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Effect of field of views on cone beam computed tomography radiation dose: phantom study

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Background : *Cone beam computed tomography (CBCT) devices with various types of field of view (FOVs) are currently available in dentistry. Thus, the selection of proper FOVs and number of scans should be considered according to the clinical applications and ALARA principle.*

Objective : *To study the effect of the number of scans and FOVs: one scan of large FOV, one scan of medium FOV and multi-scans of small FOVs, on the radiation dose from CBCT systems using a phantom.*

Research design : *Experimental study (in vitro).*

Setting : *Oral and Maxillofacial Radiology Clinic, Faculty of Dentistry, Mahidol University*

Methods : *Radiation doses from various FOVs of 3 CBCT devices were determined and recorded using a RANDO phantom. As for 3D Accuitomo170, C_{VOL} (mGy), DLP (mGy.cm) and the effective dose (E:μSv) were determined. As for Kodak devices, DAP (mGy.cm^2) was recorded. In two or three scans of small FOV, E and DAP were obtained from calculation.*

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Results : *As for 3D Accuitomo170, C_{VOL}(mGy), DLP(mGy.cm), E(μSv) of FOV (diameter (cm) × height (cm)) 17 × 5 and 17 × 12 were 7.7, 38.5, 88.55 and 6.4, 76.8,176.64, respectively. As for Kodak devices, FOV (diameter (cm) × height (cm)) 5 × 3.7, 15 × 9, 20.6 × 18 and multi-small FOVs (width (cm) × depth (cm) × height (cm)) 9.3 × 5 × 3.7, 9.3 × 7.4 × 3.7, DAP values were 131, 211, 502 and 261, 392 mGy.cm^2 respectively. Two and three scans of FOV 5 × 3.7 were 262 and 393 mGy.cm^2, respectively.*

Conclusion : *The CBCT radiation dose is affected by the field size and number of scans taken. In one scan, the radiation dose is higher when the FOVs increase. In the same FOV, the radiation dose increases with the number of scans taken. However, one scan of medium FOV provides less radiation dose than two and three scans of small FOV. Thus, when two or three localized region are required, one scan of medium FOV is more recommended than two or three scans of small FOV. As large FOV provides highest radiation dose, it is therefore recommended to use when the maxillofacial region is required.*

Keywords : *Cone beam computed tomography, CBCT, dosimetry, multi-scans of small FOV, dose area product.*

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วรางคณา วีระวานิช, อัญชลี กฤษณจินดา. ผลของฟิลด์อ็อฟวิวต่อปริมาณรังสีของเครื่องถ่ายภาพรังสีตัดขวางอาศัยคอมพิวเตอร์ชนิดลำรังสีรูปกรวย: ศึกษาในหุ่นจำลอง. จุฬาลงกรณ์เวชสาร 2558 ม.ค. – ก.พ.; 59(1): 23 – 35

เหตุผลการทำวิจัย : *ในปัจจุบันเครื่องถ่ายภาพรังสีตัดขวางอาศัยคอมพิวเตอร์ชนิดลำรังสีรูปกรวยที่ใช้ในทางทันตกรรมมีหลายแบบ ซึ่งแต่ละแบบมีฟิลด์อ็อฟวิวหลายขนาดให้เลือกใช้ตามความเหมาะสม การเลือกใช้ฟิลด์อ็อฟวิวและจำนวนครั้งในการสแกน ขึ้นอยู่กับการนำไปใช้ทางคลินิก และหลักการลดปริมาณรังสีจนเป็นที่ยอมรับ (ALARA)*

วัตถุประสงค์ : *เพื่อศึกษาผลของจำนวนครั้งที่สแกนและขนาดฟิลด์อ็อฟวิว ได้แก่ ขนาดใหญ่ 1 ครั้ง ขนาดกลาง 1 ครั้ง และขนาดเล็กหลายครั้ง ต่อปริมาณรังสีจากเครื่องถ่ายภาพรังสีตัดขวางอาศัยคอมพิวเตอร์ชนิดลำรังสีรูปกรวย 3 เครื่อง โดยใช้หุ่นจำลอง*

