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A Comparative Study of the Diagnostic Accuracy of Cone Beam Computed Tomography and Phosphor Storage Plate for Detection of Noncavitated Occlusal Caries

Analiza porównawcza wartości diagnostycznej tomografii stożkowej i radiografii cyfrowej w wykrywaniu próchnicy początkowej na powierzchniach żujących

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of article

Abstract

Background. Recent Studies have shown that a significant portion of occlusal caries could not be diagnosed in the early stages because of various reasons. Early detection of superficial caries is important for preventive dentistry.

Objectives. This study aims to compare the quality of occlusal caries detection using digital phosphor storage plate (PSP) and cone beam computed tomography (CBCT).

Material and Methods. For this experimental study 88 human molars were used. The clinical appearances of the occlusal surfaces of the teeth ranged from sound to discolor with no macroscopic cavitation. They were imaged using a digital system (PSP) and CBCT (NewTom 3G). Three independent observers assessed the images twice. ROC curve was used for assessment of the imaging systems accuracy for the detection of caries. A histological investigation was used as a gold standard. Methods were analyzed by ANOVA and t-test with p value of 0.05. Tests were performed with STATA software (version 11). Intra and inter observers agreement for each image set was assessed by ICC.

Results. The average of observers results in caries detection with PSP images was 0.34 (P value = 0.208) and with CBCT images was equal to 0.45 (P value = 0.722). This showed that the diagnostic accuracy of CBCT and PSP was not acceptable compared with the gold standard. Although CBCT was a little higher than PSP on ROC curve, statistically there were no significant differences between both images in detecting occlusal caries. The ICC results showed acceptable agreement between observers in caries detection by CBCT and PSP, but the agreement between observers using these image modalities and the gold standard was poor.

Conclusions. The accuracy of NewTom 3G CBCT for detecting occlusal caries was slightly better than PSP (not significantly), but none of them had the sufficient diagnostic accuracy for detecting incipient occlusal caries. Therefore, in these cases it is necessary to use other methods to improve detection (*Dent. Med. Probl.* 2016, 53, 2, 186–192).

Key words: occlusal caries, CBCT, PSP.

Słowa kluczowe: próchnica powierzchni żujących, tomografia stożkowa, radiografia cyfrowa.

More than 75% of dental caries in children and adolescents occurs in occlusal surfaces [1]. Studies over the past two decades have shown that a significant portion of occlusal caries could not

be diagnosed in the early stages because of various reasons including dentists' carelessness and inappropriate instruments [2]. Researchers believe that the diagnosis of occlusal caries was more difficult

than other forms of decay and, therefore, requires much more skill and precision on the part of the dentists as well as the application of new tools and methods [3, 4]. Early detection of superficial caries is important for preventive dentistry, but there is no accurate definition and criteria for evaluating the depth and extension of occlusal caries. This leads to incorrect diagnosis and consequently causes excessive or insufficient treatments.

Dental caries can be detected by different methods such as: probing, visual examination, transillumination, intra oral images [5, 6]. Recently, laser fluorescent, measurement of electrical current and ultrasound has been recommended. However, none of these methods give us exact information about caries lesions [7, 8]. Intra oral radiography is most commonly used in dental practice [9, 10]. Both conventional and digital intra oral radiographies provide us two-dimensional information about a tooth and the neighboring mineralized structures, and are usually valuable for the detection of proximal caries. Thus, for the detection of occlusal caries, especially in the early stages, the value of conventional and digital intraoral radiography is controversial [11].

In recent years, CBCT has become more useful in dentomaxillofacial imaging. CBCT generates three dimensional multiplanar data, and has been used in several fields, such as surgery and traumatology, implantology, orthodontics, endodontics, periodontology and TMJ disease [12].

Recent studies about proximal caries detection [13–22] and occlusal caries detection by CBCT [16, 21–25] are controversial. Most of the articles concluded that CBCT is not better than intraoral films in caries detection. Based on inadequate number of published researches about occlusal caries detection, we performed this study to evaluate the accuracy of CBCT and PSP images and compared it with histology for detection of noncavitated occlusal caries.

