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Effective Dose from Direct and Indirect Digital Panoramic Units

朝鮮大學校 大學院

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Effective Dose from Direct and Indirect Digital Panoramic Units

직 · 간접 디지털파노라마의 유효선량

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목 차

표목차

도목차

\<국문초록\>

직 · 간접 디지털파노라마의 유효선량

이근선

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서론; 최근 다양한 디지털 파노라마 장치가 이용되고 있다. 방사선 검사를 할 때 이들의 방사선 위험도가 정확히 비교 평가되어야 할 필요가 있다. 이 연구는 판톰과 노출에 따른 직접 및 간접 디지털 파노라마 방사선 촬영 시 유효선량을 비교하고 유효선량 계산 시 관여 조건을 평가하기 위한 것이다. 이를 위하여 두경부 판톰과 전신 판톰을 이용하고 4종의 디지털 파노라마 촬영을 시행하여 등가선량과 유효선량을 계산하였다.

연구방법: 두부판톰 (남자형)과 전신판톰 (여자형) 2개의 계측판톰 (Rando, Alderson Research Laboratories, Long beach, CA)을 이용하여 4종의 디지털 파노라마 촬영을 시행하였다. TLD칩은 Harshaw TLD-100 (Thermo Electron Co, Oakwood Village, OH) 60개 와 96 개의 TLD 두 세트를 사용하여 선택된 부위에서 흡수선량을 측정하였다. 각 판톰의 내부와 표면에 30 부위 (두부)와 48 부위 (전신)를 선택하여 부착하였고. Ludlow와 Ivanovic의 24 부위와 비교되었다. 모든 dosimeter는 실험중 동일 형태와 범위 내의 방사선을 사용하여 계산되었다. 매 방사선 노출 전 TLD는 100℃에서 1 시간, 400℃에서 2 시간 anealing하고 나서 35℃까지 식혔다. 모든 TLD는 각 노출 후 Harshaw 3500 TLD 판독기 (Harshaw/Bicron, Solon, OH)를 이용하여 제조사의 지시에 따라 판독, 각 장기의 여러 부위에 위치시킨 TLD로 부터 측정된 모든 흡수선량을 평균하여 그 장기의 평균흡수선량으로 하고, 이때 항상 배경방사선을 공제하였다. 그 조사받은 장기가 해당 장기 전체의 몇 퍼센트에 해당하는가를 추정하여 이를 각 장기의 평균흡수

선량에 곱하여 전신등가치화 한 다음, 방사선가중계수를 곱한 등가선량 (equivalent dose; H_T)를 구하고. 유효선량은 $E = \Sigma H_T \times W_T$, 즉 각 장기가 받은 등가선량에 조직가중계수 (W_T)를 곱한 값의 합으로 구하였다. 조직가중계수는 2007 weighting factor가 사용되었다.

실험 결과: 서로 다른 파노라마장치에 대한 유효선량의 범위는 8.9 μSv에서 39.0 μSv를 나타내었다. 두부판톰 사용시 직접디지털 파노라마장치인 ProMax와 ProlineXC의 유효선량이 37.8, 27.6 μSv로 간접디지털 파노라마장치인 Orthopantomograph OP100과 ProlineXC의 8.9, 15.9 μSv 보다 높았다. Orthopantomograph OP100 (CR)에서 72 kVp, 12mA의 노출로 전신판톰을 사용하여 두부만 계산한 유효선량은 13.6 μSv를 나타내었고, 두부판톰를 사용하면 8.9 μSv를 나타내었다. ProlineXC (DR)에서 70 kVp, 12mA의 노출로 전신판톰을 사용하여 두부만 계산한 유효선량은 36.8 μSv를 나타내었고 두부판톰에서는 27.6 μSv를 나타내었다. 직,간접디지털 파노라마장치 모두, 여자에 해당하는 전신판톰 사용한 두부계산 유효선량이 남자에 해당하는 두부판톰 사용 유효선량보다 높았다. 두부 및 전신판톰을 사용한 모든 경우에서 Ludlow와 Ivanovic의 계산법에 의한 유효선량이 본 실험의 계산법에 의한 유효선량보다 낮았다. 동일 파노라마장치에서 보다 높은 kVp를 사용했을 때 낮은 kVp를 사용했을 때 보다 유효선량이 높았다.