รูปแบบการวิจัย : *การศึกษาเชิงทดลอง (นอกกาย)*

สถานที่ทำการศึกษา : *คลินิกรังสีวิทยาช่องปากและใบหน้า ขากรรไกรคณะทันตแพทยศาสตร์ มหาวิทยาลัยมหิดล*

วิธีการศึกษา : *ทำการศึกษาปริมาณรังสีจากเครื่องถ่ายภาพรังสีตัดขวางอาศัยคอมพิวเตอร์ชนิดลำรังสีรูปกรวย 3 เครื่อง ในหุ่นจำลอง โดยใช้ฟิลด์อ็อฟวิว ขนาดต่างๆ กันโดยศึกษาปริมาณรังสีในปริมาตรเป็นค่าซีวอลลุ่ม (มิลลิเกรย์) ปริมาณรังสีตามความยาวของการสแกน (มิลลิเกรย์.เซนติเมตร) และปริมาณรังสียังผล (ไมโครซีเวิร์ต) จากเครื่องถ่ายภาพรังสีผลิตภัณฑ์ 3D Accuitomo 170 ส่วนเครื่องถ่ายภาพรังสีผลิตภัณฑ์ Kodak9000 3D และ Kodak9500 CB 3D จะศึกษาผลคูณของปริมาณรังสีกับพื้นที่ (มิลลิเกรย์.ตารางเซนติเมตร) สำหรับการสแกนฟิลด์อ็อฟวิวขนาดเล็ก 2 หรือ 3 ครั้ง ปริมาณรังสีจะได้จากการคำนวณ*

ผลการศึกษา : *ค่าซีวอลลุ่ม (มิลลิเกรย์) ปริมาณรังสีตามความยาวสแกน (มิลลิเกรย์.เซนติเมตร) ปริมาณรังสียังผล (ไมโครซีเวิร์ต) ที่ได้จากฟิลด์อ็อฟวิว (เส้นผ่านศูนย์กลาง (เซนติเมตร) × สูง (เซนติเมตร))17 × 5 และ 17 × 12 ของเครื่อง 3D Accuitomo 170 มีค่าเท่ากับ 7.7, 38.5, 88.55 และ 6.4, 76.8, 176.64 ตามลำดับ สำหรับเครื่อง Kodak9000 3D และ Kodak9500 CB 3D ผลคูณของปริมาณรังสีกับพื้นที่ของฟิลด์อ็อฟวิว (เส้นผ่านศูนย์กลาง (เซนติเมตร) ×สูง (เซนติเมตร)) 5×3.7, 15×9, 20.6×18 และฟิลด์อ็อฟวิวขนาดเล็กหลายฟิลด์ (กว้าง (เซนติเมตร) ×ลึก(เซนติเมตร) ×สูง (เซนติเมตร)) 9.3×5×3.7, 9.3×7.4×3.7 มีค่าเท่ากับ 131, 211, 502 และ 261, 392 มิลลิเกรย์.ตารางเซนติเมตร ตามลำดับ และผลคูณของปริมาณรังสีกับพื้นที่ที่ได้จากการสแกนฟิลด์อ็อฟวิวขนาด 5 × 3.7 สองและสามครั้ง มีค่าเท่ากับ 262 และ 393 มิลลิเกรย์.ตารางเซนติเมตร ตามลำดับ*

สรุป : *ขนาดฟิลด์อ็อฟวิวและจำนวนครั้งที่สแกนมีผลต่อปริมาณรังสี โดยในการสแกน 1 ครั้ง ปริมาณรังสีจะเพิ่มขึ้นเมื่อขนาดฟิลด์อ็อฟวิวใหญ่ขึ้น และปริมาณรังสีจะเพิ่มขึ้นเมื่อจำนวนครั้งในการสแกนฟิลด์อ็อฟวิวขนาดเดียวกันเพิ่มขึ้น อย่างไรก็ตามการสแกนฟิลด์อ็อฟวิวขนาดกลาง 1 ครั้งให้ปริมาณรังสีน้อยกว่าการสแกนฟิลด์อ็อฟวิวขนาดเล็ก 2 และ 3 ครั้ง ดังนั้นในการถ่ายเฉพาะตำแหน่ง 2 หรือ 3 ตำแหน่ง แนะนำให้ถ่ายด้วยฟิลด์อ็อฟวิวขนาดกลาง 1 ครั้งมากกว่าการถ่ายด้วยฟิลด์อ็อฟวิวขนาดเล็ก 2 หรือ 3 ครั้ง ส่วนฟิลด์อ็อฟวิวขนาดใหญ่ให้ปริมาณรังสีมากที่สุด จึงแนะนำให้ใช้เมื่อต้องการถ่ายบริเวณช่องปากและใบหน้าขากรรไกร*