Material and Methods

For this experimental study, 88 human molars were used. The extracted teeth were molars with severe periodontal problems or third molars with severe pericoronitis. Teeth with loss of tissue or with fillings were excluded. The clinical appearances of the occlusal surfaces of the teeth ranged from sound to discolored with no macroscopic cavitations. They were cleaned with cotton gauze and disinfected in sodium hypochlorite 2% for 20 minutes and mounted inside the Ross wax. For reconstruction of soft tissues, teeth were put in water. All the teeth were imaged using two systems:

1. Digital radiographs were obtained using digital sensor size 2 (Minary, Sordex, Tussula, Finland) and periapical radiographic device (Soredex company, Helsinki, Finland). Exposure condition was standard ($T = 0/06$ s, $KVP = 60$, $mA = 7.20$ cm tube-tooth distance). The sensors were scanned in an Optime scanner (Sordex company, Helsinki, Finland). Images were saved in Scanora software.

2. The CBCT data was acquired from New-Tom 3G system (Verona, Italy) in an FOV of 6 inches and voxel size of $200\mu\text{m}$ with the standard condition ($T = 0.6$ s, $KVP = 110$, $mAs = 1.80$).

Images were evaluated by NNT Viewer software (Verona, Italy) and sectioned in sagittal and coronal planes and saved in bmp format.

Three independent observers assessed PSP and CBCT images in a semi dark room twice with two week interval without any time limit or changing contrast and brightness.

A five-point rating scale was used to assess the presence and extent of primary occlusal carious lesions as follows: 1' = Radiolucency reaching the pulpal third of the dentine, 2' = Radiolucency in the middle third of the dentine, 3' = Radiolucency in the outer third of the dentine, 4' = Radiolucency confined to the enamel, 5' = No radiolucency.

After imaging, the teeth were sectioned in buccolingual plane with 0.1 mm diamond bur (TIZ KAVAN, Tehran, IRAN). Sections assessed with stereo microscope (Olympus, Tokyo, Japan LG-PS2) at $\times 10$ magnification. A carious lesion was defined as a demineralized, opaque white or yellowish brown discolored area in the enamel or dentine.

A five-point rating scale used for histological observations as a gold standard in order to conduct a true assessment of the extent of any carious lesions present. 1' = Caries involving the inner half of the dentine, 2' = Caries limited to the outer half of the dentine, 3' = Caries extending to inner half of the enamel but not to dentine-enamel junction, 4' = Caries lesion limited to the outer half of the enamel, 5' = No caries.

Digital imaging results and gold standard results compared with receiver operating characteristic (ROC) curve analysis to assess the accuracy of the presence or absence of caries.

Intra and inter observers agreement for each image set was assessed by ICC (intraclass Correlation Coefficient). Methods were analyzed by ANOVA and t-test with p value of 0.05. Tests were performed with STATA software (version 11).

Results

The actual status of the 88 occlusal surfaces, as determined by histological examination, was as follows: 6 sound (6.8%), 25 (28.4%) with superfi-

cial enamel caries, 28 (31.8%) with deep enamel caries, 12 (13.6%) with superficial dentin caries, 17 (19.3%) with deep dentin caries (Table 1).

The results gained from observers' analysis of CBCT and PSP images in comparison with gold standard results are showed in Tables 2 and 3.

The results of ROC curve and calculations of the area under the curve and their standard errors

are presented in Table 3. The average results from observers in caries detection with PSP images was 0.34 (P value = 0.208) and with CBCT images was equal to 0.45 (P value = 0.722). This showed that the diagnostic accuracy of CBCT and PSP was not acceptable compared with the gold standard (Table 4 and Figs 1, 2).

The intraclass Correlation Coefficient (ICC) was used to assess the agreement between observers and imaging systems. Agreement between observed groups and PSP devices was equal to 0.61 (Cronbach's Alpha = 0.833, $0.8 \leq \alpha \leq 0.9$); between observers and CBCT machine 0.54 (Cronbach's Alpha = 0.786, $0.7 \leq \alpha \leq 0.8$); between observers using CBCT and PSP 0.73 (Cronbach's Alpha = 0.847, $0.8 \leq \alpha \leq 0.9$); between observers with PSP and the gold standard 0.32 (Cronbach's Alpha = 0.491, $\alpha < 0.5$), and between observers using CBCT and the gold standard was 0.35 (Cronbach's Alpha = 0.532, $0.5 \leq \alpha \leq 0.6$).

