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Evaluation of Two Dental Digital Imaging Systems Based on Quality Scorings, Burn-Out Effects and Cervical Width Determination

SUMMARY

Background/Aim*: The aim of the present study is to evaluate diagnostic accuracy of two generic image receptors with CMOS and PSP sensors for image quality scoring (IQS), burnout incidences (BI) and cervical widths (CW) with regard to four different exposure times.* ***Material and Methods:*** *43 incisor teeth within 15 paraffin block models were exposed at 4 different exposure times both for the CMOS and PSP groups, and a total number of 120 images were obtained. All images were evaluated by 3 dentomaxillofacial radiologists via 3 different criteria; IQS, BI, CW.* ***Results:*** *Diagnostic quality scorings between groups displayed statistically significant difference for 0,1; 0,125 and 0,16 sec exposure times. PSP group revealed higher IQS. For 0,125 and 0,16 seconds exposure times, PSP group showed higher percentages of BI. Average CW were lower in PSP group. Although no statistically significant difference was found between average CW vs. exposure times in the CMOS group; PSP group revealed significant differences among exposure times. We can state that, the PSP system displayed higher image quality so exposure times can be reduced, alas, the same conclusion is not possible with CMOS system used.* ***Conclusions:*** *Image quality perception is higher in PSP system we used, compared with CMOS system. PSP system display more burnout effects with increasing exposure times, while CMOS system is constant.*

Key Words: Dental Digital Imaging, Phosphor Plate, Subjective Evaluation

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Introduction

The photographic film, which is the X-ray photon detector commonly used in oral radiography has some drawbacks, so more advanced methods were needed. The main disadvantages of the films are: photons cannot be absorbed completely; the images cannot be changed; in processing, environmentally polluting chemical solutions can be used and the radiation dose is relatively high[1]. Nowadays, digital radiography is commonly used in dentistry. Significant benefits have been achieved in the field of intra-oral radiography with the emergence of digital imaging; the most important one is the reduction of exposure dose[2].

In addition, contrast, blur, and noise can be changed digitally, image quality can be smoothed after image acquisition. In digital imaging, sensors are used instead of films, and image data is presented and stored as images via computers[3]. Two different sensors are commonly used in digital systems. One of these is the Direct Digital Imaging System in which a visible light-sensitive charge-coupled device (CCD) or Complementary Metal Oxide Semiconductor (CMOS) sensor is used, which first requires X-ray energy to be converted to visible light and then transferred from the sensor via a fiber-optic system to a computer. In addition, a second system based on a photo-stimulable phosphor imaging plate system (PSP) generally named as the Indirect Direct Digital System for oral radiography has been developed[1,4]. The advantages and disadvantages of two systems are frequently discussed in the literature. Regardless of repeated radiation exposure, dose in CCD system is reported to be lower than the PSP systems in optimal individual radiation exposure[4,5]. On the other hand, PSP systems have a wider dynamic range, which provides better quality images compared to other sensors. PSP sensor is more flexible, and the lack of connection cable makes it easy to use. However, taking into consideration the duration of the exposure and scanning, it may make it time-consuming[6]. Besides, it is necessary to evaluate the image quality which have many variables that depend on studies.

Pittayapat *et al*, evaluated the radiographic image quality acquired by two X-ray devices in combination with two types of image receptors: CMOS and PSP. The study revealed that radiological image quality was significantly higher for PSP compared with the CMOS digital receptor system[7]. Farrier *et al.* reported that, although using CCD system images were produced with a lower expected radiation exposure, the image quality was superior using the phosphor plate system[4]. With respect to subjective image quality, dynamic range and radiation dosage Borg *et. al.* revealed that the storage phosphor system performed better than the CCD systems[1].

The objective of the present study is to evaluate diagnostic performance of two generic image receptors: a CMOS and a PSP system based on image quality scoring, burnout incidences and cervical widths with regard to clinically common used exposure times.

Material and Methods

The study was conducted with the approval of Istanbul Medipol University, Non-Interventional Ethics Comittee numbered 10840098-604.01.01-E.8816.

One photostimulable phosphor plate system (PSP) (Sopro S.A., ACTEON Group, La Ciotat, France) and one direct digital radiography system with CMOS imaging sensor (Kodak 5100, Carestream Dental, Atlanta, Canada) were used with similar size sensors and resolution for comparison of subjective image quality. Technical specifications for the PSP are; 24 x 40 mm active surface dimensions and 14 lp/ mm resolution; and for the CMOS are 22 x 30 mm active surface dimensions and 14 lp/mm resolution.