คำสำคัญ : *เครื่องถ่ายภาพรังสีตัดขวางอาศัยคอมพิวเตอร์ชนิดลำรังสีรูปกรวย, ซีบีซีที, การวัดรังสี, การสแกนฟิลด์อ็อฟวิวขนาดเล็กหลายครั้ง, ผลคูณของปริมาณรังสีกับพื้นที่.*

Cone beam computed tomography (CBCT) device has been developed for dentistry since the late 1990s. Then, it becomes widely used in dentistry as an alternative to medical CT[1] and a compliment to conventional radiograph. As the use of CBCT increases, the patient radiation dose has become a major concern even though the dose from CBCT, compared to that of the medical CT, is low. [1, 2]

CBCT devices are currently available from various manufacturers. Each device provides variety of field of views (FOVs), making it possible to select an appropriate field of view for particular task [1, 3] such as large FOV for maxillofacial region, medium FOV for the maxilla/mandible, and small FOV for localized region. A full dental arch, can be divided into 6 localized regions, namely: the upper right posterior region, upper anterior region, upper left posterior region, lower left posterior region, lower anterior region and lower right posterior region.

In practice, some areas are not adjacent to the other, such as upper right molar region and lower anterior region referred to undertake this technique. Thus the appropriate decision to choose one large FOV, medium FOV or multi-scans of small FOV should be considered based on clinical applications and ALARA (as low as reasonably achievable) principle.

The patient radiation dose depends on FOVs[3 - 6], kVp, mA [4] and the number of scans taken. However, many studies reported the radiation dose from only one scan, so it is quite important to study the radiation dose taken from different number of scans taken through various FOVs for the benefit of the patients.

The objective of this study was to study the effect of number of scans and field of views: one scan of large FOV, one scan of medium FOV and multi-scans of small FOV, on the radiation dose from CBCT systems using a phantom.

Materials and Methods

CBCT devices

The three CBCT systems used in this study were: firstly, 3D Accuitomo 170 (J. MORITA Mfg. Corp., Kyoto, Japan) with 9 FOVs, as shown by diameter (cm) x height (cm): 4 x 4, 6 x 6, 8 x 8, 10 x 5, 10 x 10, 14 x 5, 14 x 10, 17 x 5 and 17 x 12: secondly Kodak 9000 3D Extraoral Imaging System (Carestream Health, Inc., New York, USA) with 3 FOVs. (One was small FOV, as shown by diameter (cm) x height (cm): 5 x 3.7 and the others were multi-small FOVs, as shown by width (cm) x depth (cm) x height (cm): 9.3 x 5 x 3.7, 9.3 x 7.4 x 3.7): thirdly Kodak 9500 Cone Beam 3D System (Carestream Health, Inc., New York, USA) with 2 FOVs, as shown by diameter (cm) x height (cm): 15 x 9 and 20.6 x 18. As for all devices, a full rotation scan (360°) was performed.

As for all devices, the quality control (QC) was performed in order to verify the radiation dose with the dose described in the manufacturer’s manual. The acquisition parameters and the size of FOVs were used according to the manufacturer’s manual (Table 1).

In dose record, acquisition parameters were used according to the protocolused in clinic for adult patients (Table 2).

