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Does 3D Emboss Image Processing Filter Improves Detecting Proximal Recurrent Caries in Digital Bitewing Radiograph?

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ABSTRACT

Background: Most digital imaging systems provide a variety of image processing techniques. The aim of the present study was to compare the performance of bite wing digital radiography with and without the application of 3D emboss image processing filters in identifying recurrent proximal caries.

Materials and methods: In the current study, cavities were created in both proximal surfaces of 52 healthy premolar teeth for Class II amalgam restoration. Caries lesions were artificially created by a 0.5 mm trend burr randomly in each tooth and repaired with amalgam. Standard digital radiographs were performed using the Digora® Optime system. Unfiltered and filtered images with 3D emboss filter were observed by 2 radiologists with at least 2 years of work experience and the final results were analyzed with Chi-square statistics.

Results: The obtained results demonstrated that the sensitivity and specificity of caries detection changes with the change in the observer, although no significant difference was observed between the sensitivity and specificity of the third and fourth observers. In addition, the results of this research showed that the sensitivity, accuracy and specificity of detecting recurrent secondary caries in radiographs without using the 3D emboss filter for all observers participating in this project was more significant than the sensitivity, accuracy and specificity of radiographs with 3D emboss filter.

Conclusion: The obtained data documents that use of the 3D emboss filter failed to improve the diagnosis of recurrent secondary caries through reduces the sensitivity, accuracy and specificity of diagnosis.

Keywords: Digital Radiography, 3D Emboss Filter, Secondary Caries, Bite Wing.

INTRODUCTION

Diagnosis of secondary caries is one of the problems faced by dentists. Secondary caries is the re-initiation or return of caries at the edges of the restoration, which occurs immediately adjacent to the restoration and following microleakage or insufficient expansion of the restoration or insufficient removal of primary caries (1). About 75% of dental works include the replacement of restoration for various reasons, among which dentists state the main cause of this replacement in most cases is secondary caries (2). Today, secondary caries detection methods include clinical examination

in a dry and clean environment with sufficient light and visual observation, tactile sensation with a dental probe, dental floss, and radiography (3). Radiographs are suitable and excellent methods for diagnosing caries that are not clinically obvious (4).

In recent years, the digital imaging system has been chosen as an alternative to radiography with film, and according to studies, the diagnostic accuracy of digital systems is comparable to conventional films (5). One of the most important advantages of the digital system of light-sensitive phosphor plates (PSP) is the possibility of enhancing images using the enhancement methods available in its software, which are claimed to improve image visibility and detection accuracy. Also, PSP digital systems have a wide dynamic range, which makes it flexible in correcting images (overexposure) and underexposure (underexposure) without the need to repeat (6). Different processing methods have been invented to improve image quality. Noise Reduction, Sharpening-smoothing, Edge Enhancement and 3D emboss are examples of these algorithms. 3D emboss filter is a new radiographic technique with various applications. In other words, in the 3D emboss process, a 3D image is created from a 2D image. When the 3D emboss filter is applied, it often creates an image similar to the original image, but like an embossed image on a piece of paper or metal. The image with sharp graphic edges is desirable (7). Maximum contrast can be obtained using this method without reducing the spatial resolution, so the main advantage of this method may be the improvement of edge quality (8). Accordingly, the aim of the current study was to investigate the efficacy of 3D emboss image processing filter in detecting proximal recurrent caries in digital bitewing radiograph.