결론: 두부판톰과 전신판톰 사용 모두에서 직접디지털 파노라마장치가 간접디지털 파노라마장치 보다 유효선량이 높았다. 그러나 동일한 파노라마장치를 사용하더라도 사용된 판톰의 성별, TLD의 수와 위치 그리고 kVp의 변화에 따라 유효선량은 다르게 나타났다. 따라서 다양한 치과 방사선장치에 대한 방사선위험도를 비교하기 위하여는 임상에서 통상 사용하는 노출조건을 이용하고, 동일한 판톰의 위치, 동일한 TLD의 부착 부위와 수를 이용하되, 판톰에 따른, 즉 성 (gender)에 따른 유효선량이 평가될 필요가 있다고 생각된다.

I. INTRODUCTION

Panoramic radiographs are widely used as a diagnostic tool because it is easy to produce a radiographic overview of teeth and surrounding anatomical structures.[1-2] Recently, a growing number of dental practitioners prefer digital radiography to conventional film radiography.[3-6] One of the main advantages of digital radiography compared with conventional film radiography is the possibility to save radiation dose.[7] Diagnostic benefit and possible dose hazards trade-offs are important considerations in choices of radiographic procedures. Because X-ray risks are cumulative, it is imperative that the choice of radiographic unit for dose reduction be considered in examining all patients.[8] Some different digital panoramic units should be evaluated and be used for the application of as-low-as-reasonably achievable principles to maxillofacial panoramic imaging.

The use of Effective dose (E) is a concept and approach recommended by the International Commission on Radiological Protection (ICRP)[9] to estimate damage from radiation to an exposed population. E is a widely used calculation that permits comparison of the detriment of different exposures, including specific area exposure,[10] to ionizing radiation to an equivalent detriment produced by a full body dose of radiation.[8] White[11] used this approach in 1992 when assessing the radiation risk from various dental radiographic examinations. Effective dose, expressed in Sv, is calculated using the equation: $E = \Sigma H_T \times W_T$ where E is the product of the tissue weighting factor (W_T), which represents the relative contribution of each organ or tissue to the overall risk, and the equivalent dose H_T.[12] The whole-body risk is found by the summation of the weighted equivalent doses to all tissues or organs exposed. The earlier 1990 ICRP tissue-weighting factors,[13] 2005 weighting factors, and the new 2007 weighting factors[12] were used to calculate effective dose.[7,8,14] Newly adopted recommendations of ICRP provide revision of tissue-weighting factors and inclusion of salivary glands as a weighted tissue. These changes will likely

result in an upward reassessment of effective dose from oral and maxillofacial radiographic examinations.[12]

The studies of the absorbed dose or effective dose from each exposure program of the film based panoramic machine with a limbless whole body phantom and a head phantom respectively were reported by Lecomber et al (2000)[15] and Choi et al (2001)[16]. The tissue-absorbed dose and the whole-body effective dose (E) for a new generation film based panoramic machine (Planmeca PM 2002 CC Proline), operating in the panoramic examination mode with a head phantom was studied by Danforth et al (2000)[14]. Gijbels et al[7] reported that effective radiation doses ranged between 4.7 μSv and 14.9 μSv for the various digital panoramic units with a head phantom using the recommendations of ICRP adopted in 2005.

Few studies have been reported about the difference in radiation dose between direct and indirect digital panoramic exposures. And, to our knowledge, no studies have been published about the difference in the calculation of effective dose between using head and whole body phantom.

Ludlow and Ivanovic (2008)[8] reported that an even greater difference was seen between the Iluma CBCT unit "Standard" exposure and the "Ultra" exposure and described that a substantial difference in effective doses from the same unit were seen with the technique variations. As above, it is necessary to prepare the standardized conditions for calculation of effective dose to compare the radiation risk from various dental radiographic examinations.

The aim of the present study is to provide comparative measurements of effective dose from direct and indirect digital panoramic units with phantom and exposure parameters. Average tissue-absorbed dose, weighted (equivalent) radiation dose, and effective dose were calculated for the anatomy of the head and neck area and the whole body with the corresponding phantom respectively.