Table 1. Parameters for QC of three CBCT devices: 3D Accuitomo 170, Kodak 9000 3D and Kodak 9500 CB 3D

Devices	FOVs	kVp	mA	Time (s)
3D Accuitomo 170	4 × 4	90	5	17.5
	6 × 6			
	10 × 10			
	17 × 12			
Kodak 9000 3D	5 × 3.7	68	6.3	10.8
	9.3 × 5 × 3.7			
	9.3 × 7.4 × 3.7			
	5 × 3.7	70	8	10.8
	9.3 × 5 × 3.7			
	9.3 × 7.4 × 3.7			
	5 × 3.7	70	10	10.8
	9.3 × 5 × 3.7			
	9.3 × 7.4 × 3.7			
	5 × 3.7	74	10	10.8
	9.3 × 5 × 3.7			
	9.3 × 7.4 × 3.7			
Kodak 9500 CB 3D	15 × 9	80	5	10.8
	20.6 × 18			

Table 2. Parameters for dose record of three CBCT devices: 3D Accuitomo 170, Kodak 9000 3D and Kodak 9500 CB 3D.

Devices	FOV	kVp	mA	Time (s)
3D Accuitomo 170	All FOVs	80	5	17.5
Kodak 9000 3D	All FOVs	80	5	10.8
Kodak 9500 CB3D	All FOVs	80	5	10.8

QC materials: Dosimeter and phantom

Unfors Xi CT ionization chamber, Unfors Xi base unit with mAs display and PMMA 16 cm diameter cylindrical phantom (FLUKE Biomedical, Model: 76-419-4150 (CT Dose Phantom Kit for Adult/Pediatric Head and body)) were used to measure C_{VOL} in 3D Accuitomo 170 to compare with C_{VOL} in the manufacturer's manual.

DAP meter, PTW Freiburg Model Diamentor E, was used to measure DAP in Kodak 9000 3D and Kodak 9500 CB 3D to compare with DAP in the manufacturer's manual.

Radiation dose record

A RANDO phantom was used in this study to simulate the patient in similar positioning.

In 3D Accuitomo 170, the radiation doses were recorded in C_{VOL} (mGy) and then DLP (mGy.cm) was calculated by the following formula:

$$\mathbf{DLP} = \mathbf{C_{VOL}} \times \mathbf{L} \quad (1)$$

where DLP is dose length product (mGy.cm); C_{VOL} is volume CT air kerma index (mGy): and, L is scan length (cm). Then the effective dose (E) was calculated by the following formula:

$$\mathbf{E} = \mathrm{DLP} \times \mathbf{E_{DLP}} \quad (2)$$

where E is effective dose (mSv): DLP is recorded in mGy.cm; and, E_{DLP} is conversion coefficient (0.0023 mSv. $(mGy.cm)^{-1}$).[7]

As for Kodak 9000 3D and Kodak 9500 CB 3D, the radiation doses were recorded in dose area product (DAP, $mGy.cm^2$).

FOVs

FOVs were divided into three categories (Table 3) according to the region of interest. First was large FOV which was used for taking the maxillofacial/craniofacial regions. Second was medium FOV which was used for taking the maxilla/mandible region. Third was small FOV which was used for taking any localized region. Small FOV could be used to get larger field size similar to the medium or large FOV by taking two or more scans.

Table 3. Three categories of FOVs of three CBCT devices: 3D Accuitomo 170, Kodak 9000 3D and Kodak 9500 CB 3D.

Devices	Type of FOVs	FOVs
3D Accuitomo 170	Small	4 × 4
		6 × 6
	Medium	8 × 8
		10 × 5
		10 × 10
		14 × 5
		14 × 10
		17 × 5
	Large	17 ×12
Kodak 9000 3D	Small	5 × 3.7
	Multi-small	9.3 × 5 × 3.7
		9.3 × 7.4 × 3.7
Kodak 9500 CB 3D	Medium	15 × 9
	Large	20.6 × 18

In this study, two or three scans of small FOV were performed, and doses, E and DAP, were obtained by multiplying both parameters of single exposure by 2 or 3. However, Kodak 9000 3D has stitching program, the system of which scanned two or three times automatically and small FOVs were combined into larger single as well as a single DAP value obtained by using this program. Thus, the multiplication of 2 or 3 to obtain the radiation dose from multi-small FOV of Kodak 9000 3D were not necessary.