MATERIAL AND METHODS

Samples collection and preparation

In the current research, 52 adult human premolar teeth were selected from the extracted teeth in random dental offices in Ahvaz, Iran. The teeth were clinically and visually healthy without decay or previous restoration. The teeth were randomly divided into 13 groups of 4 to be reconstructed in the respective blocks. In the proximal part of the teeth, a standard box was created for Class II amalgam restoration. Caries lesions were artificially created by a 0.5 mm process bur in half of the proximal boxes at the junction between the buccal and lingual walls and the gingival floor or at the interface between the buccal and lingual walls and filled with red wax and half. Each of the other teeth samples were considered as controls. Also, boxes were prepared randomly in some samples in the mesial and in some samples in the distal and were repaired with amalgam. Then the teeth were randomly mounted in acrylic in groups of 4 and under the same conditions as the clinic. The thickness of acrylic in all samples was constant and equal to 2 cm. In order to make the samples parallel, the bottom of the acrylic blocks was smoothed with a trimmer. Also, for better diagnosis, a hole was made in the mesial part of all the blocks by a burr and filled with gutta-percha.

3D embosses image procedure

Indirect digital radiographs were prepared by PSP plates in the DIGORA™ Optime system, Sordex, Finland. Digital radiographs were processed with 3D EMBOSS filter, then recurrent caries was observed in conventional and digital radiographs with 3D emboss filter by 2 radiologists with at least 2 years of work experience and 2 final year students. The obtained findings from two type of radiography were calculated with the gold standard. Irradiation to the plates was done with the Xgenus dc device (de Gotzen, Italy) and the exposure conditions kvp70, 8 mA, irradiation time 0.32 seconds, with a total aluminum filtration thickness of 2 mm and a focal spot-receptor distance of 32 cm. The type and degree of 3D EMBOSS filter was selected by Scanora software. All observers used the same monitor in a room without windows, low light and the same conditions to view the images. In order to avoid eye fatigue, observers banned to see more than 20 images in each round of evaluation. The radiographs were coded and it was determined which tooth numbers would be included in each radiograph.

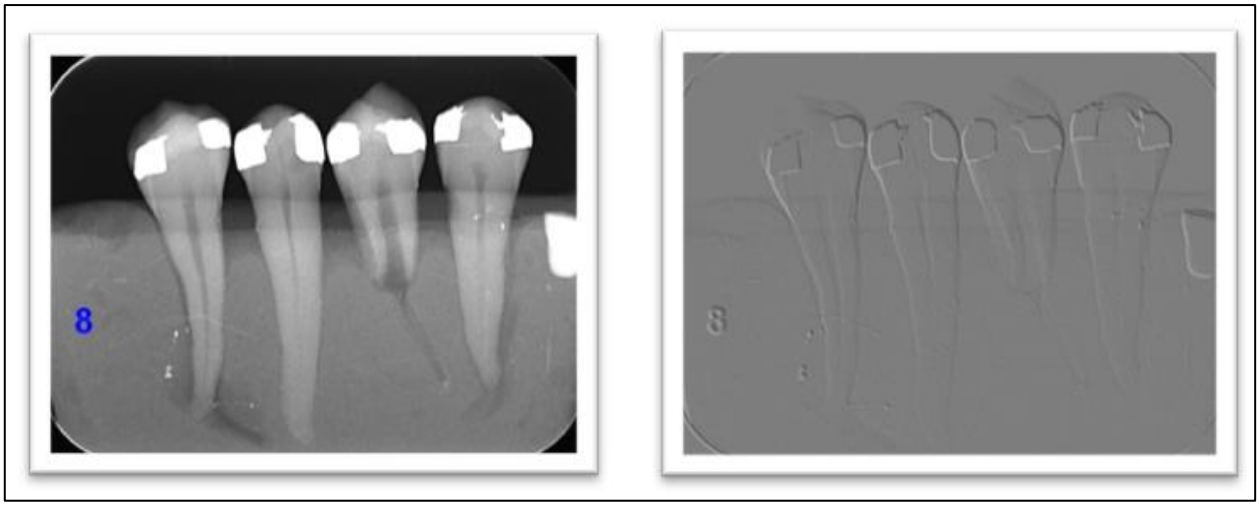

Figure 1. Conventional digital radiography and digital with 3D emboss filter.

Statistical analysis

Paired T-test and chi-square test (Ch2) were used via SPSS version 20 software. LSD test was used as post hoc test and the values with $p \leq 0.05$ considered as significant difference.