The ICC results showed the acceptable agreement between observers in caries detection by

Table 1. Results of histological analysis of occlusal caries in 88 extracted teeth

Percentage	Number of teeth	Histological degree of caries (Gold standard)
19.0	17	1'
13.6	12	2'
31.8	28	3'
28.4	25	4'
6.8	6	5'
100	88	total number of teeth

Table 2. Average of results gained from 3 observers for PSP images in two observations in comparison with the gold standard results [For example in column 1 the table shows that from total of 17 teeth with degree 1 of histological caries (gold standard) observers diagnosed only 6 teeth (35.3%) with degree 1, 2 teeth (11.8%) with degree 2 etc. ... (concerning radiographic scale)]

Gold standard										Degree	Average of 3 observers re- sults in analysis of PSP images in comparison with Gold stan- dard results
5		4		3		2		1			
per- cent	num- bers	per- cent	num- bers	per- cent	num- bers	per- cent	num- bers	per- cent	num- bers		
16.7	1	4	1	14.3	4	33.3	4	35.3	6	1'	
33.3	2	8	2	10.7	3	25	3	11.8	2	2'	
33.3	2	20	5	17.9	5	16.7	2	41.2	7	3'	
16.7	1	24	6	35.7	10	16.7	2	5.9	1	4'	
0	0	44	11	21.4	6	8.3	1	5.9	1	5'	
100	6	100	25	100	28	100	12	100	17	total	

Table 3. Average of results gained from 3 observers for CBCT images in two observations in comparison with gold standard results [For example, in column 1 the table shows that from a total of 17 teeth with degree 1 of histological caries (gold standard) observers diagnosed only 6 teeth (35.3%) with degree 1, 2 teeth (11.8%) with degree 2 etc. ... (concerning radiographic scale)]

Gold standard										Degree	Average of 3 observers re- sults in analysis of CBCT images in comparison with Gold stan- dard results
5		4		3		2		1			
per- cent	num- bers	per- cent	num- bers	per- cent	num- bers	per- cent	num- bers	per- cent	num- bers		
16.7	1	4	1	3.6	1	33.3	4	35.3	6	1'	
16.7	1	12	3	3.6	1	33.3	4	11.8	2	2'	
16.7	1	8	2	39.3	11	0	0	41.2	7	3'	
50	3	60	15	39.3	11	16.7	2	5.9	1	4'	
0	0	16	4	14.3	4	16.7	2	5.9	1	5'	
100	6	100	25	100	28	100	12	100	17	total	

Table 4. Surface under ROC curve (PSP, CBCT)

Surface under ROC curve	Standard error	95% confidence interval of the difference		P value	System
		lower	upper		
0.346	0.086	0.177	0.514	0.208	PSP
0.456	0.113	0.234	0.679	0.722	CBCT

Fig. 1. The comparison of ROC curve for PSP results (blue line) and the gold standard (green line) **Fig. 2.** The comparison of ROC curve for CBCT results (blue line) and the gold standard (green line)

CBCT and PSP, but agreement between observers using these image modalities and the gold standard was poor (Table 5).

Discussion

In this study we used teeth with intact occlusal surfaces or with superficial caries but not cavitated, because of the need for the detection of non-cavitated carious lesions that have been emphasized repeatedly in the literature for preventive dentistry [11]. Accurate diagnosis of the activity of a carious lesion is important, because preven-

tion and remineralization are possible. Diagnosis of occlusal caries is difficult due to the morphology of the occlusal surfaces. Intra oral radiography provides us two-dimensional information that is not certain. The accuracy of caries detection with digital and conventional images is similar [25, 26]. Because CBCT is a relatively new imaging modality, its diagnostic potential for caries detection is unclear.

In this study, 17.9–24% of enamel caries were detected with PSP and that is not sufficient for the diagnosis of enamel caries. 25–35.3% of dentin caries were diagnosed with PSP and that is slightly better because of deeper caries (Table 2).