II. MATERIALS AND METHODS

Dosimetry

Dose measurements were carried out on two anthropomorphic phantoms (Rando, Alderson Research Laboratories, Long beach, CA). The head phantom representing an average man (175 cm tall, 73.5 Kg male) (Fig. 1) and the limbless whole body phantom representing an average woman (155 cm tall, 50 Kg female) (Fig. 2) are consisted of 9 and 31 transverse sections respectively. The reservoirs for the placement of radiation dosimetry measuring devices were prepared to correspond to the anatomic sites of interest. Lithium fluoride thermoluminescent dosimeter (TLD) chips (Harshaw TLD-100, Thermo Electron Co, Oakwood Village, OH) were used as dosimeter. The absorbed doses at selected locations, corresponding to the radiosensitive organs of interest, were measured using two sets of 60 and 96 TLDs. The 30 and 48 phantom sites both inside and on the surface of each phantom can be seen in Table 2. Two dosimeters were placed in each anatomical site to calculate the mean value of each location, while retaining the same dosimeters in the same positions for

Fig. 1. The limbless woman whole body phantom

Fig. 2. The head phantom representing a man

each exposure. A set of dosimeters were kept separately to record the background radiation. Before the study, all dosimeters were calibrated using the same type and range of radiation that would be used during the experiments. Prior to every exposure, the dosimeters were annealed at 100°C for 1 hr, 400°C for 2 hrs and then cooled to 35°C. All TLDs were read in accordance with the manufacturer's directions after each exposure using a Harshaw 3500 TLD Reader (Harshaw/Bicron, Solon, OH).

Exposures

The digital panoramic units used for this study were ProMax (Planmeca, Helsinki, Finland), Orthopantomograph OP100 (Imaging, Tusula, Finland) and 2 ProlineXC (Planmeca, Helsinki, Finland). Table 1 shows the technical and phantom parameters for each unit used. Taking the small amount of radiation and the exposure latitude of the TLDs into account, after loading with TLDs, the phantom was exposed ten times in order to provide a reliable measurement of radiation by the dosimeters. Later, these values were divided by ten to provide one individual value for each region after subtraction of each background dose. The phantom was positioned in accordance with the manufacturer's specifications for each machine, following the reference lines and head rests. The standard examination was carried out for each unit and the dosimetry was performed two times for each technique in order to ensure reliability.

Table 1. Exposure and phantom parameters for the panoramic units

	ProMax	ProlineXC		ProlineXC	Orthopantomograph		
Type	Direct	Direct		Indirect	Indirect		
kVp	70	70	70	70	72	72	83
mA	10	12	12	12	12	12	12
Phantom	Head	Body	Head	Head	Body	Head	Head

Dose calculations

After reading, an individual sensitivity value was applied for each TLD. Exposure doses were recorded in nanocoulombs (nC) and, after the application of energy calibration factors (RCF, reader calibration factor; and ECC, element correction coefficient), the dosimetry data were converted into micrograys (uGy) and subsequently recorded. The standard deviation of the readings from TLD-100 is less than 30%. Doses from the two TLDs located at different points in the same tissue or organ were averaged, resulting in the average organ absorbed dose. The weighted dose for bone marrow of whole body phantom was calculated using the sum of the radiation from calvarium, mandibular body and ramus, cervical, thoracic and lumbar vetebra, and sacrum. The weighted dose for bone marrow of head phantom was calculated using the sum of the radiation from calvarium, mandibular body and ramus, and cervical vertebra. Sublingual, submandibular and parotid salivary gland doses were used for calculating the weighted dose for salivary glands. The thyroid gland dose was individually calculated taking its specific weighted factor into consideration. For the skin surface area, fifteen points were measured: posterosuperior surface of head, thyroid surface, back of thorax, and both sides of right and left of temporal region, lens of eye, cheek, back of neck, axilla, and breast (Table 2).