RESULTS

Results of processing filters in identifying recurrent proximal caries according to observers

According to Table 1, the first observer (radiologist) in image processing without using 3D emboss filter of 52 teeth with recurrent caries has identified 50 cases as correct (true positive) and 2 cases as incorrect (false negative) and out of 52 teeth Salem has recognized 49 cases as correct (true negative) and 3 cases as incorrect (false positive), while in image processing using the 3D emboss filter of 52 teeth with recurrent caries, 37 cases were correct (true positive) and 15 He has diagnosed the case as wrong (false negative) and out of 52 healthy teeth, he has diagnosed 40 cases as correct (true negative) and 12 cases as wrong (false positive). The sensitivity, specificity and accuracy of the first observer in image processing without using the 3D emboss filter were 0.96, 0.94 and 0.95 respectively and in image processing using the 3D emboss filter were 0.71, 0.77 and 0.77 respectively. It was 0.74. Kappa agreement coefficient of the first observer for radiographic images without using 3D emboss filter and using 3D emboss filter was obtained 0.904 and 0.481, respectively, both of which are significant at $p<0.001$ level. The second observer (radiologist) has identified 49 cases as correct (true positive) and 3 cases as false (false negative) out of 52 teeth with recurrent caries in image processing without using 3D emboss filter, and 48 cases out of 52 healthy teeth are correct (negative). real) and detected 4 cases as false (false positive), while in image processing using the 3D emboss filter of 52 teeth with recurrent caries, 35 cases were detected as correct (true positive) and 17 cases were detected as false (false negative). and out of 52 healthy teeth, 35 were correct (true negative) and 17 were wrong (false positive). The sensitivity, specificity and accuracy of the second observer in image processing without using the 3D emboss filter was 0.94, 0.92 and 0.93, respectively, and the sensitivity, specificity and accuracy of the second observer in image processing using the 3D emboss filter was 67. was 0 The Kappa agreement coefficient of the second observer for radiographic images without using the 3D emboss filter and using the 3D emboss filter was 0.865 and 0.346, respectively, both of which are significant at the $p<0.001$ level. The third observer (student) in image processing without using the 3D emboss filter, of 52 teeth with recurrent caries, identified 39 cases as true (true positive) and 13 cases as false (false negative), and out of 52 healthy teeth, 42 cases were correct (negative). real) and 10 cases were detected as false (false positive), while in image

processing using 3D emboss filter of 52 teeth with caries, 27 cases were detected as correct (true positive) and 25 cases were detected as false (false negative). and out of 52 healthy teeth, 30 were correct (true negative) and 22 were wrong (false positive). The sensitivity, specificity and accuracy of the third observer in image processing without using 3D emboss filter were 0.75, 0.81 and 0.78 respectively and in image processing using 3D emboss filter respectively 0.52, 0.58 and it was 0.55. The Kappa agreement coefficient of the third observer for radiographic images without using the 3D emboss filter was 0.558, which was significant at the $p<0.001$ level, but the Kappa agreement coefficient of the third observer for radiographic images using the 3D emboss filter was 0.096. It was not significant at the $p<0.05$ level ($p=0.326$). The fourth observer (student) in image processing without using the 3D emboss filter, of 52 teeth with recurrent caries, identified 35 cases as true (true positive) and 17 cases as false (false negative), and out of 52 healthy teeth, 36 cases were correct (negative). real) and 16 cases were detected as false (false positive), while in image processing using 3D emboss filter of 52 teeth with caries, 26 cases were detected as correct (true positive) and 26 cases were detected as false (false negative). and out of 52 healthy teeth, 25 were correct (true negative) and 27 were wrong (false positive). The sensitivity, specificity and accuracy of the fourth observer in image processing without using 3D emboss filter are 0.67, 0.69 and 0.68 respectively and in image processing using 3D emboss filter respectively 0.50, 0.48 and it was 0.49. The Kappa agreement coefficient of the fourth observer for radiographic images without using the 3D emboss filter was 0.365, which was significant at the $p<0.001$ level, but the Kappa agreement coefficient of the fourth observer for radiographic images using the 3D emboss filter was -0.019. It was found that it was not significant at the $p<0.05$ level ($p=0.844$) (Table 1).

