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Reduce Radiation Exposure from Dental Radiation Energy Area

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Abstract

Objectives: This study measured and assessed radiation exposure and the image quality from the acquired image using aluminum filters in an aim to provide basic data for minimizing the exposure dose in X-ray test from dental Digital Radiography system and gaining the optimum image for diagnosis. **Methods/Statistical Analysis**: The measurement values of CNR and SNR were different depending on the image quality from the acquired image using aluminum filters. **Findings**: The reduction of entrance exposure dose showed 3.15-25.93 % difference according to the thickness of aluminum additional filters and the conditions of radiation exposure, but it showed consistent tendency regardless of the tube current (mAs) when the tube voltage goes up. In the radiation test for dental areas, the image quality was excellent when higher than 60 kV for the qualitative evaluation and in 0.1 mm according to the difference in added filtration. **Improvements/ Applications**: This result will be suggested for the data to expect the application of aluminum additional filters and decide the test methods in future dental diagnosis test. It is expected that it will be much utilized for the important basic data to reduce medical radiation exposure.

Keywords: Aluminum Filter, Dental Radiation, Glass Dosimeter, Radiation Exposure, Shielding

1. Introduction

X-ray, which began with the production of Crookes tube in 1876 has been rapidly utilized in the medical field in human society with the discovery of Rontgen in 1895. In Korea, X-ray for medical purpose is being used with the extended life expectancy and improved income level of Korean people. The number of diagnostic X-ray equipment including radiation equipment for dental examination in various types of hospitals is 72,626, showing 7% increase annually with the number of the test cases on the rise[1].

The exposure dose of dental radiography among the diagnostic radiation exposures is only around 0.3%, but the number of radioactive examination cases is around 11%, marking the second after general X-ray. This shows that the exposure dose of dental radiography is low while dental radiography is a frequently used test from children to the elderly. Preparing methods to reduce radiation exposure of dental radiography is greatly needed[2,3].

Added filtration is used for the purpose of absorbing the radiation in certain energy areas before it enters the patients by inserting the metal plate in front of the X-ray tube. It has benefits of reducing the radiation exposure and improving the contrast by effectively absorbing the high energy elements from X-ray[4].

Since added filtration not only absorbs the photon in certain energy areas but the energy of all the photons, it has the drawback that it needs to increase the radiation exposure to make up for the loss[4,5].

For this reason, in the area of diagnostic radiation, if the thickness of added filtration is over certain limit, it only causes the reduction of radiation exposure rate without improvement of the image quality[5].

Therefore, in the area of acquiring medical images, we need to choose the thickness of filters rightly to improve

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the image quality without greatly reducing the radiation exposure rate.

Digital Radiography (DR) detects the information of X-ray that has been projected into the human body through Flat Panel Detector system (FPD). This has the characteristic of wide latitude and high contrast resolution compared to the existing equipment that use films and intensifying screen, which makes it possible to reduce the exposure dose of patients without decline of the image quality[6–8].

The universal utilization of DR was expected to have the effect of reducing radiation exposure dose of patients and improving the image quality, but in reality, the radiation exposure dose is increasing due to the Dose Creep phenomenon caused by the operational immaturity and carelessness of radiation related workers[9]. However, utilization of DR is increasing because it is excellent in analysis of contrast and detection of the minute lesion and also effective in reserving and managing the image information data[10].

For the radiation exposure in DR equipment, there were researches on exposure changes and image quality improvement according to the added filtration in breast X-ray equipment to reduce the exposure dose of breasts[4] on the combination of added filtration and the Ion chamber sensor to reduce the exposure dose of patients in digital chest X-ray[5] and on the examination of head and neck exposure area by measuring the spatial dose distribution of dental panorama equipment[11]. Most of the researches focused on reduction of radiation exposure in computed tomography and on the image quality[12–20].

There is no research on the radiation exposure dose using added filtration in low energy that is used in medical dental area.

