RADIATION DOSE IN DENTAL ROENTGENOGRAPHY, WITH SPECIAL REFERENCE TO ENLARGEMENT DENTAL RADIOGRAPHY

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The purpose of this paper is to describe radiation dose received by dental patients and dentists in dental clinics in Japan. In addition an attempt was made to compare the results with those by our enlargement technique.

METHOD AND RESULTS

I) X-ray units used

For this study four types of X-ray unit were used. On the one hand unit A made in Holland in 1952 generated an electric tension of 24 kVeff, when a filter of 0.5 mm Al was attached. The radiation mouth was circular and 9 cm in diameter. Unit B made in Germany about 20 years age generated X-rays of 22 kVeff. The diameter of the radiation mouth was 9.7 cm. Unit C was a latest Japanese dental X-ray unit capable of emitting X-rays of 29 kVeff. These units were used only for dental radiography with the focus-skin distance of 20 cm.

On the other hand unit D was constructed for enlargement radiography with a large electric capacity[1]. A special long cone made of Eslon-tube 4 cm in diameter and 120 cm in length was attached to the radiation mouth, and a rotating anode X-ray tube with a focal spot of 1.5 mm in size was used to sharpen the images of the radiogram. Unit D was operated under the condition of 60 kVp and 200 mA. The radiation field was 4 cm in diameter.

II) Phantom

A phantom made of paraffin was used for measuring exposure doses. The phantom was made based on a whole-body plaster of Paris of a Japanese of medium size. The lungs in the phantom were made of cork with a specific gravity of 0.2. Three holes were constructed in the oral cavity, lower abdomen (ovary region) and testicular region of the phantom for facilitating insertion of a dosimeter.

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III) Gonad dose

In dental radiographic technique, the exposure time and direction of X-ray was varied according to location of the teeth examined. In this study the radiation dose in radiography of the maxillary and mandibular bicuspid of both sides and maxillary occlusal technique was measured. The ionization chamber of Victreen type was inserted into the hole in the ovary region. One hundred seconds X-ray exposure was made by using each of the four types of unit. From this measurement, the gonad dose per exposure was obtained and tabulated in Table 1.

TABLE 1. Gonad Dose per Exposure with Four Types of Unit Used in Dental Radiography, Unit: mr

Unit used	Unit A		Unit B		Unit C		Unit D	
Sex	Male	Female	Male	Female	Male	Female	Male	Femal e
Tooth to be radiographed								
Right maxill. bicuspid	0.62	0.05	0.96	0.20			0.16	0.03
Right mandib. bicuspid	0.78	0.04	1.12	0.15			0.17	0.03
Left maxill. bicuspid	0.64	0.03	0.96	0.19			0.20	0.03
Left mandib. bicuspid	0.72	0.03	1.24	0.11			0.24	0.03
Maxillary occlusal	3.25	0.38	1.68	1.01	0.75	0.50	0.24	0.06

IV) Exposure Dose Received by the Skin Surface of the Face

Radiation dose was measured by the Victreen dosimeter attached to the skin of the upper and lower areas of the oral angle, the center of the eye-ball surface, buccal process of both sides, mid-portion of the lower labium, nasal apex, mid-portion of the frontal region, mentalis region, and thyroid cartilage region. The results are shown in the Table 2.

V) Exposure Dose of the Portion Radiographed

The dosimeter was inserted into the hole of the mouth (tooth area) of the phantom, and dosimetered. When the right maxillary bucuspid was radiographed, it was irradiated by X-rays of 0.66 r with unit A and 2.84 r with unit B. In radiography of the right mandibular bicuspid, it was 0.30 r. The details are summarized in Table 3.

VI) Dose Distribution in the Cranium

The paraffin phantom was cut through three sagittal planes including the nasal apex and external eye angle of both sides. Industrial Fuji X-ray films were directly inserted into these fissures, and were irradiated by X-rays under the exposing conditions of actual radiography. These films were developed by a standard method and densitometried. The density of films was represented by the radiation dose, and the dose values are shown in Table 4.