Table 1. The sensitivity of digital bite wing radiography w

Accuracy	Specificity	Sensitivity	Total	Tooth		Diagnosis	Radiology	Observer
				No decay	With decay			
0.95	0.94	0.96	53	3	50	decay	No Filter	**First (Radiologist)**
			51	49	2	No decay		
			104	52	52	Total		
0.74	0.77	0.71	49	12	37	Decay	3D embosses	
			55	40	15	No decay		
			104	52	52	Total		
0.93	0.92	0.94	53	4	49	decay	No Filter	**Second (Radiologist)**
			51	48	3	No decay		
			104	52	52	Total		
0.67	0.67	0.67	52	17	35	decay	3D embosses	
			52	35	17	No decay		
			104	52	52	Total		
0.78	0.81	0.75	49	10	39	decay	No Filter	**Third (Student)**
			55	42	13	No decay		
			104	52	52	Total		
0.55	0.58	0.52	49	22	27	decay	3D embosses	
			55	30	25	No decay		
			104	52	52	Total		
0.68	0.69	0.67	51	16	35	decay	No Filter	**Fourth (Student)**
			53	36	17	No decay		
			104	52	52	Total		
0.49	0.48	0.50	53	27	26	decay	3D embosses	
			51	25	26	No decay		
			104	52	52	Total		

Comparing the sensitivity with and without using the 3D emboss filter

As shown in Table 2, according to the results of the chi-square test (Ch2) in radiography without using the 3D emboss filter, there was no significant difference between the sensitivity of the first observer (radiologist) and the second observer (radiologist). The sensitivity of the first observer was significantly higher than the sensitivity of the third observer (student) and the fourth observation (student) ($p<0.01$). The sensitivity of the second observer was significantly higher than the sensitivity of the third observer and the fourth observation ($p<0.01$). There was no significant difference between the sensitivity of the third and fourth observers ($p=0.378$). In radiography without using the 3D emboss filter, no significant difference was obtained between the first observer and the second observer ($p=0.696$). The characteristic rate of the first observer was significantly higher than the characteristic rate of the third observer and the fourth observation ($p<0.05$). The specificity of the second observer was significantly higher than the sensitivity of the fourth observer ($p=0.003$). No significant difference was observed between the second and third observer and the third and fourth observer ($p>0.05$). In radiography using 3D emboss filter, there was no significant difference between the sensitivity of the first observer and the second observer ($p=0.671$). The sensitivity of the first observer was significantly higher than the sensitivity of the third observer and the fourth observation ($p<0.05$). There was no significant difference between the sensitivity of the second observer, the third observer, and the fourth observation, as well as between the sensitivity of the third and fourth observers ($p>0.05$). In radiography using the 3D emboss filter, no significant difference was obtained between the first observer and the second observer ($p=0.274$). The characteristic rate of the first observer was significantly higher than the characteristic rate of the third observer and the fourth observation ($p<0.05$). The specificity of the second observer was significantly higher than the sensitivity of the fourth observer ($p=0.047$). There was no significant difference ($p>0.05$) between the characteristics of the second and third observers, as well as between the third and fourth observers (Table 2).

