compared with the results obtained by incised teeth stereoscopy. The findings were logged into the checklists. Finally, the accuracy of both types of radiography in detecting interproximal caries was obtained in this study.

Table 1. Results of visual examination.

Visual Examination	No Color Change	Color Change Under Wet Conditions	Color Change Under Dry Conditions	Topical Fracture and Enamel Color Change	Enamel Cavitations and Dentin Color Change	Total
Quantity	57	10	11	0	0	78

Table 2. Results of conventional radiography.

Conventional Radiography	Definitely No Caries	Probably No Caries	Uncertain	Probably There is Caries	Definitely There is Caries	Total
Quantity	53	9	1	1	14	78

Table 3. Results of digital radiography.

Conventional Radiography	Definitely No Caries	Probably No Caries	Uncertain	Probably There is Caries	Definitely There is Caries	Total
Quantity	55	0	3	3	17	78

The agreement between the accuracy of conventional and digital radiographies as well as between these and the stereomicroscopy is presented in Table 4.

Table 4. Agreement of methods compared to the gold standard.

Diagnostic Method		Microscopy			
		Without Color Change		Color Change in Dentin	
		N	%	N	%
Visual Method	Without Color Change	48	61.5	9	11.5
	Color Change in Dentin	6	7.7	15	19.2
Conventional Radiography	Without Color Change	51	65.4	12	15.4
	Color Change in Dentin	3	33.8	12	5.4
Digital Radiography	Without Color Change	52	66.7	5	6.4
	Color Change in Dentin	2	2.6	19	24.4

According to the results presented in Table 4, the use of visual, conventional, and digital methods (61.5%, 65.4%, and 66.7%) of the samples, respectively, remained unchanged in terms of colors compared to the microscopy method. To determine the diagnostic value of a test, it should be compared with a gold standard method. The gold standard divides the population into two groups: with and without color change. Table 5 shows the comparison between the gold standard and the intended methods.

The agreement rate between the visual, digital, and conventional methods, compared with the gold standard method (microscopic histology), was measured using the Kappa agreement coefficient. This coefficient was 53% for the visual method, 78% for the digital method, and 50% for

the conventional method ($p<0.001$). Moreover, the sensitivity, specificity, positive, and negative predictive values are presented in Table 6. The sensitivity shows that the percentage of color change is positive based on the results of the other three methods. In fact, the sensitivity is the proportion of the samples that actually have had a color change and have been correctly detected positive in the test. It is observed that the highest sensitivity is related to the digital method with 96 - i.e. from among 100 samples which actually had a color change based on the gold standard, 96 cases have been correctly detected by the digital method. Furthermore, the lowest sensitivity is related to the visual method with a value of 88%.

Table 5. Conflict between test results and gold standard.

		Golden Standard	
		Color Change	Without Color Change
Test	Positive	TP	FP
	Negative	FN	TN

TP = Sample with positive test (color change) and real color change; FP = Sample with positive test (color change) and really without color change; FN = Sample with negative test (without color change) and real color change; TN = Sample with negative test (without color change) and really without color change.

Table 6. Sensitivity, specificity, accuracy, positive predictive value and negative predictive value.

Methods \ Indices	Sensitivity	Specificity	Accuracy	Positive Predictive Value	Negative Predictive Value
Visual Method	88%	62%	80%	84%	71%
Digital Radiography	96%	79%	91%	91%	90%
Conventional Radiography	94%	50%	80%	80%	80%

The specificity of this test is the proportion of samples without color change that has been correctly detected negative by three methods. According to the results, the highest specificity is related to the digital method with a value of 79%. This means that from among 100 samples, which are without color change based on the gold standard, 79 are tested negative by this method. Moreover, the lowest specificity is related to the conventional method with 50%.

The sensitivity and specificity do not have the ability to predict and respond to the probability of the existence or nonexistence of the color change, in case the test result is positive or negative. Therefore, the positive and negative predictive were calculated.