TABLE 2. Radiation Dose of the Skin Surface of the Face, Unit: mr/Exposure

Unit used	Unit A					Unit B				Unit C			Unit D		
Part radiographed→ / Part dosimetried↓	Right maxill. bicuspid	Right mandib. bicuspid	Left maxill. bicuspid	Left mandib. bicuspid	Maxillary occlusal	Right maxill. bicuspid	Left maxill. bicuspid	Left mandib. bicuspid	Maxillary occlusal	Left maxill. bicuspid	Left mandib. bicuspid	Maxillary occlusal	Left maxill. bicuspid	Left mandib. bicuspid	Maxillary occlusal
Upper part of r. oral angle	4720	1760	60	1800	7700	0005	6160	3000	6120	67	21		10	1	
Lower part of r. oral angle	2120	2740	100	200	6200	5000	3360	3300	1140	17	13		15	1	
Upper part of l. oral angle	50	860	4720	1480	4500	2700	8080	4800	8160	967	117		350	50	
Lower part of l. oral angle	30	80	760	5520	300	2900	5080	7600	5760	334	909		60	350	
Middle of mouth	1380	1640	1080	3520	7600	2600	6160		7200						
Middle of lower lip	380	1400	140	3280	2100	4100	4280	4700	5040						
Right eye	32	80	10	1000	100	100	240	850	240	8	4		2	1	3
Left eye	10	520	40	4	100	100	2200	100	660	8	4		1	2	2
Nasal apex	800	1120	480	1360	10400	4000	7960	2800	8700						
Middle of right buccal region	40	20	20	80	0	200	200	833	60						
Middle of left buccal region	16	27	100	20	0	700	600	800	2580						
Frontal region	4	20	10	4	0	50	80	33	60			17	0.7	0.3	0.5
Mentalis region	650	340	140	120	1900	1900	3160	3100	3300			1200			0.6
Thyroid region	490	40	67	4	200	100	1600	100	1500			67	3	3	3

TABLE 3. Radiation Dose of the Portion Radiographed (Region in Contact with the Film). Unit: r

Unit used	Unit A	Unit B	Unit C	Unit D
Tooth radiographed				
Right maxill, bicuspid	0.66	2.84		
Left maxill. bicuspid	0.86	2.84		
Right mandib. bicuspid	1.30			
Left mandib. bicuspid	1.68	3.54		
Maxillary occlusal	1.30	4.0	0.56	0.82

VII) Dose Distribution of Scattered X-rays in the Dental Room

In the majority of dental clinics in Japan, even today, the X-ray apparatus is usually installed in the corner of the dental room without any lead protection. Therefore, in this study, dose distribution of scatrered X-rays was surveyed under such enviromental conditions. The X-ray units used were the four types set in the respective dental room. X-rays were generated under the same conditions as in actual radiography. The phantom was placed on the dental table in the same position as actual patients receiving X-ray examination. Dose-rate meter made in Japan was used. Measurement was performed at the points at intervals of 50 cm to 200 cm at levels of 50 and 100 cm from the floor. In this paper we will describe only the results of measurement of scattered X-ray distribution in radiography of the maxillary occlusal technique measured at a level of 100 cm from the floor, because, when the same generator was used, scattered X-rays were found to be approximately of the same level, irrespective of the tooth radiographed.

Unit A was used, operated at the corner of a dental room of about 4×5 m^2 in size, in which three dental chairs were arranged. When the maxillary occlusal radiogram was taken, the dose-rate of scattered X-rays was 2500 mr/h for an area of 50 cm from the X-ray tube. Even the dental chair as far as 3 m from the tube received about 30 to 50 mr/h of scattered rays (Fig. 1).

Unit B was examined in the same situation. The dose intensity was over 2500 mr/h at a point 1 m behind the tube. In the dental chair 3 m away from the tube the dose-rate was 100 to 300 mr/h, which was about ten times of that with unit A. Even in a neighbouring room separated by a wall of 15 cm in thickness, about 1 to 5 mr/h of scattered rays were detected (Fig. 2).