Table 2. Comparing the sensitivity in images with and without using the 3D emboss filter.

p value	Specificity		*p* value	Sensitivity		Radiology
	Observer			Observer		
0.696	Second 0.92	First 0.94	0.647	Second 0.94	First 0.96	**No filter**
*0.038	Third 0.81	First 0.94	**0.002	Third 0.75	First 0.96	
**0.001	Fourth 0.69	First 0.94	***0.001 <	Fourth 0.67	First 0.96	
0.085	Third 0.81	Second 0.92	**0.007	Third 0.75	Second 0.94	
**0.003 0.174	Fourth 0.69 Fourth 0.69	Second 0.92 Third 0.81	***0.001 0.387	Fourth 0.67 Fourth 0.67	Second 0.94 Third 0.75	
0.274	Second 0.67	First 0.77	0.671	Second 0.67	First 0.71	**3D embosses**
*0.037	Third 0.58	First 0.77	*0.044	Third 0.52	Firs 0.71	
**0.002	Fourth 0.48	First 0.77	*0.027	Fourth 0.50	First 0.71	
0.311	Third 0.58	Second 0.67	0.110	Third 0.52	Second 0.67	
*0.047 0.326	Fourth 0.48 Fourth 0.48	Second 0.67 Third 0.58	0.073 0.844	Fourth 0.50 Fourth 0.50	Second 0.67 Third 0.52	

***$p<0.001$, **$p<0.01$, *$p<0.05$

Comparing the sensitivity and specificity of digital bite wing radiography with and without the use of 3D emboss filter in identifying recurrent caries

As shows in Figure 2a, according to the results of the chi-square test (Ch2) in the first observer (radiologist), the second observer (radiologist) and the third observer (student), the sensitivity of radiography without using the 3D emboss filter is significantly It was more than radiography using 3D emboss filter ($p<0.05$). In the fourth observer (student), the sensitivity of radiography without using 3D emboss filter was more than radiography using 3D emboss filter, but this difference is statistically significant (P=0.073). The specificity of radiography without using 3D emboss filter in all four observers was significantly higher than radiography with 3D emboss filter ($p<0.05$). Based on the results presented in Figure 2b, the specificity of detecting secondary caries in images without 3D emboss filter in all four observers was higher than in radiography using filter, although this difference was not significant in the fourth observer.

