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Clinical Evaluation of Dose Reduction on Image Quality of Panoramic Radiographs

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Abstract

Aim: The purpose of this study was to evaluate the effect of tube current reduction on image quality using medium and regular intensifying screens as well as a digital system for panoramic radiography.

Methods and Materials: A total of 150 panoramic images of 75 patients were obtained in the study. The initial images were taken at standard exposure settings, and secondary images were exposed with the tube current reduced at different rates.

Results: There was no statistically significant difference ($p>0.05$) between the two exposures for Group 3 (the rate of dose reduction 25%) while a statistically significant difference ($p<0.05$) was found in Group 4 (the rate of dose reduction 50%) using medium intensifying screens for all observers. No statistically significant difference was found between the two exposures on digital panoramic images.

Conclusion: According to the results of this study a dose reduction of 25% was achieved for medium intensifying screens and for digital panoramic images without any loss of image quality.

Clinical Significance: A substantial reduction in radiation exposure can be achieved in conventional panoramic radiography using a medium intensifying screen and in digital panoramic radiography without any loss of image quality needed for radiological evaluation of anatomical structures and pathological conditions.

Keywords: Panoramic radiography, dose reduction, intensifying screens, digital radiography

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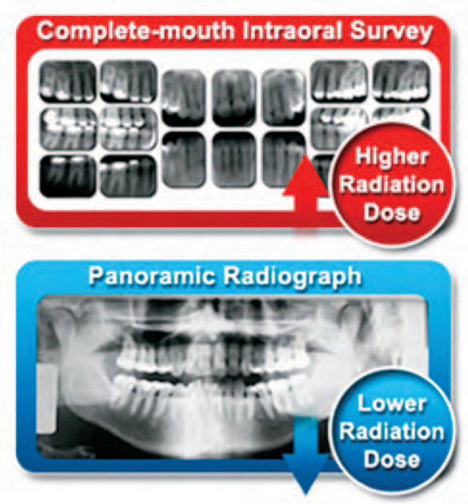
Introduction

Dose reduction within the limits of optimum image quality is a goal of radiography in order to minimize radiation exposure to patients, radiology staff, and the environment. Dose reduction can be achieved through the manipulation of tube potential (measured in kV) and tube current (measured in mA) and by using different screen-film systems as well as the use of digital imaging.[1]



Panoramic radiographs are widely used to obtain a comprehensive survey of the maxillofacial complex. One of the advantages is reduction in radiation dose compared with a complete-mouth intraoral survey.[2] Film-screen systems using a medium intensifying screen (speed class 200) have been accepted in extraoral radiography while the regular intensifying screen (speed class 400) has gained uniform acceptance in the field of maxillofacial radiology. Alteration of tube potential and tube current can reduce the radiation dose but it can also result in poorer image quality.[1]

Digital imaging was first introduced in dentistry for intraoral radiography but is now widely available for panoramic radiography based on either a charged couple device (CCD) or storage phosphor receptor.[3] The advantages of digital techniques compared with film techniques are rapid transmission of images, the small storage space for images needed, and a lower contamination of the environment.[4] Previous studies have demonstrated it is possible to achieve a degree of dose reduction in digital panoramic radiography.[5,6,7]

The purpose of this study was to evaluate the effect of tube current reduction on image quality using medium and regular intensifying screens as well as a digital system for panoramic radiography.

Methods and Materials

This study had been approved by the Ethics Committee of Gazi University, Faculty of Dentistry in Ankara, Turkey in order to satisfy the Helsinki Declaration.

Seventy-five patients (41 female and 34 male) who required panoramic radiography for diagnostic purposes participated in the study. Exclusion criteria were pregnancy, age 17 years or less, occupational X-ray exposure, and patients with previous extensive radiographic examinations. The patients were divided into five groups with each having 15 subjects. Two panoramic images were taken of each of the 75 patients (150 radiographs) on separate days. The first image was taken at standard exposure settings and the second image was taken with the tube current reduced at different rates.