15 models involving a total number of 43 single rooted incisor teeth that were embedded in paraffin blocks are used as shooting materials. To assist observers' scoring of the image quality with regard to contrast, a 10 stepped 99,5% aluminum wedge with uniform 1 mm steps is included in all shootings.

The standard geometric configuration for the x-ray source – object distance was set at 30 cm, with zero degrees horizontal and vertical angulations of the x-ray beam. All x- ray shootings were performed by CS 2200 (Carestream Health, Inc. 150 Verona Street Rochester, NY 14 608, USA) operating with 60 kV and 7 mA electric power supply. The paraffin block models were exposed at 4 different exposure times both for the CMOS and PSP groups, and a total number of 120 images were obtained. For both groups 0,08; 0,1; 0,125 and 0,160 sec of exposure time were performed; these times were selected due to being common clinical exposure times.

Image evaluation

All PSP images were immediately scanned via PSPIX imaging plate scanner (ACTEON Group, La Ciotat, France). The CMOS images were detected by Kodak Imaging software and all images from both systems including 4 different exposure times were transferred in a personal computer (ASUS X550L Notebook PC, with 1366 x 768 pixel screen resolution) and analyzed by 3 calibrated dentomaxillofacial radiologists. No manual adjustments were performed on the images for enhancement. Analysis of the images were performed in a dimmed room, to avoid interrupting light source.

Diagnostic performance of all images were evaluated via 3 different criteria; diagnostic quality scoring, burnout presence and cervical width determination. First criteria included scoring for diagnostic image quality; images were scored using a 1 to 5 scale. Defining the ratings; 1: completely insufficient (very low contrast, insufficient density, and very low detail formation), 2: almost insufficient (low contrast, limited density, and low detail formation), 3: partially sufficient (diagnostically acceptable; sufficient contrast, diagnostically acceptable density and sufficient detail), 4: almost perfect (diagnostically good; good contrast, good density and good detail) and 5: completely perfect (diagnostically perfect; perfect contrast ratio, perfect density and perfect detail). All dentomaxillofacial radiologists were calibrated for the scoring and focus was made for the image quality including contrast, resolution and interpretation of the anatomical properties of the teeth. All scorings were computed for all exposure times by each 3 dentomaxillofacial radiologists. Second evaluation criteria included evaluation of burnout presence of each teeth including both systems, for all 4 exposure times and by all 3 dentomaxillofacial radiologists. Statistical differences of two systems were analyzed via burnout percentages for all exposure times. The third evaluation criteria involved measurement of cervical diameters of all teeth for both systems again for all exposure times. This measurement was performed in order to respond if burn-out causes dimensional decrease in mesio-distal dimension of the cervical area, as well as providing supportive data for the subjective burn-out evaluation at the second evaluation criteria. Averages of the cervical widths are determined for all exposure times and all 3 radiologists in order to make comparisons. A model involving 4 exposure times for PSP and CMOS systems side by side is shown in Figure 1 for image quality outcomes.

