SB

160

FISCAL NOTE

STATE OF ALASKA
1998 LEGISLATIVE SESSION

BILL NO. CSSB 160(L&C)

Revision Date:
Department: Commerce and Economic Development
Title: An Act relating to radiological equipment used in the practice of dentistry.
BRU: Occupational Licensing
Component: Operations
Sponsor: Senator Taylor by request
Requestor: Senate Labor & Commerce
COMPONENT SERIAL NO. 1844

Expenditures/Revenues (Thousands of Dollars)

OPERATING EXPENDITURES	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04
PERSONAL SERVICES	20.3	20.3	10.1	10.1	10.1	10.1
TRAVEL	0.0	0.0	0.0	0.0	0.0	0.0
CONTRACTUAL	3.0	3.0	1.5	1.5	1.5	1.5
SUPPLIES	1.0	1.0	1.0	1.0	1.0	1.0
EQUIPMENT						
LAND & STRUCTURES						
GRANTS, CLAIMS						
MISCELLANEOUS						
TOTAL OPERATING	24.3	24.3	12.6	12.6	12.6	12.6
CAPITAL EXPENDITURES						
CHANGE IN REVENUES	48.6	0.0	25.2	0.0	25.2	0.0

FUND SOURCE (Thousands of Dollars)

1002 Federal Receipts						
1003 GF Match						
1004 General Fund						
1005 GF/Program Receipts	24.3	24.3	12.6	12.6	12.6	12.6
1037 GF/Mental Health						
Other (Specify Type)						
TOTAL	24.3	24.3	12.6	12.6	12.6	12.6

Estimate of any current year (FY 98) cost: $ 0.0

POSITIONS

FULL-TIME						
PART-TIME	1	1	1	1	1	1
TEMPORARY						

ANALYSIS: (Attach a separate page if necessary)

CSSB 160(L&C) transfers regulation of x-ray equipment in a dentist office from the Division of Public Health, Department of Health and Social Services to the Board of Dental Examiners in the Division of Occupational Licensing, Department of Commerce and Economic Development. The board currently regulates level of entry into the profession and the practice of dentistry. By assuming responsibilities in the bill, new costs will be incurred through establishing necessary regulations, registering equipment and requiring periodic inspection of radiological equipment. An explanation of the costs are explained on the attached page.

Prepared by: Jennifer Strickler, Administrative Manager
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Date: 4/2/98

Approved by Commissioner: Deborah B. Sedwick
Date: 4/2/98
Agency: Commerce and Economic Development

PREPARER: TO PROVIDE ALL DISTRIBUTION COPIES TO GOVERNOR'S LEGISLATIVE OFFICE
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FISCAL NOTE

STATE OF ALASKA
1998 LEGISLATIVE SESSION

BILL NO.: CSSB 160(L&C)

ANALYSIS: (Continued)

DEPARTMENT OF COMMERCE AND ECONOMIC DEVELOPMENT
FISCAL NOTE CALCULATIONS

Personal Services

Occupational Licensing Examiner I position, Range 12, PPT, GGU	20.3

This half-time position will be responsible to monitor and maintain inspection records of dental x-ray equipment and collect applicable fees. Additionally, this position will assist the board in preparing regulations regarding dental radiological equipment. It is anticipated that a half-time position will only be necessary for the first two years. By the third year and thereafter, only a quarter time of the position is anticipated to be necessary in providing support to these tasks.

Contractual Services	3.0

The contractual services will fund expenses associated with adoption of new regulations concerning x-ray equipment in dental offices, including public notices, postage, printing of the regulations and registration forms, and regulation hearings via teleconferencing. This expense is reduced after the first two-years assuming the regulations will be in place.