Conventional panoramic radiographs were obtained with a Trophy OP100 (Instrumentarium, Tuusula, Finland) panoramic unit. Medium (Eastman Kodak Co, Rochester, NY, USA) and regular (Dr. Goos Suprema GmbH, Heidelberg, Germany) intensifying screens (15x30 cm cassette) and Kodak T Mat G films (Eastman Kodak Co, Rochester, NY, USA) were used in the study. Film radiographs were developed in an automatic film processor (Velopex, Extra-X, Medivance Instruments Ltd, London, UK and NW107A) using freshly prepared processing chemicals.

Digital panoramic images were obtained with an Orthoralix 9200 DDE (Gendex Co, Milan, Italy) panoramic unit which is a CCD-based system used with VixWin 2000 software (Gendex Co, Milan, Italy). The images were assessed on the monitor using an 8-bit resolution. The screens, digital system, and mA settings used for each patient group are listed in Table 1.

All radiographs were assessed by three oral radiologists with at least ten years of experience each. The observers evaluated the images using a three-point scale[1] (1=well visible, 0=partly visible, and -1=not or hardly visible) for anatomical structures and pathological findings (Table 2) which are commonly found on panoramic radiographs.

The film radiographs were assessed using a x2 magnification X-viewer (Luminosa, CSN Industrie, Italy) in a quiet room with subdued ambient lighting. Images from the digital system were displayed directly on a 17 inch monitor screen in the same ambient lighting. To avoid observer fatigue, an interval of at least one week separated each viewing session.

Data Analysis

SPSS-version 15.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for all calculations. Image quality of the groups and comparison of the observers were assessed by using the non-parametric Kruskal-Wallis and Mann-Whitney U tests. The Mann-Whitney U test was used to compare the two exposures with the anatomic structures and pathological findings for each group and observer. The Kruskal-Wallis test was used to compare observers in the two exposures and the anatomic structures and pathological findings. The level of statistical significance was $\alpha=0.05$.

Results

Seventy-five patients with a mean age of 21.60 participated in the investigation from which a total of 150 radiographs were obtained for the study.

There was no statistically significant difference ($p>0.05$) between the two exposures in terms of image quality of anatomical structures, but a statistically significant difference ($p<0.05$) in image quality was found between the two exposures of pathological findings for Group 1 and the first observer. For Group 1 and second observer, there was a statistically significant difference ($p<0.05$) in image quality between the two exposures of both anatomical structures and pathological findings. For Group 1 and third observer, there was no statistically significant difference ($p>0.05$) in image quality between the two exposures of either anatomical structures or pathological findings.

For Group 2, a statistically significant difference ($p<0.05$) in image quality was found between the two exposures of both anatomical structures and pathological findings for the first and second observers. For Group 2 and the third observer, there was no statistically significant difference ($p>0.05$) in image quality between the two exposures of pathological findings while a statistically significant difference ($p<0.05$) in image quality was found between the two exposures of anatomical structures.

For Groups 3 and 5, there was no statistically significant difference ($p>0.05$) in image quality between the two exposures of either anatomical structures or pathological findings for all observers.

Table 1. Screen-digital system combinations and mA settings in the study.

Combinations	Groups (n=15)	Dose Reduction (%)	First Exposure (kV/mA)	Second Exposure (kV/mA)
Regular-Regular Screen	Group 1	33.3	66/12	66/8
	Group 2	46.6	66/12	66/6.4
Medium-Medium Screen	Group 3	25	66/16	66/12
	Group 4	50	66/16	66/8
Digital-Digital Radiography	Group 5	25	70/4	70/3

Table 2. Evaluated anatomical structures and pathological findings.