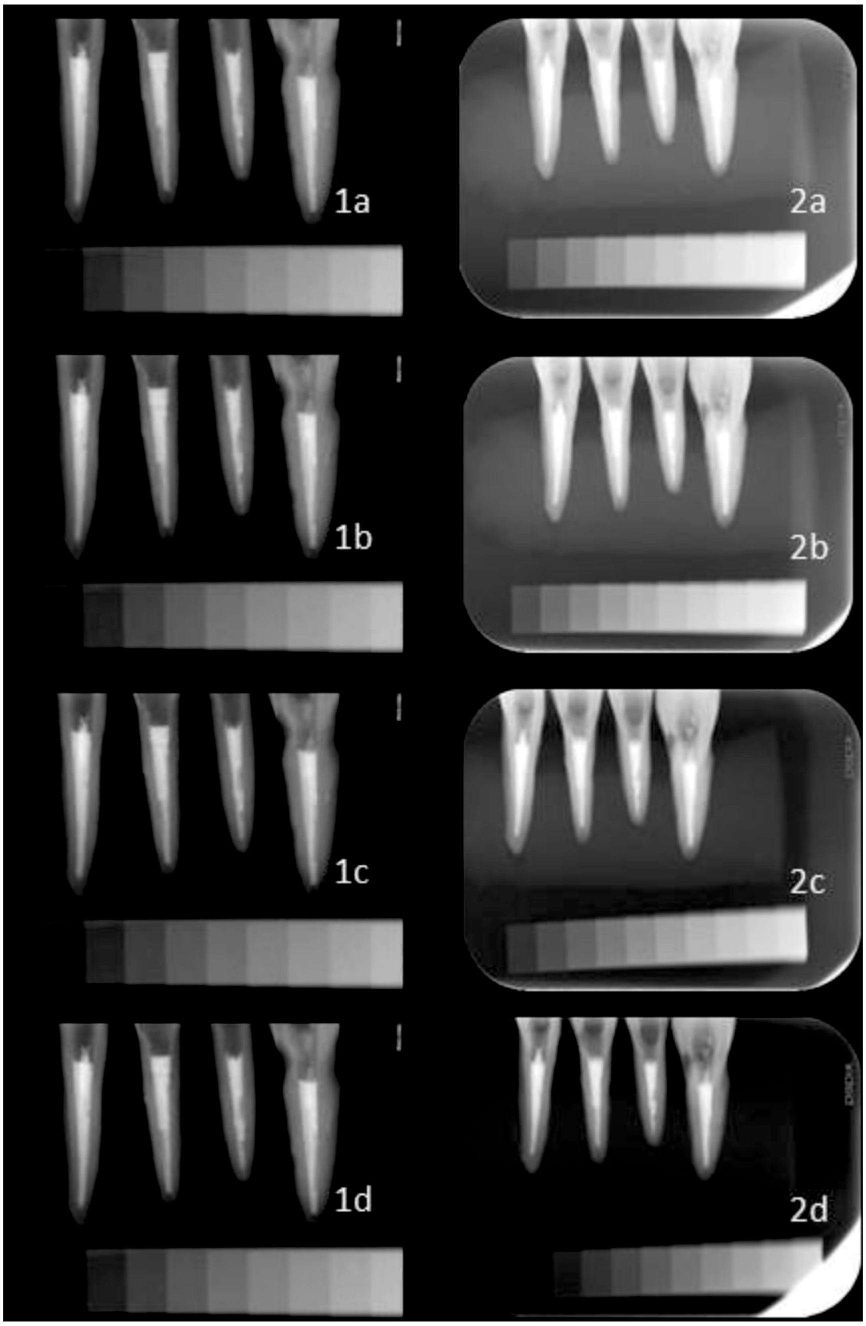

Figure 1. Alignment of a set of images obtained from CMOS system 1a) 0,08 sec., 1b) 0,1 sec, 1c) 0,125 sec.; 1d) 0,16 sec exposure PSP sysytem 2a) 0,08 sec., 2b) 0,1 sec, 2c. 0,125 sec., 2d) 0,16 sec exposure times. Image quality, burn out effects and radiopacity of the images can be compared

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics 22 (IBM SPSS, Turkey) software. For the assessment of study data, Kolmogorov-Smirnov and Shapiro Wilks tests were used to evaluate the compatibility of parameters to normal distribution and it was determined that parameters were not compatible with normal distribution. Wilcoxon signed-rank test was used for comparison of PSP and CMOS groups. Friedman test (Wilcoxon post hoc) was used for evaluations between exposure times. In-class correlation coefficient (ICC) was calculated for inter-observer compatibility. Significance was evaluated at $p<0,05$ level.

Results

Inter-researcher agreement among observers was 90 %, as a result of evaluations made on 10% sample group via Inter Class Correlation (ICC:0,900; %95 CI:0.844-0.940).

Outcomes of diagnostic quality scorings of CMOS/ PSP groups regarding exposure times are presented in Table 1. Among the performed 4 exposure times, most of the images were rated to be partially sufficient (52,63%) or almost perfect (37,7%) within the used CMOS and PSP groups Very few observations were scored as completely insufficient (0,9%), almost insufficient (3,5%), or completely perfect (5,3%).

Table 1. Diagnostic quality scorings of CMOS/PSP groups with regard to exposure times

Exposure Time (sec)	CMOS Mean±SD	PSP Mean±SD	[1]p
0,08	3±0	3±0,33	1,000
0,1	3,05±0,23	3,32±0,48	0,025*
0,125	3,05±0,23	3,89±0,46	0,000*
0,16	3,05±0,23	4±0,82	0,001*
[2]p	0,392	0,000*	

[1]Wilcoxon Sign Test [2]Friedman Test * p<0,05

Diagnostic quality scorings of CMOS and PSP groups displayed no statistically significant difference for 0,08 seconds exposure time (p>0,05); on the other hand, significance was found for 0,1 (p: 0,025; p<0,05); 0,125 (p: 0,000; p<0,05) and 0,16 (p: 0,000; p<0,05) seconds exposure times. Diagnostic quality scoring is found to be higher in PSP group images.

Diagnostic quality scorings of CMOS group with regard to exposure times showed no statistically significant difference (p: 0,392; p>0,05).