Results

In QC of 3D Accuitomo 170, the C_{VOL} from measurement and from manual and the percent deviation for 4 FOVs are shown in Table 4. Measured C_{VOL} were less than manual C_{VOL}. Different values between measured and manufacturer's manual C_{VOL} of FOV (cm x cm) 4 x 4, 6 x 6, 10 x 10 and 17 x 12 were 2.9, 2.39, 0.43 and 1.05 mGy respectively.

In QC of Kodak devices, the percentage of deviations between the measured and that in the manufacturer's manual DAP are shown in Table 5. In Kodak 9500 CB 3D, absolute percentage of deviations of FOVs (cm x cm) 15 x 9 and 20.6 were 27.93 and 31.8, respectively.

Table 6 shows C_{VOL} (mGy) in each FOVs of 3D Accuitomo 170. DLP (mGy.cm) and E (μSv) in FOV (∅ (cm) x height (cm)) 17 x 5 and 17 x 12 were 38.5, 88.55 and 76.8, 176.64, respectively.

Figure 1. shows the bar charts of the effective dose, μSv of FOV (∅ (cm) x height (cm)) 17 x 5 and 17 x 12

Table 7 shows DAP values of Kodak devices. As for FOV (diameter (cm) x height (cm)) 5 x 3.7, 15 x 9, 20.6 x 18 and multi-small FOVs (width (cm) x depth (cm) x height (cm)) 9.3 x 5 x 3.7, 9.3 x 7.4 x 3.7, DAP values were 131, 211, 502 and 261, 392 $mGy.cm^2$, respectively.

The DAP values from Kodak 9000 3D and Kodak 9500 CB 3D are displayed in bar charts in Figure 2.

Table 4. Comparison of measured and manufacturer's manual C_{VOL} values in 3D Accuitomo 170

Acquisition FOV (cm^2)	MeasuredC_{VOL}	C_{VOL} from manual	Different values	% deviation
4 × 4	1.70	4.6	2.9	-63
6 × 6	3.31	5.7	2.39	-42
10 × 10	6.47	6.9	0.43	-6.23
17 × 12	7.65	8.7	1.05	-12.03

Note: Minus sign (-) of % deviation means that measured C_{VOL} were less than C_{VOL} from manual.

Table 5. Comparison of measured and manufacturer's manual DAP values of Kodak devices.

Devices	kVp	mA	FOVs	DAP ($mGy.cm^2$) from measurement	DAP ($mGy.cm^2$) from manual	% deviation
Kodak 9000 3D	68	6.3	5 × 3.7	130	131	-0.76
			9.3 × 5 × 3.7	260	263	-1.14
			9.3 × 7.4 × 3.7	390	394	-1.02
	70	8	5 × 3.7	170	175	-2.86
			9.3 × 5 × 3.7	350	349	0.29
			9.3 × 7.4 × 3.7	520	524	-0.76
	70	10	5 × 3.7	210	218	-3.67
			9.3 × 5 × 3.7	440	436	0.92
			9.3 × 7.4 × 3.7	650	654	-0.61
	74	10	5 × 3.7	230	235	-2.13
			9.3 × 5 × 3.7	470	471	-0.21
			9.3 × 7.4 × 3.7	700	706	-0.85
Kodak 9500 CB 3D	80	5	15 × 9	133.33	185	-27.93
	80	5	20.6 × 18	296.67	435	-31.80

Note: Plus (+) and minus (-) sign of % deviation means that measured DAP was more than and less than DAP from manual, respectively.