Anatomical Structures	Pathological Findings
Anterior nasal spine	Calculus
Articular eminence	Caries
Condylar process	Cyst and tumour like lesions
Coronoid process	Fracture of condyle
Disc space	Impacted teeth
External auditory meatus	Overextended root canal filling
External oblique ridge	Periapical lesion
Floor of maxillary sinus	Root fracture
Inferior concha	Root fragment
Inferior cortex	Strange material
Interdental septum	Underextended root canal filling
Mandibular canal	
Maxillary sinus	
Maxillary tuberosity	
Mental foramen	
Nasal septum	
Periapical lamina dura	
Periodontal ligament space	
Styloid process	
Zygomatic arch	
Zygomatic bone	

Table 3. Results of the Mann-Whitney U test.

1st- 2nd Exposures							
		1st Observer		2nd Observer		3rd Observer	
Groups	**Statistics**	***A***	***P***	***A***	***P***	***A***	***P***
Group 1	M-W U**	81.500	45.000	49.500	27.000	82.500	105.000
	P	0.065	0.000*	0.003*	0.000*	0.073	0.317
Group 2	M-W U	30.000	37.500	30.000	70.500	75.000	90.000
	P	0.000*	0.000*	0.000*	0.047	0.016*	0.073
Group 3	M-W U	104.500	97.000	97.500	90.000	97.500	105.000
	P	0.524	0.276	0.291	0.073	0.291	0.317
Group 4	M-W U	22.500	7.500	22.500	7.500	27.500	45.000
	P	0.000*	0.000*	0.000*	0.000*	0.000*	0.001*
Group 5	M-W U	104.500	112.500	112.000	97.000	112.500	112.500
	P	0.524	1.000	0.962	0.276	1.000	1.000

** Mann-Whitney U statistics.
* Correlation is significant at the 0.05 level
A: Anatomical structures.
P: Pathological findings

For Group 4, there was a statistically significant difference ($p<0.05$) in image quality between the two exposures of both anatomical structures and pathological findings for all observers. The results of Mann-Whitney U test are shown in Table 3.

For all groups and observers, no statistically significant difference ($p>0.05$) was found between the image quality of anatomical structures and pathological findings (Table 4).

For all groups, no statistically significant difference ($p>0.05$) in image quality was found between the two exposures of anatomical structures and between the first exposures for pathologies in a comparison of observers. For Groups 1, 2, and 4, there was a statistically significant difference ($p<0.05$) in image quality between the second exposures of pathologies; no statistically significant difference ($p>0.05$) was found between the second exposures of pathologies in other groups in a comparison of observers (Table 5).

Pairwise comparisons (Mann-Whitney U test) were performed between Groups 1, 2, and 4. For Groups 1 and 2, a statistically significant difference ($p<0.05$) in image quality was found between the first and third and second and third observers. For Group 4, a statistically significant difference ($p<0.05$) was found between the first and third observers.

A linear relationship between dose reduction and the individual ratings could not be shown so a calculated mean, standard deviation, and the mean difference between the scores of the standard and reduced mA images for all observers in the groups was used in the data analysis (Table 6).

Figure 1 illustrates mean differences and the rates of tube current reduction for all observers.

Discussion

The effect of a reduction in tube current was evaluated based on image quality using medium and regular intensifying screens as well as a digital system for panoramic radiography in this study.

In the study by Dannewitz et al.[8] the image quality of anatomical structures and pathological findings were assessed on digital panoramic images and the image quality of anatomical structures was assessed on various film-screen combinations and digital panoramic systems by Kaeppler et al.[1] In the present study the image quality of both anatomical structures and pathological findings were assessed using two different intensifying screens for conventional panoramic radiography and a digital panoramic system based on CCD receptor.