Statistically significant findings with regard to diagnostic quality scorings were obtained among different exposure time results in PSP group (p: 0,000; p<0,05). As a result of binary assessments to determine the origin of significance between exposure times; rate scores in 0,08 seconds exposure time were found lower than rate scores in 0,1; 0,125 and 0,16 exposure times respectively (p1: 0,014; p2: 0,000; p3: 0,001; p<0,05). Also; rate scores for 0,1 seconds exposure time were lower than scores for 0,125 and 0,16 exposure times (p1: 0,001; p2: 0,013; p<0,05). No statistically significant difference between rate scores for 0,125 sec and 0,16 sec exposure times was found (p: 0,366; p>0,05).

Assessment of burnout evidence percentages of CMOS/ PSP groups with regard to exposure times are presented in Table 2. In terms of burnout evidence percentages for CMOS and PSP groups, no significant difference was found for 0,08 and 0,1 sec exposure times (p>0,05). For 0,125 and 0,16 sec exposure times, PSP group showed higher burnout percentages (p1: 0,032, p2: 0,015; p<0,05) than the CMOS group.

Table 2. Assessment of burn out evidences of CMOS/ PSP groups versus exposure times

Exposure Time (sec)	CMOS Mean±SD	PSP Mean±SD	[1]p
0,08	55±41,9	63,95±40,5	0,449
0,1	57,81±40,91	66,58±41,17	0,555
0,125	59,56±42,01	82,28±31,3	0,032*
0,16	59,56±42,01	91,49±19,14	0,015*
[2]p	0,066	0,000*	

*[1]Wilcoxon Sign Test [2]Friedman Test * p<0,05*

Burnout evidence percentages with regard to exposure times within the CMOS group showed no statistically significant relationship (p: 0,066; p>0,05); though significant relationships were found in PSP group (p: 0,000; p<0,05). Binary comparisons among exposure times of PSP group for burn out percentages showed no statistically significant differences between 0,08 sec and 0,1 sec exposure (p: 0,157; p>0,05); on the other hand burn out percentages were lower in 0,08 sec than 0,125 and 0,16 sec (p1: 0,011; p2: 0,007; p<0,05); also lower percentages were found in 0,1 sec exposure than 0,125 and 0,16 sec (p1: 0,027; p2: 0,012; p<0,05).

Assessment of cervical width versus exposure times among the used CMOS and PSP groups are presented in Table 3. Cervical width averages of the PSP group were significantly lower than the CMOS group for all 0,08; 0,1; 0,125 and 0,16 sec exposure times (p1: 0,001; p2: 0,002; p3: 0,001; p4: 0,001; p<0,05).

Table 3. Assessment of cervical width versus exposure times among CMOS and PSP groups

Exposure Time (sec)	CMOS Mean±SD	PSP Mean±SD	[1]p
0,08	269,97±60,54	192,78±35,22	0,001*
0,1	269,38±61,82	194,18±36,7	0,002*
0,125	269,28±62,06	190,81±36,95	0,001*
0,16	268,52±61,79	189,86±35,71	0,001*
[2]p	0,591	0,000*	

[1]Wilcoxon Sign Test [2]Friedman Test * p<0,05

Regarding average cervical widths, no statistically significant differences were found between exposure times in CMOS group (p: 0,591; p>0,05); alas, the PSP group revealed significant differences among exposure times (p: 0,000; p<0,05).

For PSP group; average cervical widths were found higher in 0,08 seconds exposure time than 0,125 sec (p1: 0,014; p<0,05) and 0,16 sec (p2: 0,013; p<0,05); despite no difference was found between 0,08 sec and 0,1 sec (p: 0,554; p>0,05). Results showed higher average values for 0,1 sec than 0,125 sec (p1: 0,009; p<0,05) and 0,16 sec (p2: 0,006; p<0,05). No statistically significant difference was observed between 0,125 sec and 0,16 sec in terms of average cervical width (p: 0,368; p>0,05).

Discussion

The present study evaluated diagnostic performance of two generic image receptors; using CMOS and PSP sensors based on image quality scoring, burnout incidences and cervical widths with regard to four clinically common used exposure times. For quality determination, dental radiographs are often subjectively evaluated[8,9,10,11], and researchers may use different grading scales for scoring of image quality; i.e. Borg and Grondahl[1] used a 10 grade scale, while Yalcinkaya *et al.*[10] used a 5 grade scale. In this study, we also used a 5 grade scale and 90% inter researcher reliability was obtained.