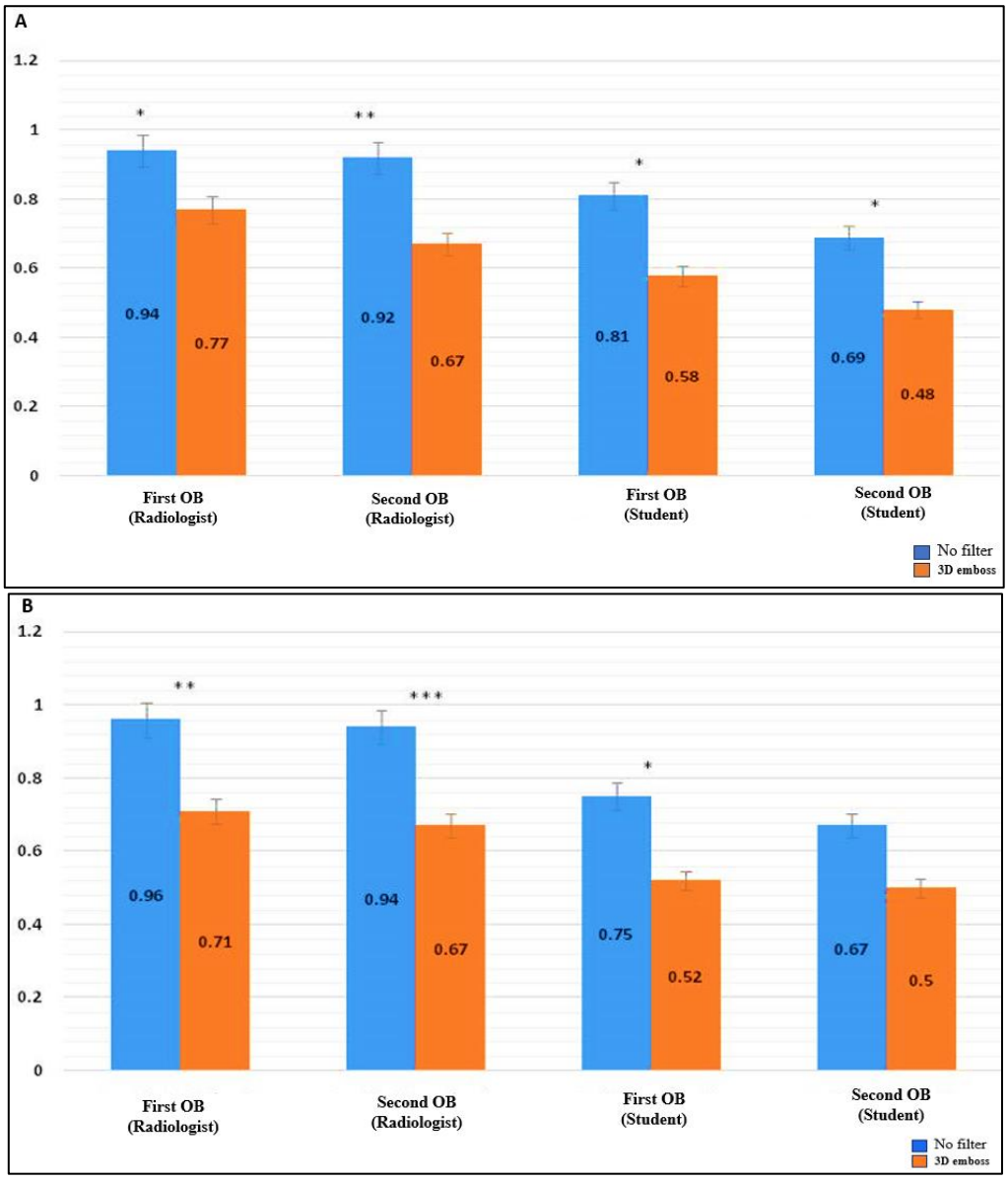

Figure 2. Comparison of digital bitewing radiography A: Sensitivity and B: Specificity with and without using 3D emboss filter.

DISCUSSION

Diagnosis of secondary caries is one of the problems faced by dentists. Imaging in dentistry is done with the aim of revealing and examining the internal structures of teeth in order to diagnose and treat oral and dental abnormalities (9). With the help of dental X-ray images, the patient's problem is identified and fixed more accurately and quickly; But examining dental images by a dentist is tiring and time-consuming (10). Also, there is always the possibility of error and misdiagnosis by the dentist due to factors such as low-quality images and vision error (11). Therefore, accurate identification of damaged tooth points using dental image processing is very important in speeding up the treatment process. In recent years, the digital imaging system has been chosen as an alternative to radiography with film, and according to studies, the diagnostic accuracy of digital systems is comparable to conventional films (12). Digital imaging eliminates the emergence and proof of chemicals and hazardous waste materials (13). On the other hand, intraoral digital image receivers require less radiation than radiographic film, so they reduce the absorbed dose of the patient which shows acceptable performance of digital radiography systems in the diagnosis of recurrent secondary caries. Many researches have proven the acceptable quality of digital radiographs in the diagnosis of dental caries. in a study by Peymani et al investigated the power of digital subtraction radiography in diagnosing secondary caries. The results showed that the use of digital subtraction radiography is useful in diagnosing secondary caries, especially in the distal surface of the tooth (14). there are contradictions regarding the strength and accuracy of caries detection by radiographs, one of the reasons for which is the presence of radiolucent flooring materials that have a radiographic appearance similar to secondary caries (15-16). Another study by Talaeipour et al compared the power of conventional and digitally scanned radiographic images in the diagnosis of proximal caries. The results showed that there is no significant difference between the use of conventional and digitally scanned radiography in the diagnosis of proximal caries (17).