The products of these average organ absorbed doses and the percentage of a tissue or organ irradiated (Table 3, 4) in a radiographic examination were used to calculate the equivalent dose (H_T) in microsieverts (μSv).[12] The effective dose was calculated by multiplying actual organ doses (equivalent dose; H_T) by 'risk weighting factors' as follows: $E = \Sigma H_T \times W_T$. The tissue weighting factor (W_T) represents the contribution that each specific tissue or organ makes to the overall risk. The whole-body risk was found by the summation of the tissue weighted equivalent doses to all tissues or organs exposed. This dose was expressed in microsieverts (μSv). In this study, author used the weighting factors (Table 5), including salivary tissue in the risk estimation, approved by the ICRP Main Commission[12]. The obtained effective dose from each panoramic

unit was compared with the dosimetric values calculated from the 24 anatomical sites of phantoms used by Ludlow and Ivanovic[8].

Table 2. Locations of TLD chips in phantoms

Head and Neck	ID	Body	ID
Posterosuperior surface	1	Right lung (13)	31
Right temporal surface (2)	2	Left lung (13)	32
Left temporal surface (2)	3	Thoracic spine (13)	33
Calvarium anterior (2)	4	Back (13)	34
Calvarium right (2)	5	Right axilla (14)	35
Calvarium left (2)	6	Left axilla (14)	36
Calvarium posterior (2)	7	Right breast surface (15)	37
Mid brain (2)	8	Left breast surface (15)	38
Pituitary (3)	9	Heart (15)	39
Right lens of eye (3)	10	Stomach (18)	40
Left lens of eye (3)	11	Liver (18)	41
Right orbit (4)	12	Right kidney (22)	42
Left orbit (4)	13	Left kidney (22)	43
Right cheek (5)	14	Lumber vertebra (24)	44
Left cheek (5)	15	Sacrum (27)	45
Right parotid (6)	16	Right ovary (29)	46
Left parotid (6)	17	Left ovary (29)	47
Right ramus (6)	18	Bladder (31)	48
Left ramus (6)	19		
Center C spine (6)	20		
Right back of neck (7)	21		
Left back of neck (7)	22		
Right mandible body (7)	23		
Left mandible body (7)	24		
Right submandibular gland (7)	25		
Left submandibular gland (7)	26		
Center sublingual gland (7)	27		
Midline thyroid (9)	28		
Thyroid surface (9)	29		
Esophagus (9)	30		

Table 3. Estimated percentage of tissue irradiated with head phantom

Head and Neck		ID	%
Bone marrow			16.5
	Mandible	18, 19, 23, 24	1.3
	Calvaria	1-7	11.8
	Cervical spine	20	3.4
Thyroid		28,29	100.0
Esophagus		30	10.0
Skin		1-3 ,10, 11, 14, 15, 21, 22, 29	9.0
Bone surface*			16.5
	Mandible	18, 19, 23, 24	1.3
	Calvaria	1-7	11.8
	Cervical spine	20	3.4
Salivary glands			100.0
	Parotid	16, 17	100.0
	Submandibular	25, 26	100.0
	Sublingual	27	100.0
Brain		8, 9	100.0
Remainders			
	Lymphatic nodes	16-20, 23-28, 30	10.0
	Muscle	16-20, 23-28, 30	5.0
	Extrathoracic airway	12, 13, 16-20, 23-28, 30	100.0
	Oral mucosa	16-19, 23-27	100.0

* Bone surface dose = bone marrow dose x bone/muscle mass energy absorption, coefficient ratio=-0.0618 x 2/3 kV peak + 6.9406 using data.[cited from 8]