Table 6. C_{VOL} (mGy) in each FOVs of 3D Accuitomo 170 and DLP (mGy.cm), E (μSv) in FOV (∅ (cm) × height (cm)) 17 × 5, 17 × 12

Type of FOVs	FOVs (∅ (cm) × height (cm))	C_{VOL} (mGy)	DLP (mGy.cm)	E (μSv)
Small	4 × 4	3.4	-	-
	6 × 6	4.3	-	-
Medium	8 × 8	4.9	-	-
	10 × 5	6.0	-	-
	10 × 10	5.1	-	-
	14 × 5	7.3	-	-
	14 × 10	6.0	-	-
	17 × 5	7.7	38.5	88.55
Large	17 × 12	6.4	76.8	176.64

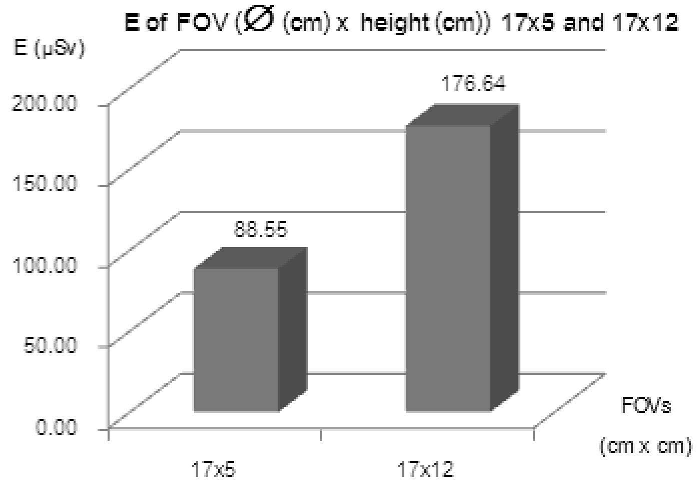

Figure 1. The effective dose at two FOVs (∅ (cm) × height (cm)), 17 × 5 and 17 × 12, of 3D Accuitomo 170

Table 7. DAP (mGy.cm^2) from one scan in each FOVs of Kodak 9000 3D and Kodak 9500 CB 3D and DAP (mGy.cm^2) from two and three scans in small FOV of Kodak 9000 3D.

Devices	Type of FOVs	FOVs	DAP (mGy.cm^2)	DAP×2 (mGy.cm^2)	DAP×3 (mGy.cm^2)
Kodak 9000 3D	Small	5 × 3.7	131	262	393
	Multi-small	9.3 × 5 × 3.7	261	-	-
		9.3 × 7.4 × 3.7	392	-	-
Kodak 9500 CB 3D	Medium	15 × 9	211	-	-
	Large	20.6 × 18	502	-	-

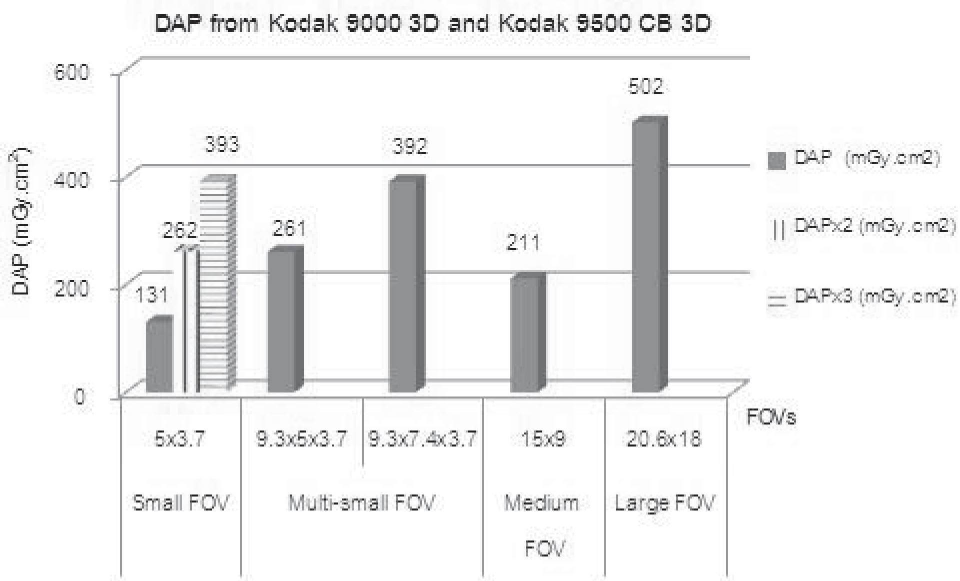

Figure 2. DAP values from Kodak 9000 3D and Kodak 9500 cone beam 3D at various FOVs.