The results obtained in this research showed that the sensitivity and specificity of caries detection changes with the change in the observer. This significant difference in the sensitivity of caries detection was observed in different observers both in the condition of radiography without filter and with filter. Many researches have pointed out the significant effect of using different observers in the sensitivity of tooth decay detection (18-19). Tafakhori et al in a study investigated the diagnostic sensitivity of filtered panoramic digital radiography in the diagnosis of proximal caries and compared it with bite wing radiography. The results showed a significant difference in the use of radiographic methods. They also showed that the sensitivity of caries detection changes with the change in the observation personnel (20). Although in some reports, the effects of using different observers on the correctness of caries diagnosis have not been significant (21).

Also, based on the kappa coefficients and the obtained values of sensitivity, accuracy and specificity for radiologists and students, it can be concluded that final year students have less ability than radiologists in detecting secondary caries and this difference in both radiographs with and without filter Filter found. Tavakoli et al investigated the ability of final semester dental students to diagnose interdental caries based on conventional bite wing radiography. The results showed that most of the teeth that need restoration or care measures are not recognized by the final semester dental students. At the same time, most healthy teeth are not misdiagnosed from the radiographic point of view, and this issue had little effect on gender (22). The possible reason for the weakness of final year dental students in diagnosing this type of caries should be the low quality of students' education, the large number of students in the department, the failure to observe the correct ratio of students to professors, the lack of sufficient talent in students to study in this field, training to He knew the compact and periodical form as well as his little experience.

In addition, the results of the current research showed that the sensitivity, accuracy and specificity of detecting recurrent secondary caries in radiographs without the use of 3D

emboss filter for all observers participating in this project is higher than the sensitivity and specificity of radiographs with 3D emboss filter. was, although the detection sensitivity was not significant in the fourth observer. In addition, the Kappa coefficients of agreement for all observers in detecting recurrent secondary caries in radiographs without using the 3D emboss filter were significantly higher than in radiographs using the filter. This means that the use of 3D emboss filter cannot improve the sensitivity and specificity of secondary caries diagnosis, but it reduces the sensitivity, accuracy and specificity of diagnosis. The result obtained in this research was in line with the results of researchers performed by Silveira et al which reported that the lower accuracy of digital radiography with 3D emboss filter can be due to the change in appearance and improvement of the image (23). A study by de Azevedo Vaz et al investigated the diagnosis of CBCT external analysis of the effect of root images. The software used in the above study was smooth and sharpening. The study was conducted on 20 premolar teeth and the result of the study indicated that the above software has little effect in diagnosing lesions compared to normal images, which is similar to the result obtained in the present study (24). According to the reports, it can be concluded that the use of different filters does not improve the accuracy of tooth decay detection. Although according to the claim of the digital systems manufacturing factories, this device and various software are aimed at improving and helping to diagnose lesions, but there is not enough clinical evidence about their diagnostic efficiency.

The positive effect of filters on the sensitivity of tooth decay detection was also observed in the research by Dabaghi et al which compared the performance of digital radiography with and without the use of image processing filters (low sharpen, intermediate sharpen, high sharpen and inversion filter) in identifying recurrent proximal caries. The results indicated that images with low sharpen filter and images with high sharpen filter respectively have the highest and lowest sensitivity, specificity and overall accuracy among the images (25).

In summary, the results obtained in this research showed that the sensitivity and specificity of caries detection changes with the change in the observer. This significant difference in the sensitivity and specificity of caries detection was observed in different observers both in radiography conditions without filter and with filter. Also, the results of this research showed that final year students have less ability than radiologists in diagnosing secondary caries. In addition, the results of this research showed that the sensitivity and accuracy of detecting recurrent secondary caries in radiographs without using 3D emboss filter for all observers participating in this project is significantly higher than the sensitivity of radiographs with 3D emboss filter. although the detection sensitivity in the fourth observer was not significant in radiographs without filter and with filter. This means that the use of the 3D emboss filter cannot improve the accuracy of the diagnosis of recurrent secondary caries, but reduces the sensitivity of the diagnosis.

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Ethical Approval

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Data Availability

The data that support the findings of this study are available on request from the corresponding author.

CONFLICT OF INTEREST

There is no any conflict of interest.

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