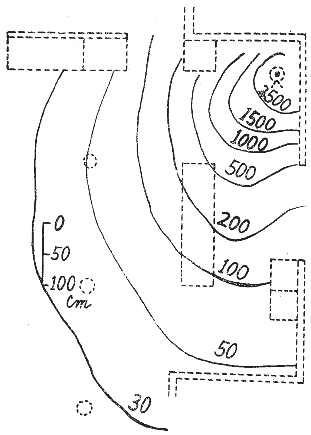

FIG. 1. Dose distribution of scattered X-rays in dental radiography using unit A.

TABLE 4. Dose Distribution in the Cranium in Dental Radiopraphy, Unit, mr/Exposure

Unit used	Unit A					Unit B					Unit C					Unit D			
Part radiographed→ / Part dosimetried ↓	Right maxill. bicuspid	Right mandib. bicuspid	Left mixill. bicuspid	Left mandib. bicuspid	Maxillary occlusal	Right maxill. bicuspid	Right mandib. bicuspid	Left maxill. bicuspid	Ltft mandib. bicuspid	Maxillary occlusal	Right maxill. bicuspid	Rght mandib. bicuspid	Left maxill. bicuspid	Left mandib. bicuspid	Maxillary occlusal	Right maxill. bicuspid	Left maxill. bicuspid	Left mandib. bicuspid	Maxillary occlusal
Nasal vestivulum	1280	760	1000	620	1900	1840	1360	2400	1680	4620	220	30	380	40	900	15	10	0	380
Hard palate	840	700	700	240	1350	960	720	960	720	1440	140	110	190	160	400	5	6	6	280
Upper incisor	1960	1200	1300	920	2600	1680	1440	3040	1440	2480	200	110	300	230	510	590	620	6	320
Lower incison	1280	1280	1040	1300	2000	1440	2000	1620	2880	1680	150	130	230	380	500	290	280	700	0
Tongue	780	400	700	660	1150	800	840	760	800	1080	75	80	110	180	300	230	230	420	40
Tongue root	290	80	100	60	250	460	240	480	480	350	60	80	75	100	270	0	0	15	30
Hypophysis	84	16	4	0	5	20	120	25	120	60	15	15	15	5	3		0	0	0
Oblongata	0	0	0	0	0	0	20	140	20	30	10	15	2	0	5		0	0	0
Larynx	80	84	90	0	100	200	120	160	10	100	30	5	5	15	60		0	0	30
Right eye-ball	16	16			75					90	40	50	35	40	75		0	0	0
Right maxillary sinus	44	260			750					650	35	25					0	0	0
Proximal ear	58	0			40					65	80	90					0	0	0
Oropharynx	126	108	100	60	300	220	200	240	160	650	20	15				10	15	14	0
Left maxillary sinus	380	90			590					400						15	10	20	30