Supplies

Funding provides daily desk top and other operating supplies.	1.0
TOTAL:	**$24.3**

SENATE COMMITTEE REPORT

DATE: 4/3/98

FURTHER: Finance

DATE TURNED IN TO OFFICE: 4/8/98

HESS Committee considered SENATE BILL NO. 160

"An Act relating to registration, inspection, and testing relating to radiological equipment in dentists' offices."

and recommends:

Senate Bill:

[ ] be **replaced** with _____ CS _____ (_____) [✓] same title [ ] new title

[✓] adopt **previous** _____ CS SB 160 (L+C) **House Bill:** [ ] same title [ ] technical title [ ] new: SCR#_____

[ ] attached amendment(s)

[ ] adopt Letter of Intent by _____ Committee

[ ] further referral to the _____ Committee

SIGNING DO PASS	*DP*	*OTHER RECOMMENDATIONS*	*NR*	*DNP*	*AM*
		Drew D. Lewis	✓		
		Jo Ellis	✓		
		Linda Green	✓		
		Jim Ward	✓		
CHAIR:	✓	*CHAIR:*			

NEW FISCAL NOTE(S):

Department	Date	Zero	Fiscal

PREVIOUS FISCAL NOTE(S):*

Department	Date	Zero	Fiscal
Commerce + Econ Development	4/2/98		✓

[ ] **APPROPRIATION -- no fiscal note**

***include fiscal notes accompanying Governor's bill**

Senator Ellis -
per your request
Thank you.
Kate

Chairman and Members of the Committee

My name is Kate Coleman. I am one of two radiological health specialists employed by Alaska's Department of Health and Social Services.

All over the country, it is public health week. In Alaska, we are concerned that we are diminishing the capacity of public health by diluting the regulation of dental x-ray. On the international radiation protection scene, the International Council of Radiation Protection would like to lower the exposure to occupationally exposed radiation workers. The bill before us will remove from occupationally exposed dental workers government regulation aimed at keeping their radiation exposures to as low as reasonably achievable.

Questions have been raised about the health effects and risk related to dental x-ray exposure. It is difficult to quantify. But ask any member of the public or this audience whether they are concerned about x-ray and they will probably answer in the affirmative.

There is an indication of risk in the technical paper of Dr. Stuart Smith of the UCLA School of Dentistry. "While the risk from dental radiography is certainly small in terms of other risks we readily assume during our daily lives such as driving, smoking, eating fatty food, there is no basis to assume it is zero. . . .prudence suggests we should be cautious because of the large numbers of people exposed to dental radiography. . . Recent studies suggest the lifetime cancer risk from exposure to low levels of ionizing radiation may be greater than previously estimated . . ..The International Commission for Radiation Protection data show that the estimated risk has increased four-fold, . . . Cancers other than leukemia typically start to appear about 10 years following exposure and remain in excess for the lifetime of the exposed individuals." Citing specific cancers, Dr. White notes "an association with leukemia, the risk to children being greater. Thyroid cancers increases in humans following exposure to ionizing radiation. About 10% of individuals with such cancers die from their disease. A case-control study has shown an association between brain cancer and previous medical or dental radiography. Several studies have shown an association between tumors of the salivary glands and dental radiography. " As long as there is a risk it needs to be monitored. DHSS has responsibility for protecting the public health.

Specific comments on this bill include:

The Dental Bd will establish standards and there is no role for the Department, there is an absence of checks and balances. The bill presents a conflict of interest.

The credentials for inspectors are lax. For instance, are they qualified to operate radiation measuring equipment, to calculate skin dose, to evaluate film quality, perform shielding calculations and scatter radiation measurements. A certification program for the inspectors administered by the state should be in place to keep the standards high.

Who will design the inspection procedures?

Will the Board be taking on responsibilities for physics and engineering?

What role will the Bd have in regulating radionuclides included in Section 08.36.075 (g)?

The proposed bill does not include radiation protection, film processing, nor x-ray operator competence. Yet, the majority of problems in dental radiography are a result of film processing and operator error. Frequently, in an attempt to improve film quality, an inexperienced operator will increase the radiation exposure rather than use appropriate film processing.

This bill creates duplicate functions between two state agencies. The type of organization proposed by this bill is unusual by any state's standards since the professional board is so distant from the technical aspects of radiation protection. Alaska, like many other states, lacks a sufficiently trained supply of personnel to meet the public health needs of the State. It is wasteful to establish parallel lines of expertise in two separate departments.

AS 18.60.475(a)(7) authorizes DHSS to "contract with other State agencies to assist them in performing functions that require expertise in determining and reducing the hazards of radiation." This far-sighted authorization is cognizant of the unique qualifications necessary to understand and satisfactorily implement a responsible radiation control program. It is clearly designed to assure that this relatively rare expertise is shared with other parts of the government. It seems wasteful to depart from that philosophy and establish duplicative expertise in another department.