Table 4. Estimated percentage of tissue irradiated with whole body phantom

Whole body		ID	%			ID	%
Bone marrow				Salivary glands			100.0
	Mandible	18, 19, 23, 24	1.3		Parotid	16, 17	100.0
	Calvaria	1–7	11.8		Submandibular	25, 26	100.0
	Cervical spine	20	3.4		Sublingual	27	100.0
	Thoracic spine	33	14.1	Brain		8, 9	100.0
	Lumbar vertebra	44	10.9	Remainders			
	Sacrum	45	13.9		Lymphatic nodes	16–20, 23–28, 30, 35, 36, 39	40.0
Colon		41–43, 48	100.0		Muscle	16–20, 23–28, 30, 33, 44, 45	43.9
Lung		31, 32, 39	100.0		Extrathoracic airway	12, 13, 16–20, 23–28, 30	100.0
Stomach		39, 40	100.0		Oral mucosa	16–19, 23–27	100.0
Breast		37, 38	100.0		Adrenals	40	100.0
Gonads		46, 47	100.0		Gall bladder	41	100.0
Bladder		48	100.0		Heart	39	100.0
Liver		41	100.0		Kidneys	42, 43	100.0
Thyroid		28,29	100.0		Pancreas	40	100.0
Esophagus		30, 39	100.0		Small intestine	42, 43	100.0
Skin		1–3,10, 11, 14, 15, 21, 22, 29, 34–38	36.0		Spleen	40	100.0
Bone surface*			16.5		Thymus	39	100.0
	Mandible	18, 19, 23, 24	1.3		Uterus/cervix	48	100.0
	Calvaria	1–7	11.8				
	Cervical spine	20	3.4				
	Thoracic spine	33	14.1				
	Lumbar vertebra	44	10.9				
	Sacrum	45	13.9				

* Bone surface dose = bone marrow dose x bone/muscle mass energy absorption coefficient ratio=−0.0618 x 2/3 kV peak + 6.9406 using data.[cited from 8]

Table 5. Tissue weighting factors for calculation of effective dose 2007[12] recommendations

Tissue/Organ	Weighting factor 2007
Bone marrow	0.12
Breast	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.04
Esophagus	0.04
Gonads	0.08
Liver	0.04
Thyroid	0.04
Bone surface	0.01
Brain	0.01
Kidney	Remainder
Salivary glands	0.01
Skin	0.01
Remainder tissues	0.12†

† ; Adrenals, *extrathoracic region*, gall bladder, heart, kidneys, *lymphatic nodes*, *muscle*, *oral mucosa*, pancreas, prostate, small intestine, spleen, thymus, and uterus/cervix. Italicized text represents remainder tissues used for calculation of maxillofacial dose.

III. RESULT

The dosimetric results can be found in Table 6. The equivalent doses and the effective doses were expressed in µSv. The greatest individual organ doses for all examination were measured in the salivary tissue.

Effective radiation doses ranged between 8.9 µSv and 37.8 µSv for the 4 digital panoramic units. By using head phantom, the effective doses from direct digital panoramic units of ProMax (37.8 µSv) and ProlineXC (27.6 µSv) were higher than those from indirect units of Orthopantomograph OP100 (8.9 µSv) and ProlineXC (15.9 µSv).

The effective dose from the same panoramic unit (Orthopantomograph OP100) using same head phantom was higher with 83 kVp than with 72 kVp.

Table 6. Equivalent dose (H_T) to tissues/organs and Effective doses from direct (DR) and indirect (CR) digital panoramic units   unit; µSv

	ProMax (DR)	ProlineXC (DR)		ProlineXC (CR)	Orthopantomograph (CR)		
kVp (mA)	70 (10)	70 (12)		70 (12)	72 (12)		83 (12)
Phantom	Head	Head	Body	Head	Head	Body	Head
Bone marrow	33.4	18.5	24.6	14.2	8.2	8.9	8.1
Colon			1.0			0.0	
Lung			3.4			0.7	
Stomach			2.0			0.0	
Breast			0.8			0.0	
Gonads			2.4			0.0	
Bladder			2.3			0.0	
Liver			0.2			0.0	
Thyroid	73.7	37.5	41.8	26.9	28.8	14.9	25.0
Esophagus	10.6	4.4	22.3	4.6	4.4	7.0	3.5
Skin	10.2	7.0	10.2	5.7	3.4	3.8	3.7
Bone surface*	135.6	75.0	99.8	57.7	32.7	35.3	28.6
Salivary glands	1161.1	880.9	1214.6	522.5	203.0	447.1	414.0
Brain	29.2	14.9	25.0	1.6	5.2	9.2	6.5
Remainders	1853.2	1510.9	2036.2	761.8	451.3	754.2	652.9
Effective dose	37.8	27.6	39.0	15.9	8.9	13.9	12.7

Table 7. Comparison of effective doses with parameters　　　　　unit; μSv

	Type	kVp	mA	Phantom		Effective dose
ProMax	Direct	70	10	Man	Head	37.8
ProlineXC	Direct	70	12	Woman	Body	39.0
					Head (cal)*	36.8
				Man	Head	27.6
ProlineXC	Indirect	70	12	Man	Head	15.9
Orthopantomograph	Indirect	72	12	Woman	Body	13.9
					Head (cal)	13.6
				Man	Head	8.9
		83	12	Man	Head	12.7

∗ Head (cal); calculation of only head portion of whole body phantom.