The positive predictive value reveals the probability of color change in case the diagnostic test is positive. The highest positive predictive value (91%) was related to the digital method; it means that if the test is positive, this method has 91% probability of color change. Also, the lowest positive predictive value (80%) was related to the conventional method.

The negative predictive value shows the probability of no color change in the tooth if the diagnostic test result is negative - i.e. how many percent of the samples with negative test results are actually without color change. In other words, it shows the likelihood of having no color change if test was negative. The results show that the highest negative predictive value (90%) was related to the digital method; it means that if the test to check the color change by digital method is negative, it

is 90% likely that no color change has occurred. Furthermore, the lowest negative predictive value (71%) was related to the visual method.

The accuracy of a test is, in fact, the ratio of the correct responses of each diagnostic test. It reveals for how many percent of the cases the test is correct compared to the gold standard. The highest diagnostic accuracy (91%) among these three methods, compared to the microscopic histology was related to the digital mode.

Discussion

Over the past two decades, studies have been performed on the accuracy, efficiency, and repeatability of conventional methods of decay diagnosis; these methods were compared with new methods. The present study was also conducted in this light.

The results here showed that digital radiography images have a higher diagnostic value for interproximal caries than conventional radiographic images, but the difference between these two diagnostic methods was not significant. Therefore, our results are consistent with previous findings, in which posterior teeth were examined by digital radiography and bitewing; there was no significant difference between the two radiographic methods [12]. Some authors also performed the same comparison on the proximal surfaces of 56 premolar teeth and compared two digital systems (Denoptix and Digora) and four radiographic films. There was no significant difference between the Digora method and the radiographic film, but the Denoptix system was less accurate [9].

In addition, one study conducted research on the proximal surfaces of 208 molar and premolar teeth by conventional radiography and digital radiography. Similar to the present study, the results showed that there was no significant difference between them in decay diagnosis, but these two methods are not powerful in the caries diagnosis of the enamel [13]. In our study, the results showed that the diagnostic power of these two methods was approximately equal and less comparable with the results of stereomicroscopy, which showed that 54 teeth definitely had caries and 24 had not caries whatsoever.

Similar to the present study, another researcher have investigated the accuracy of digital radiographic images and conventional radiographic films for the diagnosis of proximal caries. They have found that these methods are not significantly different and digital images can be used to store the radiographs without loss of important information [14]. Another study was showed no significant difference was found between different resolutions and the radiographic film [15]. In another study, the authors have shown that radiographic film quality is significantly more effective than digital radiographic imaging [16]. A similar study compared different digital cameras with different resolutions and found no significant difference between different digital images with different resolutions [17].

Previous study investigated investigated the proximal areas of milk teeth by using conventional and digital radiography; their results show that the accuracy of digital radiography is lower [18]. In 2010, while conducting an in vivo study, some authors tried to evaluate the diagnosis

of dentin caries by visual methods, bitewing radiography, and fluorescence laser application. As many as 144 first molar and second molar teeth were examined in 41 patients with a seemingly healthy (macroscopic) and caries-free occlusal groove. The sensitivity and specificity were 89% and 44% in the visual method, 13% and 100% in the radiographic method, and 7% and 84% in the diagnodent method. Also, the decay diagnosis by the combination of the visual and diognodent had a sensitivity of 67% and specificity of 94%. Data analysis showed that the combination of visual and diagnodent examinations is of higher value [19]. This study suggests combining different diagnostic methods with visual observations. Similar studies should be conducted with bigger statistical populations. Besides, similar studies using other diagnostic methods, such as the use of diagnodent, conventional, and digital radiographic images, should be performed.

It is suggested that similar studies are performed using molar teeth and then compared with the results of the study on premolar teeth to determine the diagnostic power of different methods for different teeth. These studies may also be performed in vivo.

Conclusion

There is no significant difference between various methods in the detection of interproximal caries through conventional radiography and digital radiography. And the only advantage of the digital method is that digital images may be used for storing radiographs without losing important information.

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Conflict of Interest: The authors declare no conflicts of interest.

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