There are finite resources available state-wide to support this function in Alaska. Passage of this bill would serve to provide less protection for Alaskan citizens. Already thin resources will be spread less effectively. There is no benefit to Alaskan citizens in implementing this bill.

1992 Assessment of radiation risk from dental radiography

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Received 29 October 1990 and in final form 18 March 1992

Recent studies suggest that the lifetime cancer risks from exposure to low levels of ionizing radiation may be greater than previously estimated. This review first summarizes the findings of these studies as they pertain to dental radiology, then uses their concepts in combination with dosimetry from the dental literature to estimate the radiation risk from dental radiology. Estimation of risk from groups of exposed individuals requires use of mathematical models that fit the epidemiological data. The ICRP estimates that a single brief whole-body exposure of 1 Gy to 10 000 people results in about 500 additional cancer deaths over the lifetime of the exposed individuals, assuming a dose rate effectiveness factor of 2 for cancers other than leukaemia. Leukaemias are seen as a wave from 5 to 30 years following exposure. Cancers other than leukaemia typically start to appear about 10 years following exposure and remain in excess for as long as most exposed populations are followed, presumably for the lifetime of the exposed individuals. The gonadal dose is so small from dental radiography that the risk of heritable defects is negligible in comparison with the somatic risk. The dental literature contains several studies reporting sufficient dosimetric data for radiosensitive sites in the head and neck to allow estimation of the risk of fatal cancers from intra-oral and panoramic radiography. The highest estimated risks (using the ICRP data) are for leukaemia (bone marrow), thyroid and bone surface cancer. The total risk is estimated to be 2.5 fatal malignancies per 10^6 full-mouth examinations made with D-speed film and round collimation. The effective dose from a full-mouth examination made under the same conditions is estimated to be 84 μSv, equivalent to 1 week of background exposure. Use of E-speed film and rectangular collimation will substantially reduce the total risk.

Keywords: Radiation; radiation dosage; risk; radiography, dental

Dentomaxillofac. Radiol., 1992, Vol. 21, 118–26, August

Recent studies (1988–90) suggest that the lifetime cancer risks from exposure to low levels of ionizing radiation may be greater than previously estimated. Three agencies have comprehensively reviewed this subject and each has described an elevated risk compared with previous estimates. These agencies are the International Commission on Radiological Protection (ICRP)[1], the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)[2] and the Committee on the Biological Effects of Ionizing Radiations (BEIR) of the US National Research Council[3]. This review will first summarize the findings as they pertain to dental radiology and then use their concepts together with dosimetry from the dental literature to estimate the radiation risk from dental radiology.

Biological effects

The UNSCEAR 1988[2], BEIR V[3] and ICRP 1990[1] reports rely largely on data from populations of exposed humans followed for many years. They also examine the results of animal studies, particularly when such studies might help to provide a conceptual understanding of biological mechanisms involved in radiation carcinogenesis or the genetic effects resulting from radiation exposure. By far the largest group of individuals studied are the Japanese A-bomb survivors (Table I): Multiple studies have followed approximately 76 000 individuals since 1950 and an estimated 5936 cases of cancer of all types have been observed in this cohort, the large majority attributed to causes other than exposure to radiation. Only 341 cancers are considered to be radiation-induced excess deaths[4]. Other studies have followed over 14 000 British patients who received spinal irradiation for ankylosing spondylitis from 1935 to 1954. These studies excluded colon cancer from risk estimates in this group of patients because of a suspected association with ankylosing spondylitis. Several studies of patients receiving multiple fluoroscopic examinations between 1930 and 1956 during treatment for tuberculosis as well as of women treated with radiation for postpartum mastitis during the 1940s and 1950s have helped quantify the risk of breast cancer. Other studies have investigated the consequences of irradiation of the thyroid gland in two groups of children. A total of 10 834 children (ages 0–15 years) in Israel received X-radiation to the scalp to aid in treatment for *Tinea capitis* (ringworm). Also, in Rochester, New York, 2652 infants received

Table I Major data sets used for risk estimation*

Study population	Incidence or mortality	Cancer sites	Total cases†	Person-years
Atomic bomb survivors	Mortality	All	5936	2185335
	Incidence	Breast	376	940000
Ankylosing spondylitis patients	Mortality	Leukaemia	36	104000
		All other	563	104000
Canadian fluoroscopy patients	Mortality	Breast	482	867541
Massachusetts fluoroscopy patients	Mortality	Breast	74	30932
NY mastitis	Incidence	Breast	115	45000
Israel tinea capitis patients	Incidence	Thyroid	55	712000
Rochester thymus-irradiated patients	Incidence	Thyroid	28	138000