This study measured and assessed the image quality from the acquired image and exposure dose through aluminum filters in an aim to provide the basic data for minimizing the exposure dose in X-ray test from dental Digital Radiography system and gaining the optimum image for diagnosis.

2. Target and Methods of the Study

2.1 Materials and Equipment

For the dental Digital Radiography system, we used the JW medical device CXD-R185 System of FPD (Flat Panel Detector) System. To measure the exposure dose of the subject, the whole body phantom (Model PBU-31, Kyoto Kagaku, Japan) composed of body-equivalent materials was used [Figure 1] [Table 1].

The added filtration was made of aluminum with 99.9% of purity, with width 10 cm, length 10 cm and thickness 0.6 mm, 0.8 mm, and 1.0 mm [Figure 2].

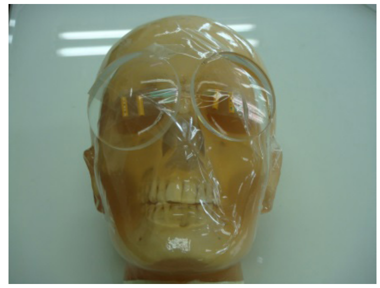


Figure 1. Glass fluorescent device's dose measurement location.

Figure 2. Schematic of added Al filter.

Table 1. Principal characteristics of Digital Radiography

Classification	Unit	Value
Panel Active Size	cm	42 x 43
Pixel pitch	μm	139
Active Pixel Matrix	ea	2560 x 3,000
Bit Processing	Bits	14
Limiting Resolution	LP/mm	3.6
MTF at 3 cycle/mm	%	70
DQE at 3 cycle/mm	%	24
X-ray generator voltage range	kVp	40~150
X-ray generator mA range	mA	10~800
Exposure time	ms	1~10,000
Focal Spots	mm	0.6/1.2
Anode angle	degree	13
Normal Voltage	kV	150
Permanent filter(mmAl)	mm	2.5

2.2 Measuring Entrance Surface Dose

For measuring Entrance Surface Dose (ESD), Electrometer (Radiation Monitor Controller Model 2026) and Ionization Chamber (Model 20×5 - 1, 800 cc, Monrovia, California, USA) that completed correction were used [Figure 3].

For measuring Entrance Surface Dose (ESD), tube voltages 40 kVp, 50 kVp, 60 kVp, 70 kVp that are generally used in dental radiography area were used and tube currents 5 mAs, 10 mAs and 20 mAs were used. The size of radiation field was 10*10 cm and SID (Source Image receptor Distance) was set 100 cm. The spatial entrance surface dose was measured as the added filtration goes up 0 mm, 0.1 mm, 0.2 mm and 0.5 mm.

To minimize the effect of scattered radiation caused by back-scattering, we made the distance between the detector and dosimeter 20 cm. Also, the reliability of measured values was secured by measuring 10 times repeatedly for different thickness and calculating the average and standard deviation[21,22] .

For data processing, we conducted Komogorov-Smimov goodness-of-fit test and indicated the average of descriptive statistics quantity after confirming normal distribution. For significance test, One-way ANOVA test was used. The significance level of all the statistics was 5%. Also, to examine the reduction rate of exposure dose with the use of filters, we set 100% before its use and tried to get percentages according to the thickness[23–30] .

Figure 3. Ionization chamber and electrometer.

2.3 Measuring CNR, SNR

For SNR (Signal to Noise Ratio), we used skull phantom and for the condition of photographing, we set 20 mAs at 60 kV and 100 cm of SID. For mandible and orbit, we established 0.3 × 0.3 cm^2 of ROI (Region of Image) by using the m-view program. After measuring the standard deviation of the pixel signal intensity of ROI, we calculated through getting the average and standard deviation of signal intensity of background except for ROI.

For measuring CNR (Contrast to Noise Ratio), we measured the standard deviation of the pixel signal intensity of ROI using m-view program just like measuring SNR and then we used the formula after getting the average and standard deviation of signal intensity of background except for ROI. The measuring repeated 5 times for different factors and Kruskal-Wallis test was conducted, which is the non-parametric statistical method, since the data processing was under 5 times[2,15].