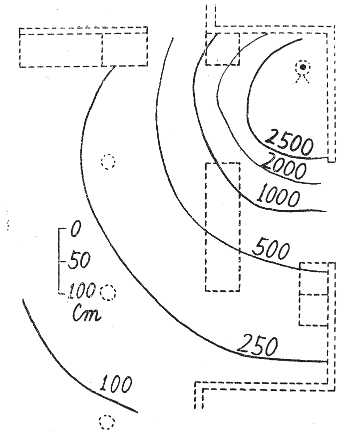

FIG. 2

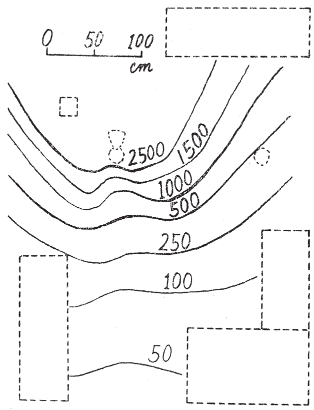

FIG. 3

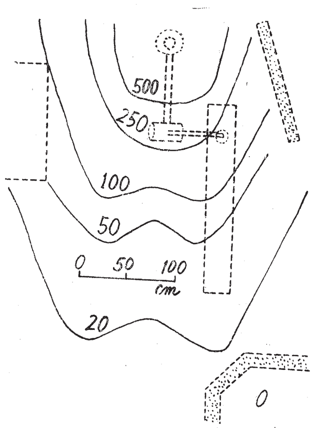

FIG. 4

FIG. 2. Dose distribution of scattered X-rays in dental radiography using unit B.
FIG. 3. Dose distribution of scattered X-rays in dental radiography using unit C.
FIG. 4. Dose distribution of scattered X-rays in dental radiography using unit D.

Unit C was set in a dental room of about 3×4 m in size, with the dental chair installed about 1.5 m from the tube. The dose distribution is shown in Fig. 3. The dose intensity in the area behind the patient appeared lowered due to absorption of scattered rays by the patient himself. Near the treatment chair, a dose-rate of 500 mr/h was measured.

Unit D was instslled in the X-ray room belonging to the Radiology Department of our hospital. The intensity distribution scattered rays is shown in Fig. 4. At a point 50 cm distant from the radiographing table, about 500 mr/h of dose-rate was recorded.

Furthermore, the dose-rate distribution was measured in a perpendicular plane including a point 50 cm distant from the tube, where the dentist or dental assistant is used to stand holding the film in the patient's mouth. When dental radiography was taken by unit A the dental assistant received scattered X-rays of over 2500 mr/h over the head, chest and upper extremity, 3000 mr/h over the testicular region, and 1000 to 1500 mr/h over the thigh. With unit B, over 2500 mr/h of scattered rays were irradiated over the upper half of the body including the gonads. With unit C, the assistant dentist standing near the patient was exposed to scattered rays of 2000 mr/h on the shoulder, 1500 to 2000 mr/h on the trunk, and 1000 to 1500 mr/h on the thigh. When unit D was operated, a film holder of special make was used, so that it became unnecessary to stand near the patient. However, even though the assistant stands and holds the film, he should receive scattered doses of less than 300 mr/h over chest, and 200 mr/h over the gonads.

DISCUSSION

Four types of X-ray unit were used in this study. Unit A was installed in the Department of Dentistry of Nagoya University, and is used daily at the present. A unit of this type may be the most widely used type in postwar Japan. Unit B was used widely in Japan about 20 years ago, and used by about 5 to 10 per cent of dentists today. Unit C is the latest Japanese made apparatus and expected to be used more in the near future. Therefore these 3 types of generator are considered to be representative of those used at present in our country. The fourth type of unit was constructed from our new idea to take enlargement radiogram[1]. The results obtained by us may have considerable universality.

The dose distribution in the dental room is of much interest, because dentists work in the same room from morning till evening, exposed to X-rays. The dose-rate curves of scattered rays in the dental room were made with consideration paid to position of dentists and dental assistants working in the room. For example, even at the present time, the dentist usually holds the film in the patient's mouth during radiography. Therefore, if the dentist conducts dental radiography 10 times a day, he should receive 10 to 30 r of X-rays on his hands a day, and 3000 to 9000 r a year. This is extremely dangerous[22][23]. Furthermore, the dentist standing near the patient was exposed to scattered rays of 2500 mr/hr on an average with dental X-ray units A, B, and C. This corresponds to about 1.4 mr per exposure. Therefore 11 exposures per day are the upper limit of irradiation dose according to maximum permissible dose[6][25].

The long-cone method, introduced in this paper, is of great value not only for taking enlargement radiogram but also for diminishing the exposure dose of dentists. Ultimately, the long-cone prevents the production of scattered rays.