*From table 4–1 of BEIR V[3].
†This is the total number of cases of cancer seen in this population. Relatively few of these are believed to be radiation-induced excess cancers.

radiation treatments to reduce the size of their thymus gland. Many other studies on smaller groups of patients have also provided useful information about these and other organs. Most of the individuals in the studies mentioned above received exposure well above the diagnostic range. Thus, it is necessary to estimate the probability that cancer will result from a small dose by extrapolation from cancer rates observed following exposure to larger doses.

Table II compares several risks estimated from these studies over the last 13 years. The ICRP data[1] show that the estimated risk has increased four-fold, from 125 lifetime excess fatal malignancies per million persons exposed to 10 mSv to 500. Comparison of the BEIR III[5] and BEIR V[3] estimates as well as the UNSCEAR 1977[6] and 1988[2] estimates, however, must include consideration of the exposure dose rate in the low-dose range. The current ICRP 1990[1], UNSCEAR 1988[2] and BEIR V[3] reports all recognize that the biological effects of low dose, low dose-rate exposures of low LET radiation show a clear dose-rate effect. The magnitude of biological effects under such conditions is between 2 and 10 times less than with high dose-rate exposures. In the older UNSCEAR[6], ICRP 26[7] and BEIR III[5] reports a linear-quadratic model was used to estimate the risks of leukaemia and all other cancers.

Table II Estimated cancer risk by study for low-dose exposure

	Year	Lifetime excess fatal malignancies 10^{-4} 10 mSv^{-1}	DREF*
ICRP Publication 26	1977	125	Included
UNSCEAR	1977	75–175	Included
BEIR III	1980		Included
Absolute risk model		77	
Relative risk model		226	
UNSCEAR	1988		2–10 recommended
Absolute risk model		400–500†	
Relative risk model		700–1100†	
BEIR V	1990	790‡	2 recommended
ICRP Publication 60	1990	500	Included

*DREF is the dose-rate effectiveness factor, a factor to be used when estimating the effects resulting from exposure to a low dose or at a low dose rate.
†The rate for cancers other than leukaemia, approximately 85% of the cancers expected following high dose and high dose rate exposure, should be reduced by a factor of 2–10 in order to compare with UNSCEAR 1977.
‡The rate for cancers other than leukaemia, approximately 85% of the cancers expected following high dose and high dose rate exposure, should be reduced by a factor of 2 in order to compare with BEIR III.

Such a model contains an implicit dose-rate effect. In the UNSCEAR 1988 and BEIR V reports a linear-quadratic model was used only for leukaemia. These reports prefer a linear model for all other cancers but did not apply a dose-rate effectiveness factor (DREF). This places the responsibility for including a DREF on the user of the data. Under low dose and low dose-rate conditions, a DREF, typically of about 2, would be used. This change in modelling has the effect of removing the influence of dose-rate effects for estimates of the rates of all cancers other than leukaemia. The ICRP 1990 report used a DREF of 2 in its risk estimates. In comparing the rates of excess fatal malignancies, note that some estimates include a DREF while others do not.

The magnitude of the DREF and recommended indications for its application are not consistent between agencies. The ICRP recommends a DREF of 2 when the dose is less than 0.2 Gy, certainly the case for diagnostic radiology. The UNSCEAR 1988 report suggests that DREF factors of 2–10 can be justified. This report defines low doses and low dose rates as less than 0.2 Gy and less than 0.05 mGy min^{-1} respectively. With this definition, diagnostic examinations are fractionated medium dose-rate exposures. The BEIR V report suggests a DREF of 2 and discusses the use of a DREF for continuous exposures. This review assumes a DREF for dental exposures of 2 as recommended by the ICRP.

There are primarily two sources of new information that contribute to the conclusion in the current ICRP, UNSCEAR and BEIR reports that the risk from exposure is greater than previously believed. First, the more recent studies of cancer had access to approximately 10 years of additional follow-up data for the survivors of the atomic bombings in Japan in 1945 as well as the other groups of exposed individuals. These populations continue to demonstrate elevated numbers of solid tumours. Cancer epidemiologists now believe that such excess tumours will continue to be found for the rest of the life of these exposed individuals.