Discussion

The discrepancies between the measured C_{VOL} and values in the manufacturer's manual at small FOVs in Table 4 result from uncertainties of the phantom and ionization chamber positioning. Measured C_{VOL} from FOVs (∅ (cm) x height (cm)) 4 x 4 and 6 x 6 were smaller than the values in the manufacturer's manual because the ionization chamber at peripheral site of the phantom was outside the primary beam and the dose distribution across the FOV was non-uniform.

When a uniform phantom was positioned at the center of field of view, the dose distribution in x-y plane of full rotation scan should be symmetry, but it was non-uniform with the highest dose at the center of rotation and gradient towards the periphery. The dose distribution should drop outside the primary beam. When the phantom was positioned off-center, the dose distribution in x-y plane of full rotation scan was asymmetry with highest dose in the region of interest. [4, 8, 9] According to asymmetrical dose distribution in off-center position, the measured C_{VOL} would be incorrect as well as the effective dose estimation of small FOV, but could be correct for large FOV with a center of rotation set in the mid-sagittal plane. [4] From our study of both small and medium FOVs, the phantom would be positioned off-center because the proper center of rotation was not identified by the manufacturer. In practice, the position of small FOV was within region of interest along the dental arch while the medium FOV, the center of rotation was located anteriorly to the center to cover the jaws. Therefore, FOV(∅ (cm) x height (cm)) 17 x 5 and 17 x 12 in 3D Accuitomo 170 were mostly acceptable for the dose calculation of DLP and E.

The percentage of deviations of DAP values in all FOVs of Kodak devices (Table 5) were within the tolerance values (30%) except in large FOV of Kodak 9500 CB 3D. This result from uncertainties in position of internal and external DAP meters.

The other limitation of this study is the conversion coefficient of DAP to E for CBCT imaging. Therefore, the DAP values were only reported in this study of different systems regard less of the beam geometry and field sizes to simulate real condition.

Table 6 and Table 7 show the effects of the field sizes and number of scans on the radiation dose. DAP values from small FOV in Kodak9000 3D increased with number of scans. DAP values from two and three scans of small FOV were not different from DAP values of multi-small FOVs, 9.3 x 5 x 3.7 and 9.3 x 7.4 x 3.7, because they were scanned in the same numbers. In one scan, the effective dose from 3D Accuitomo 170 and DAP values from Kodak devices increased with the field size.

As for the Kodak devices, the increased radiation dose was not proportional to the irradiated area according to the different devices. The previous studies showed that the CBCT dose varies among the devices.[5, 6] In this study, the difference between Kodak 9000 3D and Kodak 9500 CB 3D was technical specification (filtration). Total filtration of Kodak 9000 3D was 2.5 mm (0.10") eq. Al while total filtration of Kodak 9500CB 3D was 2.5 mm eq. Al + 0.3 mm Cu. Thus, the intensity of Kodak 9000 3D would be higher than Kodak 9500 CB 3D. This is the reason why the radiation dose from one scan of Kodak 9000 3D (131mGy.cm^2) was less than the dose from medium FOV of Kodak 9500 CB 3D (211mGy.cm^2) approximately 1.6 times while the area was much less than medium FOVs approximately 7 times.The other reason, as mentioned above, was the dose distribution of CBCT was non-uniform. As for the medium FOV that had wider cone angle than small FOV, the difference in dose within its FOV would be more pronounced owing to a longer attenuation path for angled x-rays.[9] These were also the reason why the DAP values of two and three scans of small FOV (262 and 393 mGy.cm^2), were higher than the DAP value of one scan of medium FOV (211 mGy.cm^2). Thus, it is highly recommended to use the medium FOV, rather than two or three scans of small FOV when two or three localized regions were required. If the medium FOV is not available, two or three scans of small FOV are dose-saving in comparison to one scan of large FOV, as the large FOV resulted in the highest value of 502 mGy.cm^2. Similarly, Lukat TD *et al* [10] showed two small FOV acquisitions of bilateral TMJ provided significantly less radiation dose than one scan of large FOV and recommended to take individual right and left TMJ with small FOVs (one for each TMJ) as dose reducing alternative to large FOV. However the study did not include the medium FOV.