Comparison of effective doses with parameters; exposure, phantom (gender), and calculation method can be found in Table 7.

The effective dose from ProlineXC (DR) with exposure of 70 kVp, 12mA was 36.8 μSv by the calculation for head region of whole body phantom and 27.6 μSv by head phantom. The effective dose from Orthopantomograph OP100 (CR) with exposure of 72 kVp, 12mA was 13.6 μSv by the calculation for head region of whole body phantom and 8.9 μSv by head phantom. The effective dose from direct and indirect digital unit respectively was higher with female phantom than with male one.

The effective doses calculated by Ludlow and Ivanovic method were lower than those calculated by author from each panoramic examination.

IV. DISCUSSION

The equivalent dose is used to compare the effects of different types of radiation on tissues or organs, presented as sievert (Sv). The equivalent dose (H_T) were calculated according to the equation: $H_T = \Sigma W_R \times D_T$, where the equivalent dose (H_T) for a tissue or organ is the product of the radiation weighting factor (W_R) and the average absorbed dose (D_T) measured for that specific organ.[13] The products of these values and the percentage of a tissue or organ irradiated (Table 3) in a radiographic examination were used to calculate the equivalent dose (H_T) in microsieverts (Sv).[12]

The equivalent doses from indirect and direct digital panoramic radiographys were highest in remainders and salivary glands (Table 6). Equivalent dose to another organs were high in order of bone surface, thyroid gland, and bone marrow. Several studies on panoramic units have pointed out the salivary gland tissue receives one of the highest individual organ doses during maxillofacial imaging[7,15,17] and author's results confirmed these findings. Lecomber et al[15] indicated that the influence on the calculated effective dose of treating the salivary tissue as a remainder organ deserved discussion in 2000. Ludlow and Ivanovic[8] explained with the fact that the rotational centers of panoramic units for the jaws coincide with the location of the salivary glands. Because anatomy at the rotational center is continuously exposed, effective doses from dental panoramic imaging will be larger than imaging procedures that produce a more uniform distribution of absorbed energy within the scanned region. It seems reasonable to include salivary gland exposures in calculations of effective dose until these exposures could be shown to be not significant.[18] The effective doses in this study were calculated with inclusion of the salivary gland tissue using 0.01 in 2007 ICRP tissue weights[12]. Dental radiographic examinations resulted in negligible doses to the gonads and hereditary doses were not effective for the calculation of detriment in this study. The use of head phantom or the only head region calculation of whole body phantom is thought

to be reasonable for the calculation of detriment from dental radiographic examinations.

The effective dose is the product of the ICRPs tissue weighting factor (W_T) for the type of tissue or body and the human-equivalent dose for tissue (H_T). The effective dose is calculated by multiplying actual organ doses by 'risk weighting factors' (associated with individual organ sensitivities)and represents the dose that the total body could receive and that would provide the same cancer risk as the application of different doses to various organs.[13] One sievert of effective dose carries with it a 4.1% chance of developing a fatal cancer in an adult worker and a 5.5% chance in a whole population, and a 0.8% chance of hereditary defect in future offspring.[12] The ICRP recommends limiting artificial irradiation of the public to an average of 1 mSv of effective dose per year, not including medical and occupational exposures.[12]

The effective doses from direct digital panoramic units of ProMax (37.8 µSv) and ProlineXC (27.6 µSv) were higher than those from indirect units of Orthopantomograph OP100 (8.9 µSv) and ProlineXC (15.9 µSv) by using head phantom (Table 7). Gijbels et al[7] reported that comparable results (9.35 mSv for CCD, 8.1 mSv for storage phosphor) were found for the various digital panoramic units, when the effective dose data of the direct panoramic units are averaged and compared with the indirect units. The effective doses from both types of digital panoramic unit evaluated in this study were larger than their results.