Estimation of risk from groups of exposed individuals requires use of mathematical models that fit the epidemiological data. One model, the absolute risk model, supposes that exposure to radiation results in a constant number of excess number of cancers per unit exposure for each organ. A competing concept, the relative risk model, postulates that the number of excess tumours is a multiple of the spontaneous rate for

each organ. The BEIR V and ICRP 1990 reports generally reject the absolute risk model considered in UNSCEAR 1988 and BEIR III in favour of the relative risk model. The conclusion that the relative risk model is more appropriate follows from the observation that the number of excess cancers per unit dose increases in proportion with the number of spontaneous cancers as the population at risk is ageing. Thus, the number of excess cancers induced by radiation is considered to be a multiple of the spontaneous rate rather than independent of it. Adoption of the relative risk model accounts for part of the increased risk in the BEIR V and ICRP 1990 reports. This model may also overestimate it, as individuals may not be at risk over their whole lifespan.

A second cause for the increased risk estimates is the result of reassessment of the A-bomb dosimetry, called the New Dosimetry System, or DS86. The tentative 1965 dose estimates (T65) indicated that the blast at Hiroshima contained a significant neutron component. Because of the high relative biological effectiveness of neutrons, radiobiologists believed that the neutron exposure contributed significantly to the short- and long-term morbidity and mortality. The DS86 showed that the neutron contribution was about ten times smaller than previously calculated. Thus, the adverse effects seen in Hiroshima are more attributable to the gamma ray exposure than previously believed. At Nagasaki, where scientists had thought that gamma radiation was the primary source of radiation exposure, it is now clear that it was little more than half the previous estimate. This re-analysis of the dosimetry from both cities suggests that the DS86 doses are about half the 1965 estimate and, thus, the effectiveness of gamma ray exposures is about twice the previous estimate.

Somatic effects

Somatic effects are those seen in the irradiated individual. The most important of these for individuals exposed in the low dose range is radiation-induced carcinogenesis. The estimated number of deaths attributable to low-level radiation exposure is a small fraction of the total number that occur spontaneously. The BEIR V committee estimates that a single, brief whole-body exposure of 0.1 Gy to 100 000 people results in about 443 additional cancer deaths over the lifetime of the exposed individuals, assuming a DREF of 2 for cancers other than leukaemia*. This is in addition to the 20 000 that would occur spontaneously. The BEIR V estimate compares well with the ICRP 1990 estimate of 500 lifetime fatal cancers per 10 000 exposed persons per Sv. Table III presents the ICRP estimated distribution of such radiation-induced cancers. Cancers other than leukaemia typically start to appear about 10 years following exposure and remain in excess for as long as most exposed populations are followed, presumably for the lifetime of the exposed individuals. The risk from exposure during childhood is about twice as large as for adults. When elderly individuals are exposed, the number of expected excess cancer deaths declines because these individuals may not live long enough for the cancer to develop.

Table III Lifetime mortality in a population of all ages from specific fatal cancer after exposure to low doses*

	Fatal probability coefficient (10^{-2} Sv^{-1})	
	ICRP (1977)	ICRP (1990)
Bladder	—	30
Bone marrow	20	50
Bone surface	5	5
Breast	25	20
Colon	—	85
Liver	—	15
Lung	20	85
Oesophagus	—	30
Ovary	—	10
Skin	—	2
Stomach	—	110
Thyroid	5	8
Remainder†	50	50
Total	125‡	500§

*Table B-17 from ICRP 1990[1].
†The composition of the remainder is quite different in the two cases. Currently, the remainder is composed of the following additional tissues and organs: adrenals, brain, upper large intestine, small intestine, kidney, muscle, pancreas, spleen, thymus and uterus.
‡This total was used for both workers and the general public.
§This data pertains to the general public. The total fatal cancer risk for a working population is taken to be 400×10^{-2} Sv^{-1}.

The following brief discussion of the somatic effects of exposure to radiation will pertain largely to those organs exposed during dental radiography.