2.4 Qualitative Evaluation of the Image

We conducted qualitative analysis to confirm the practicality of the clinic and acquire the images according to the changes of the thickness of added filtration using 60 kVp, 20 mAs, SID 100 cm though skull phantom. For qualitative analysis, the contrast of the image, the lesion detectability, the clarity of the boundaries were evaluated using the 5-point Likert scale by a group composed of 1 dentist, 2 dental hygienists and 2 radiologists who have more than 10 years of experience. We compared the 0.1, 0.2, 0.5 mm Al and the time when added filtration was not used. For data processing, Wilcoxon signed ranks test was used, which is the non-parametric statistical method, since the data processing was under 5 times.

3. Result and Reflection

3.1 Entrance Surface Dose according to the Changes in Thickness of AI Added Filtration

Entrance surface dose was measured low as the added filtration got thicker with the same tube voltage (kVp) and tube current (mAs).

Under the condition 70 kV 20 mAs, it was 107.30±0.10 mR when the filter was not used, 104.30±0.10 mR when the aluminum filter with 0.1 mm thickness was used, 100.87±0.29 mR when the aluminum filter with 0.2 mm was used and 91.40±0.17 mR when the aluminum filter with 0.5 mm was used. Under the condition 50 kV 5 mAs, it was 6.14±0.04 mR when the filter was not used, 5.90±0.02 mR when the aluminum filter with 0.1 mm thickness was used, 5.61±0.04 mR when the aluminum filter with 0.2 mm was used and 4.55±0.06 mR when the aluminum filter with 0.5 mm was used.

Table 2. Distribution of entrance surface dose in added filter

kV	mAs	Non	0.1 mmAl	0.2 mmAl	0.5 mmAl	p-value
				Dose		
40	5	6.14±0.04	5.90±0.02	5.61±0.04	4.55±0.06	<0.01
	10	12.37±0.04	11.85±0.01	11.26±0.03	9.77±0.01	
	20	24.89±0.02	23.69±0.01	22.63±0.02	19.54±0.04	
50	5	12.17±0.04	11.72±0.11	11.34±0.02	9.92±0.16	
	10	24.45±0.16	23.60±0.03	22.74±0.01	20.01±0.06	
	20	49.16±0.06	47.07±0.30	45.3±0.43	39.9±0.26	
60	5	19.14±0.07	18.29±0.13	17.93±0.02	15.98±0.07	
	10	38.16±0.23	36.93±0.20	36.20±0.43	31.77±0.41	
	20	76.5±0.44	74.23±0.11	71.80±0.17	64.23±0.25	
70	5	26.7±0.01	25.86±0.04	25.31±0.04	22.71±0.10	
	10	53.60±0.10	51.70±0.53	50.66±0.11	45.63±0.11	
	20	107.30±0.10	103.80±0.10	100.87±0.29	91.40±0.17	

Under the same kV and mAs, the measurement value of exposure dose according to the changes in thickness of aluminum added filtration showed statistical significance [Table 2].

Under the same kV and mAs, the measurement values of exposure dose reduction according to the changes in thickness of aluminum added filtration were 3.15-3.94 % when the aluminum filter with 0.1 mm thickness was used, 5.14-9.08 % when the aluminum filter with 0.2 mm was used and 13.94-25.93 % when the aluminum filter with 0.5 mm was used [Table 3].

This result shows that with the same kV and mAs, the attenuation of exposure dose according to the thickness of the aluminum added filtration is different and that as the tube voltage goes up, it is not affected by the increase in thickness of the added filtration and the reduction of exposure dose stays the same regardless of the tube current. This study result showed the same result as the other research results[4,5,23]. This suggests that the added filtration can be used effectively for high tube voltage.