As the large FOV provides highest dose and large irradiated areas that the critical organs such as the eyes, thyroid gland, salivary glands are involved in the primary beam during the scan; the large FOV should be taken only when maxillofacial region is required.

Endo A *et al*[11] showed DAP values of Kodak 9000 3D ranged from 260.3 - 296.4 mGy.cm^2. These values were higher approximately twice than this study because they used different exposure parameters (70 - 74 kVp, 10 mA).

The UK's Health Protection Agency[12] has proposed an achievable dose of 250 mGy.cm^2 for CBCT imaging taken for upper first molar implant in adult procedure. In this study, DAP values of one scan of small FOV and medium FOV were less than this value while one scan of large FOV exceeded this value approximately twice.

The benefit of this study is the appropriate selection of FOV and number of scans according to ALARA principle. However, this was concluded from the Kodak devices. Further study of DAP value in 3D Accuitomo 170 would be more beneficial.

Conclusions

The CBCT radiation dose was affected by the field size and number of scans taken. In one scan, the radiation dose is higher when the FOVs increase. In the same FOV, the radiation dose increases with the number of scans taken. However, one scan of medium FOV provided less radiation dose than two and three scans of small FOVs. Thus, when two or three localized regions are required, one scan of medium FOV is more recommended than two or three scans of small FOV. As large FOV provides highest radiation dose, it is recommended when the maxillofacial region is required. Selection of proper FOV and number of scans results in the reduction of patient's radiation dose.

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References

1. Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dent Clin North Am 2008 Oct; 52(4): 707-30.v
2. White SC, Pharoah MJ. The evolution and application of dental maxillofacial imaging modalities. Dent Clin North Am 2008 Oct; 52(4): 689 -705
3. Hirsch E, Wolf U, Heinicke F, Silva MA. Dosimetry of the cone beam computed tomography Veraviewepocs 3D compared with the 3D Accuitomo in different fields of view. Dentomaxillofac Radiol 2008 Jul; 37(5): 268-73
4. Lofthag-Hansen S, Thilander-Klang A, Ekestubbe A, Helmrot E, Grondahl K. Calculating effective dose on a cone beam computed tomography device: 3D Accuitomo and 3D Accuitomo FPD. Dentomaxillofac Radiol 2008 Feb; 37(2): 72 - 9
5. Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. Dentomaxillofac Radiol 2006 Jul; 35(4): 219 - 26
6. Pauwels R, Beinsberger J, Collaert B, Theodorakou C, Rogers J, Walker A, Clockmartin L, Bosmans H, Jacobs R, Bogaerts R, et al. Effective dose range for dental cone beam computed tomography scanners. Eur J Radiol 2012 Feb; 81(2): 267 - 71
7. European Commission. European Guidelines on Quality Criteria for Computed Tomography. Luxembourg: Office for Official Publications of the European Communities, 1999: 70
8. Araki K, Patil S, Endo A, Okano T. Dose indices in dental cone beam CT and correlation with dose area product. Dentomaxillofac Radiol 2013 Mar 21:42(5): 20120362
9. Pauwels R, Theodorakou C, Walker A, Bosmans H, Jacobs R, Horner K, Bogaerts R. Dose distribution for dental cone beam CT and its implication for defining a dose index. Dentomaxillofac Radiol 2012 Oct; 41(7): 583 - 93
10. Lukat TD, Wong JC, Lam EW. Small field of view cone beam CT temporomandibular joint imaging dosimetry. Dentomaxillofac Radiol 2013;42(10): 20130082
11. Endo A, Katoh T, Vasudeva SB, Kobayashi I, Okano T. A preliminary study to determine the diagnostic reference level using dose-area product for limited-area cone beam CT. Dentomaxillofac Radiol 2013 Apr; 42(4): 20120097
12. Holroyd J, Walker A. Recommendations for the design of x-ray facilities and the quality assurance of dental cone beam CT (computed tomography) systems. A report of the HPA working party on dental cone beam CT. HPA-RDP-065. Chilton: Health Protection Agency, 2010: 9 -12