Since, as above-mentioned our measurements were performed uuder relative conmon conditions, the results may be considered to be the actual irradiation circumstances in ordinary dental clinics of Japan. To protect dentists working under the above-described conditions from radiation, one cannot help but decrease the film number taken to less than 10 per day.

Recently many authors reported risk of radiation of both dentists and patients in dental radiography[10~20]. Our results also pointed to similar problems existing.

CONCLUSIONS

1) This paper deals with the radiation dose received by patients and dentists, measured with an ionization chamber and film method, using a paraffin phantom of standard size.

2) The gonad received a dose of about 0.5 to 3 mr per exposure in the males, and 0.03 to 1 mr in females.

3) Patients received radiation doses of 10 to 1000 mr per exposure at the lens, 1500 mr on the nasal apex, and 500 mr on the thyroid region. Not less than 100 mr of radiation was distributed in the pharynx and cervical spine.

4) On the hand of dentists holding the film in the patient's mouth, about 1 to 3 r of X-rays were irradiated per exposure. Also he received whole-body irradiation of scattered rays of about 500 to 2000 mr/hr.

5) The dose distribution of scattered rays in the dental room was measured with four representative types of unit used today in Japan.

6) When the long-cone and film-holding mechanism was attached to a general X-ray unit with a large electric capacity, the radiation dose could be reduced to one-tenth or less.

REFERENCES

1. KANEKO, M. ET AL.: *Nagoya J. med. Sci.* **24**: 139, 1961.
2. IIDA, H. ET AL.: *Nippon Acta radiol.* **17**: 1142, 1958 (Japanese).
3. KITABATAKE, T. ET AL.: *Nagoya J. med. Sci.* **22**: 229, 1959.
4. OKAJIMA, S. ET AL.: *Nippon Acta radiol.* **18**: 196, 1958 (Japanese).
5. MATSUDA, T. ET AL.: *Nippon Acta radiol.* **18**: 901, 1958 (Japanese).
6. KITABATAKE, T.: *Nippon Acta radiol.* **18**: 709, 1958 (Japanese).
7. TAKAHASHI, S.: *Clinical Radiol. (Tokyo)* **4**: 765, 1959 (Japanese).
8. KITABATAKE, T. ET AL.; *Nagoya J. med. Sci.* **22**: 282, 1959.
9. KITABATAKE, T.: *Nagoya J. med. Sci.* **23**: 227, 1960.
10. RICHARDS, A. G.: *J.A.D.A.* **56**: 351, 1958.
11. RICHARDS, A. G.: *J.A.D.A.* **54**: 476, 1957.
12. RICHARDS, A. G.: *J. D. Res.* **34**: 100, 1955.
13. HUDSON, D. C. AND KUMPURA, J. W.: *J. D. Res.* **34**: 743, 1955.
14. BUDOWSKY, J. ET AL.: *J.A.D.A.* **52**: 555, 1956.
15. YOUNG, H. H. AND M. G. KUNKEL.: *J.A.D.A.* **51**: 1, 1956.
16. SPEAR, L. B.: *J.A.D.A.* **51**: 7, 1956.
17. BAILY, N. A.: *Radiology* **69**: 42, 1957.
18. BUDOWSKY, J. ET AL.: *J.A.D.A.* **55**: 199, 1957.
19. MACHT, S. H. AND P. S. LAWRENCE: *Am. J. Roentgenol.* **73**: 442, 1955.
20. MURAI, T. ET AL.: *Nippon Acta radiol.* **14**: 719, 1955 (Japanese).
21. WATANABE, T.: unpublished.
22. NAKAYA, S. ET AL.: *Clinical Radiol. (Tokyo)* **3**: 780, 1958.
23. SMITH, S. W.: *JA.D.A.* **51**: 838, 1955.
24. MIYAKAWA, T. ET AL,: *Nippon Acta radiol.* **17**: 843, 1957 (Japanese).
25. Report of International Scientific Committee, 1958.
26. MURAI, T. ET AL.: *Bull. Tokyo Med. Dent. Univ.* **3**: 171, 1956.