Table 5. Comparison of agreement between observers and imaging systems in caries detection for this study

ICC	95% confidence interval of the difference		Cronbach's Alpha	Comparison between
	lower	upper		
0.609	0.495	0.710	0.833	Observers and PSP
0.547	0.428	0.656	0.786	Observers and CBCT
0.737	0.625	0.820	0.847	CBCT and PSP
0.321	0.124	0.495	0.491	Gold standard and PSP
0.354	0.161	0.522	0.532	Gold standard and CBCT

In this study CBCT diagnosed 39.3–60% of enamel caries and 33.3–35.3% of dentin caries. Diagnostic accuracy of CBCT was greater than PSP in enamel caries, but CBCT and PSP images were similar in dentin caries detection (Table 3).

The ICC results showed good agreement between observers for detecting caries with two imaging systems used in this study.

The diagnostic accuracy of CBCT and PSP was not acceptable compared with the gold standard. This was the same as the conclusion reached by Krzyzostaniak et al. [11].

In a study conducted by Kamburog et al. [25], digital CCD sensor images and CBCT images with 3 different voxel sizes were analyzed for occlusal caries detection. They gained good intra and inter observer agreement for each image set, the same as our study. They concluded that superficial enamel caries were not detectable by neither of the two imaging systems. But in deeper caries, CBCT were more efficient.

In a study conducted by Saadettin et al. [27], the diagnostic accuracy of CBCT was significantly higher than PSP and conventional film in occlusal caries but there was no significant difference between image modalities in approximal caries detection.

In a study conducted by Alomari Q. et al. [28], a comparison among conventional radiographs, digital radiographs, and CBCT, was used for occlusal dentine caries detection. There were no differences between the accuracy of image modalities in this study. However, they concluded that CBCT images were more sensitive, while PSP images were more specific.

Ertas T. et al. [29] in a comparative study of different radiographic methods for detecting occlusal caries concluded that CBCT exhibited better performance in detecting deep occlusal caries.

In a study conducted by Zhang et al. [26], the surface under ROC curve for PSP (Digora Optima with E speed film) and CBCT (Promax 3D and Kodak 9000 3D) were similar in proximal caries detection. This confirms the results of Tsuchida et al. [14] and Qu et al. [20].

In our study, the surface under ROC curve for CBCT was higher than PSP, but there were no significant differences between CBCT (with NewTom 3G) and PSP images in both superficial and deep caries diagnosis. Both of CBCT and PSP were not accurate for occlusal caries detection.

These differences in results can be attributed to the different FOV and voxel size of CBCT de-

vices applied in these studies. Systems with lesser voxel size and lower FOV can detect caries better. Qu et al. [20] analyzed 5 different CBCT systems and concluded that detector type employed in CBCT systems have no effect on accuracy of proximal caries diagnosis.

But Haiter-Neto et al. [15] reached a different result. They concluded that NewTom 3G CBCT (with lower spatial resolution than the Accuitomo system) had a lower diagnostic accuracy for detection of caries. It also had a lower diagnostic accuracy than Digora fmx and PSP film.

Shahidi et al. in another study concluded that NewTom VGI CBCT was more accurate than PSP in detecting simulated small secondary occlusal caries under amalgam restorations [24].

The review of recent research showed that some studies have reported greater diagnostic values of CBCT than the other intraoral films for detecting occlusal caries [16, 21, 25, 29]; however, in some studies there were no significant differences [11, 28] (the same as in this study). These results vary with the type of CBCT system. The NewTom 3G system had the worst scores for the detection of dentin caries and Accuitomo system had higher sensitivity [15]. The detector used in NewTom 3G system is IIT/CCD (image intensifier tube/charge couple device) that has more pixel noise and image artifacts in comparison with flat panel detector systems [11].

The limitations of this study are the *in vitro* conditions employed and the selection of materials. In a true clinical situation, various fillings or other metallic elements (such as implants, orthodontic dental brackets, and prosthodontic restorations) could be present in a patient's mouth. These materials, as well as the patient's possible movement during the examination, could be responsible for the errors in the resulting CBCT data. Moreover, spatial resolution of CBCT is about 2 lp/mm, while that for conventional film is about 20 lp/mm [11]. This can be the cause of subtle changes in mineralized tissues that are impossible to distinguish from surrounding intact tissues. Artifacts related to beam hardening are another problem that make caries detection more difficult.

The accuracy of NewTom 3G CBCT for detecting occlusal caries was slightly better than PSP (not significantly), but none of them had the sufficient diagnostic accuracy for detecting incipient occlusal caries. Therefore, in these cases it is necessary to use other methods to improve detection.

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