3.2 Entrance Exposure of CNR and SNR according to the Changes in Thickness of the Al Added Filtration

The CNR and SNR result is as shown in Table 4, by using m-view program in the mandible and orbit area after establishing ROI (Region of Image) of 0.3 × 0.3 cm^2 from the acquired image under the condition of 60 kV, 20 mAs and 100 cm of through skull phantom.

We could confirm that the values of CNR and SNR went down as the Al added filtration got thicker showing the similar tendency to the observational area of mandible and orbit. (P 〈0.05)

The Digital Radiography system detectors tend to show increase in the detecting effectiveness in proportion to the exposure dose rate and improvement in the image quality in proportion to SNR. However, even though the SNR is high, if the CNR that can distinguish the tissues is not high enough, it is hard to gain the optimum image which gives excellent diagnostic information.

Table 3. Distribution of entrance surface dose percentage in added filter

kV	mAs	Thickness (mmAl)			
		Non	0.1	0.2	0.5
40	5	100	96.04	91.32	74.07
	10	100	95.80	91.02	78.98
	20	100	95.18	90.92	78.51
50	5	100	96.30	93.18	81.51
	10	100	96.52	92.85	81.84
	20	100	95.75	92.15	81.16
60	5	100	95.56	93.68	83.49
	10	100	96.78	94.86	83.25
	20	100	97.03	93.86	83.96
70	5	100	96.85	94.79	85.06
	10	100	96.46	94.52	85.13
	20	100	96.74	94.01	85.18

Table 4. CNR and SNR of skull phantom

	Thickness (mmAl)	CNR	SNR	p-value
Orbit	non	10.31	15.34	<0.05
	0.1	9.98	14.87	
	0.2	9.64	14.53	
	0.5	9.30	13.53	
Mandible	non	7.23	11.69	
	0.1	7.08	11.13	
	0.2	6.59	10.28	
	0.5	5.83	9.86	

The result of this test showed that the reduction degree of SNR and CNR was different according to the thickness of added filtration and the areas of observation, which confirms that the application of added filtration according to the areas of test needs to be examined.

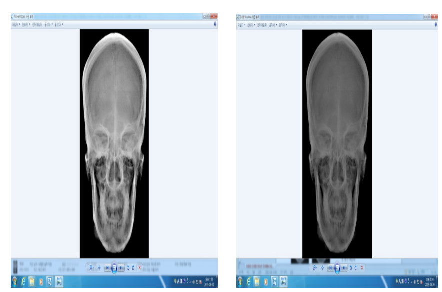
3.3 The Qualitative Evaluation of the Image According to the Changes in Thickness of the AI Added Filtration

As shown in Table 5, the result of the qualitative analysis of the contrast, clarity of boundaries and lesion detectability under the same tube voltage when Al added filtration was used did not show statistical significance.

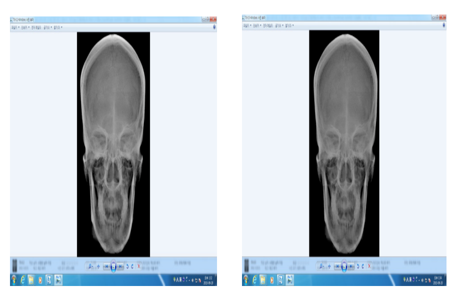
However, the result of the qualitative analysis of the contrast, clarity of boundaries and lesion detectability according to the changes in tube voltage when Al added filtration was not used showed statistical significance (P 〈0.05). This result shows that securing the tube voltage higher than 60 kV will contribute to acquiring the diagnostically valuable image in dental radiation energy area [Figures 4 and 5].