With the reason that comparison of the effective doses from the different panoramic units was difficult because of the different exposure settings, Gijbels et al[7] reported that by considering per unit of exposure (mAs), the Orthoralixw yielded the lowest dose per mAs (0.10 mSv mAs^{-1}), but the Veraviewepocsw the highest (0.17 mSv mAs^{-1}) and that the influence of the tube potential was less clear. Actually, for the comparison of the effective doses from the different units having different exposure settings recommended for the preservation of diagnostic image quality, the doses per unit of exposure are thought to be not significant. In the present study design, the X-ray parameters used were those

for an adult as usual in hospital. The obtained results itself are thought to be available for the comparison of effective doses from several digital panoramic units considering respective technical aspects of each radiation unit for good image quality such as the size of the radiation field and shape of the focal trough.

With phantom parameters, the effective dose (13.6 μSv) from indirect digital panoramic unit by the calculation for head region of whole body phantom was higher than one (8.9 μSv) by head phantom. The effective dose (36.8 μSv) from direct unit by the calculation for head region of whole body phantom was also higher than one (27.6 μSv) by head phantom (Table 7). That is, the effective dose was higher with female phantom than with male phantom in both types of digital unit. This is because the absorbed dose at each TLD dose in the phantom depends on skull size[19], and soft tissue morphology of the phantom, which simulate an actual man and woman.

The effective dose calculated from the 24 anatomical sites of phantom used by Ludlow and Ivanovic[8] was lower than the obtained effective dose from each panoramic unit in this study. The numbers of anatomical sites of phantom for the calculation of effective dose by them were less than the numbers of anatomical sites in this study. Furthermore, the difference of the location (left, center, right) and numbers of sites for TLD at the selected same organs can be accounted for the small difference in effective dose between two calculations.

Besides, small variations in collimator adjustment or phantom position within the unit may account for the very nearly 23% difference seen between the dosimeter values for the 2 modes of one unit.[8] The slight discrepancy in the location of the TLD or phantom position are magnified as the TLD is positioned in or out of the field of direct radiation.[18]

Conclusively, even the same panoramic unit showed the difference in effective doses according to the gender of phantom, numbers and location of TLD, and kVp.

Ⅴ. CONCLUSION

The effective doses from direct digital panoramic units were higher than from indirect units. To assess reasonably the radiation risk from various dental radiographic units, the effective doses should be obtained with the same numbers and location of TLD, and with usual hospital exposure. After that, the survey for the effective doses from various dental radiographic units is needed to be performed according to the gender with corresponding phantom.

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저작물 이용 허락서

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논문제목	한글 : 직ㆍ간접 디지털파노라마의 유효선량 영어 : Effective Dose from Direct and Indirect Digital Panoramic Units

　　본인이 저작한 위의 저작물에 대하여 다음과 같은 조건아래 조선대학교가 저작물을 이용할 수 있도록 허락하고 동의합니다.

- 다   음 -

1. 저작물의 DB구축 및 인터넷을 포함한 정보통신망에의 공개를 위한 저작물의 복제, 기억장치에의 저장, 전송 등을 허락함
2. 위의 목적을 위하여 필요한 범위 내에서의 편집ㆍ형식상의 변경을 허락함. 다만, 저작물의 내용변경은 금지함.
3. 배포ㆍ전송된 저작물의 영리적 목적을 위한 복제, 저장, 전송 등은 금지함.
4. 저작물에 대한 이용기간은 5년으로 하고, 기간종료 3개월 이내에 별도의 의사 표시가 없을 경우에는 저작물의 이용기간을 계속 연장함.
5. 해당 저작물의 저작권을 타인에게 양도하거나 또는 출판을 허락을 하였을 경우에는 1개월 이내에 대학에 이를 통보함.
6. 조선대학교는 저작물의 이용허락 이후 해당 저작물로 인하여 발생하는 타인에 의한 권리 침해에 대하여 일체의 법적 책임을 지지 않음
7. 소속대학의 협정기관에 저작물의 제공 및 인터넷 등 정보통신망을 이용한 저작물의 전송ㆍ출력을 허락함.

동의여부 : 동의(O) 반대(   )

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