Dula et al.[7] emphasized dose reduction should be achieved by a reduction of the mA setting rather than the kV setting due to an increase in the absorption of radiation by the tissues with lower kV settings. This result was confirmed by Gijbels et al.[9] For this reason, the mA levels were reduced while keeping the kV unchanged in this

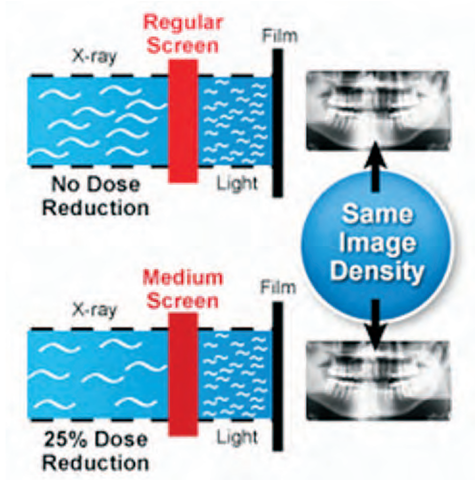


Table 4. Results of the Mann-Whitney U test for anatomical structures and pathologies.

		1st Observer		2nd Observer		3rd Observer	
Groups	**Statistics**	**A-P(1st)**	**A-P(2nd)**	**A-P(1st)**	**A-P(2nd)**	**A-P(1st)**	**A-P(2nd)**
Group 1	M-W U**	105.000	86.500	105.000	94.000	105.000	82.500
	P	0.317	0.231	0.630	0.370	0.317	0.073
Group 2	M-W U	112.500	97.000	90.000	110.500	112.500	96.000
	P	1.000	0.492	0.073	0.928	1.000	0.374
Group 3	M-W U	112.500	105.500	105.000	111.000	105.000	97.500
	P	1.000	0.654	0.317	0.929	0.317	0.291
Group 4	M-W U	112.500	70.500	112.500	89.500	105.000	85.500
	P	1.000	0.055	1.000	0.289	0.317	0.231
Group 5	M-W U	112.500	104.500	112.500	98.500	112.500	112.500
	P	1.000	0.524	1.000	0.326	1.000	1.000

** Mann-Whitney U statistics
A: Anatomical structures
P: Pathological findings

Table 5. Results of the Kruskal-Wallis test.

Groups	Statistics	A(1st)	P(1st)	A(2nd)	P(2nd)
Group 1	Chi-Square	1.760	4.093	5.890	18.455
	Df	2	2	2	2
	P	0.415	0.129	0.053	0.000*
Group 2	Chi-Square	.000	6.279	5.890	18.455
	Df	2	2	2	2
	P	1.000	0.050	0.053	0.000*
Group 3	Chi-Square	.000	2.000	.189	1.405
	Df	2	2	2	2
	P	1.000	0.368	0.910	0.495
Group 4	Chi-Square	2.000	.000	.305	6.573
	Df	2	2	2	2
	P	0.368	1.000	0.859	0.037*
Group 5	Chi-Square	.000	.000	.539	1.875
	Df	2	2	2	2
	P	1.000	1.000	0.764	0.392

* Correlation is significant at the 0.05 level

Table 6. Mean standard deviation and mean difference between the scores of standard and reduced mA images.

mA Reduction	Standard Image Mean (SD)	Reduced mA Image Mean (SD)	Mean Difference (SD)
33.3 % (Group 1)	1.08 (0.269)	1.59 (0.669)	0.511 (0.076)
46.6 % (Group 2)	1.06 (0.313)	1.71 (0.738)	0.656 (0.085)
25 % (Group 3)	1.05 (0.214)	1.21 (0.493)	0.167 (0.059)
50 % (Group 4)	1.01 (0.109)	2.17 (0.709)	1.155 (0.078)
25 % (Group 5)	1.07 (0.251)	1.13 (0.429)	0.067 (0.052)