Farrier et al. used a 3 point scale to evaluate CCD and PSP systems, the results showed that with PSP system 71% of the images were excellent and 6 % were unacceptable[4]. Borg and Grondahl revealed that image quality scorings of conventional radiography and PSP were similar; and higher than of CCD[1]. Borg *et al.* evaluated 6 different systems at different exposure ranges on a 5 point image quality scale; and presented that PSP systems provided clinically acceptable image quality over a wide exposure range, while CDR had the best image quality over the narrowest exposure range and solid state detectors had the lowest image quality[12]. In the current study, although no difference was found for 0,08 sec exposure, the used PSP system displayed higher quality rates than CMOS for 0,1; 0,125 and 0,16 sec. exposures. Meanwhile, it is also of importance that exposure range of the CMOS system had no significance for all exposure times, but PSP image quality rates increased with the dose. Again of importance, 0,125 and 0,16 sec exposures had similar results for image quality scorings. We can assume 0,08; 0,1 and 0,125 sec. exposures have better quality imaging for the PSP (Sopro) system, but increase to 0,16 sec had no better quality than 0,125 sec.

Vandenberghe and Jacobs performed a study on human cadaver skulls to investigate the possible effect of tube voltages on accuracy and subjective image quality in periodontal defects using PSP systems using 80, 120 and 160 msec exposure times. There were no statistically significant differences between measurements with different tube voltages and exposure times; besides subjective image quality in detecting lamina dura delineation, trabecular structure depiction, contrast perception and furcation involvement visibility did not differ among observers for varying exposure parameters[13].

Berkhaut *et al.* revealed that solid-state systems need long exposure time due to lack of image quality; and PSP produce good quality radiographs even at high exposure times, which may result in an unnecessarily high dose[14]. We also had similar outcomes, that image quality of the CMOS system is lower than the PSP at increasing exposure times and image quality scores of PSP system increase until 0,125 sec and then stay constant.

Melo *et al.* stated that exposure times from 0,06 sec to 0,25 sec was satisfactory for proximal caries detection, and 0,25 s is the best as indicated for this finality[15]. We can state that exposure times can be reduced in PSP with high image quality, alas, the same conclusion is not possible with CMOS.

Borg[16] and Berkhaut *et al.*[17] stated that blooming effect will be presented at lower doses in solid state systems, than burnout effects in PSP systems. Regarding our study data, we can estimate that incidence of burnout effect in CMOS are non-related to exposure doses, while PSP revealed that incidence of burnout effects increase with increasing exposure time. Similarly, comparison of groups reveal that PSP displays prominent burnout with regard to CMOS at 0,125 and 0,16 sec exposure times. This is a valuable data, to emphasize low- dose protocols will have higher quality images in PSP systems. Assuming that burnout effects commonly appear in over-exposures and the dose range of the study is limited to clinically common used exposure times; a low rate of burnout effects were obtained for the used PSP system.

Athar *et al.* conducted an in-vitro study in human cadaver mandibles with preserved molar teeth to compare performance of identifying files and root apices; and resulted with highest error rates in PSP systems while wireless CMOS receptor showed the least errors[18]. Alas, material type used for measurement in these studies were endodontic files and thus revealed discrepancy with our results Another ex-vivo study made on 40 extracted teeth with inserted endodontic files were imaged using CCD, CMOS and PSP systems; PSP plates showed higher measurement values while CCD and CMOS receptors revealed lower values compared with the standard[19].

In our study; results revealed narrower cervical width averages in PSP system; moreover evaluating PSP system in terms of exposure times, lower values were observed with increasing exposure time. This may be result of increasing burn out effects in the PSP system and it can be stated that burnout presence leads to diminished cervical width measurements. The cervical width determination was selected as an evaluation item in order to present clinical validation of burnout effects; thus smaller cervical widths were expected with increasing doses and burnouts. In harmony with burnout effect results; cervical width measurements of the CMOS remained constant and PSP group diminished through 0,08; 0,1 and 0,125 sec doses. The burnout ratings and cervical width measurements displayed consistent and supportive results. All results were in harmony with quality image scorings.

Conclusions

According to the results of this study, we can conclude that:

i. Image quality perception is higher in PSP system we used, compared with CMOS system; especially increasing with exposure time.
ii. PSP system we used revealed more burn-out effects than CMOS system in higher exposure times and these effects increased with exposure time in PSP system, while CMOS system stayed constant.
iii. Cervical width measurements of the used PSP system decreased with increasing dose, as a consequence of burnout effects.
iv. Diagnostic performance upon 3 different criteria reveals that the used PSP system has superior performance in clinically low doses.

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