Table 5. Evaluation of the clinical images

Item	kV		Thickness (mmA1)		
		Non	0.1	0.2	0.5
Contrast	40	1.38	1.29	1.21	1.20
	50	3.30	3.45	3.48	3.20
	60	4.12	4.26	4.30	4.21
	70	4.05	4.29	4.10	4.10
Clarity of boundaries	40	1.34	1.12	1.10	1.10
	50	3.21	3.36	.357	3.45
	60	4.15	4.31	4.26	4.21
	70	4.11	4.25	3.98	3.90
Lesion detectability	40	1.35	1.20	1.12	1.12
	50	3.28	3.41	3.35	3.27
	60	4.11	4.26	4.17	4.10
	70	4.02	4.15	4.00	4.00

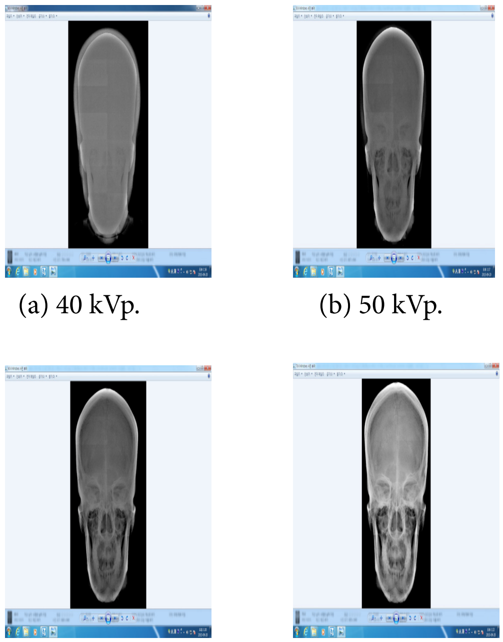


(a) non (b) 0.1 mm



(c) 0.2 mm. (b) 0.5 mm.

Figure 4. Added Al filter in accordance with changes in skull phantom imaging.



(a) 40 kVp. (b) 50 kVp.

(c) 60 kVp. (d) 70 kVp.

Figure 5. Non added Al filter in accordance with changes in tube voltage in skull phantom imaging.

Utilizing digital radiographic image acquisition system has brought changes in the radiation exposure environment in the medical radiation field. The digital medical environment can maximize the convenience of the users but in order to reduce the noise of the projection and improve the image quality, the radiation exposure of the patients can be increased[21,22].

The diagnostic radiography to acquire the medical image makes up the majority of the radiation exposures conducted by human being. The recent tendency is minimizing the radiation exposure while acquiring the medical image with excellent diagnostic image information through minimum use of radiation.

It has been found that the image quality is different according to the changes in the tube voltage in Digital Radiation images and that the used energy of the tube voltage is different according to the targeted organs. This result coincides with the result of this study[23].

As for the use of added filtration, since the diagnostic information changes according to the tube voltage in different test areas, the diagnostic test in dental area needs to be done above 60 kV [Table 5], [Figure 5].

The result shows that when conducting dental test, we need to use the tube voltage higher than certain level and proper added filtration. People working in this area need to put a lot of effort and attention into this matter to minimize the exposure dose of human body and acquire the optimum image with high diagnostic value.

In addition, it will be a great help if the groups or conferences that utilize radiography regularly educate the people working in the radioactive test field on the radiation exposure and the image quality. We need to do our best to secure the validity through minimizing the radiation exposure caused by radioactive tests and to optimize the radiation defense of the patients.

4. Conclusion

This study measured and assessed the image quality from the radiation exposure and the acquired image using aluminum filters in an aim to provide basic data for minimizing the exposure dose in X-ray test from dental Digital Radiography system and gaining the optimum image for diagnosis.

The reduction of entrance exposure dose showed difference of 3.15-25.93 % according to the thickness of aluminum added filtration and conditions of test, but it showed the consistent tendency regardless of the tube current (mAs) if the tube voltage goes up.

The measurement value of CNR and SNR showed difference depending on the test areas and statistically significant value for the difference in radiation intensity.

In dental radiation tests, in terms of the qualitative evaluation, the image quality was excellent above 60 kV and with the thickness of 0.1 mm for the added filtration.

It is expected that this result will be utilized actively as a basic data for reducing the medical radiation exposure through providing the data to expect the application of aluminum added filtration in the dental diagnostic tests and decide the test methods.

5. Acknowledgement

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