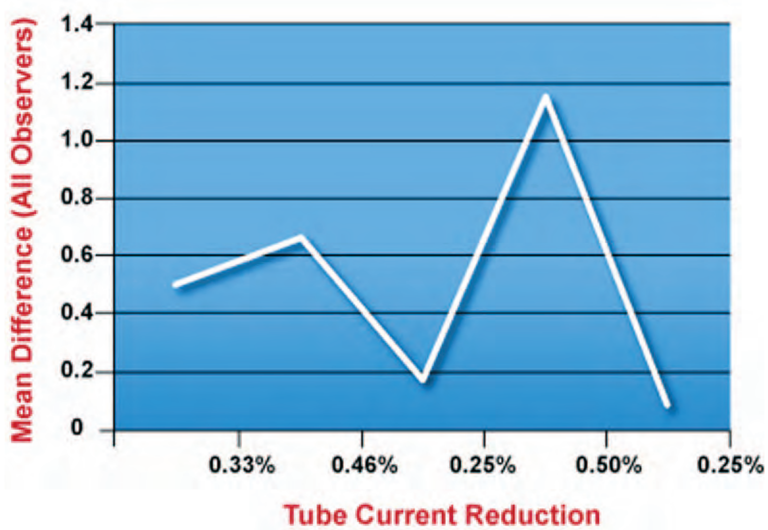


Figure 1. Mean differences and the rates of tube current reduction for all observers.

study for all groups. Because the reduction of tube current results in a decreased signal-to-noise ratio, image quality, especially high contrast, may be affected.[10] However, the software associated with Trophy OP100 and Orthoralix used in this study may have compensated for this condition. Statistically significant differences ($p<0.05$) were found between the two exposures for all observers in the groups using regular intensifying screens. It can be said dose reduction may not be achieved by only a reduction of the mA levels when regular intensifying screens are used. Use of low kV and high mA levels in conjunction with regular intensifying screens for dose reduction has been reported.[1]

In the present study there was no statistically significant difference ($p>0.05$) between the two exposures for Group 3 (the rate of dose reduction 25%) while a statistically significant difference ($p<0.05$) was found in Group 4 (the rate of dose reduction 50%) using medium intensifying screens for all observers. A dose reduction of 25% may have been achieved using medium intensifying screens. This condition is in accordance with the results of Kaeppler et al.[1]

There are several advantages of digital radiography such as the rapid transmission of images from one location to another, the small amount of physical storage space needed, image enhancement capabilities, and a lower environmental impact.[4,11] In digital radiology the diagnosis frequently depends on the correct adjustment of brightness and contrast because by altering these parameters lesions can be produced or faded away.[7] The observers in this study were not allowed to alter the brightness and contrast of the images using the software. The assessments were carried out under standardized conditions of the software in order to eliminate possible diagnostic differences in this study.

One of the main advantages of digital radiography is the possibility of minimizing the radiation dosage[12] with several authors[6,7,13] reporting a dose reduction of about 40-70% using digital panoramic radiography compared to conventional panoramic systems. Previous studies[5,8] have demonstrated the achievement of a degree of dose reduction in digital panoramic radiography without any loss of image quality. Dannewitz et al.[8] reported a dose reduction up to 50% can be achieved while maintaining a satisfactory image quality and diagnostic performance. In the present study mA levels were reduced by 25% with no statistically significant difference between the two exposures for all observers on digital panoramic images. It can be said a 25% dose reduction was achieved for digital panoramic images.

Conclusion

According to the results of this study, dose reduction caused loss of image quality using regular intensifying screens when the tube current was reduced by 33.3% and 46.6%. In further studies, the reduction of tube current could be limited to only 16.6%.

A 25% dose reduction was achieved with a medium intensifying screen and digital panoramic radiography without any loss of image quality of either anatomical structures or pathological findings. In further studies the reduction of tube current may be reduced by 37.5% using medium intensifying screens and by 50% for digital panoramic images.

As imaging technologies continue to improve, radiologists expect future images to improve in quality while using lower radiation doses. However, until the newest technologies are widely used, it is important to conduct studies on the effects of decreasing radiation exposures in the imaging systems currently used by the majority of clinicians.

Clinical Significance

A substantial reduction in radiation exposure can be achieved in conventional panoramic radiography using a medium intensifying screen and in digital panoramic radiography without any loss of image quality needed for radiological evaluation of anatomical structures and pathological conditions.

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