Leukaemia

The incidence of leukaemia (other than chronic lymphocytic leukaemia) rises following X-ray exposure to the red bone marrow. Atomic bomb survivors and patients irradiated for ankylosing spondylitis show a wave of leukaemias appearing within 5 years following exposure and returning to baseline rates within 30 years. The mortality data for leukaemia are compatible with a linear-quadratic dose-response relationship. Children under 20 years are more at risk than adults. Red bone marrow in the head and neck of adults is found in the body of the mandible, calvarium and cervical spine.

Thyroid cancer

The incidence of thryoid carcinomas (arising from the follicular epithelium) increases in humans following exposure to ionizing radiation. About 10% of individuals with such cancers die from their disease. The best studied groups are the Israeli children irradiated to the scalp for ringworm, the children in Rochester irradiated to the thymus gland, and atomic bomb survivors. Susceptibility to radiation-induced thyroid cancer is greater early in childhood than at any time later in life. Females are three times more susceptible than males to both radiogenic and spontaneous thyroid cancer (see p. 298).

Bone cancer

Irradiation of bone periosteal and endosteal surfaces carries the risk of excess bone malignancies, mostly

*This is calculated from table 4-2 of BEIR V as follows: The rate of excess leukaemia per 10 000 males exposed to 1 Sv is 110 and the female rate is 80; the average is 95. The non-leukaemia rate for males is 660 and for females is 730; the average is 695. Applying a DREF of 2 the non-leukaemia rate becomes 347.5. Thus, the total of the leukaemia and non-leukaemia rates is 442.5.

osteosarcoma. The dosimetry data on cancers arising from bone surfaces in humans following exposure to low-LET radiation is fairly sparse and not suitable for risk estimation. The Japanese A-bomb survivors show no elevated bone tumours following exposure up to 4 Gy. The BEIR V committee used data from internally deposited radon (which emits high-LET alpha particles) in humans for risk estimates. To estimate the risk of low-LET radiation, they used a relative effectiveness (quality) factor of 20 to correct for the more harmful high-LET alpha particle emission. They also reviewed risk estimates from internally deposited beta emitters (primarily ^{90}Sr) in laboratory animals ([3] see p. 306).

Oesophageal cancer

There is limited data on oesophageal cancer. Excess cancers developed in the Japanese atomic bomb survivors as well as in patients treated with X-ray for ankylosing spondylitis.

Brain and nervous system cancer

Patients exposed to diagnostic exposure in utero and to therapy doses in childhood or as adults (average midbrain dose of about 1 Gy) show excess numbers of malignant and benign brain tumours. In addition, a case-control study has shown an association between intracranial meningiomas and previous medical or dental radiography[3]. The strongest association for these meningiomas was with a history of exposure to full-mouth dental radiographs when less than 20 years of age. It is likely that these patients received substantively more exposure than when using contemporary radiographic techniques.

Salivary gland cancer

The incidence of salivary gland tumours is increased in patients therapeutically irradiated for diseases of the head and neck, in the Japanese A-bomb survivors, and in persons exposed to diagnostic levels of X-radiation. Several studies have found an association between tumours of the salivary glands and dental radiography, the risk being highest in those receiving full-mouth examinations (FMS) before the age of 20[8]. Only individuals receiving an estimated cumulative parotid dose of 0.5 Gy or more showed a significant correlation between dental radiography and salivary gland tumours[9]. The current ICRP model for estimation of cancer risk does not include the salivary glands as an organ at risk, although Velders *et al*[10] argue that there is sufficient evidence of harm to justify it.

Cancer of other organs

Other organs such as the skin, paranasal sinuses and bone marrow (multiple myeloma) also show excess cancers following exposure. The mortality and morbidity expected following head and neck exposure in these organs is much less than for those described above.

Mental retardation

Studies of individuals exposed in utero have shown that the developing human brain is radiosensitive, particularly between 8 and 15 weeks of gestational age. Severe mental retardation appears to show a threshold with a lower bound of 0.12–0.2 Gy[11]. In the case of less severe mental retardation, there is an estimated decrease of 30 IQ points per Sv during this period ([1] see p. 147). There is less risk of mental retardation occurring from exposure at other gestational ages. The risk from dental radiography is essentially non-existent; the uterine dose from a FMS is less than 0.01 μGy[12].

Table IV Estimated heritable effects of population exposure to 10 mSv per generation*

Type of disorder	*Current incidence per million live born offspring*	*Additional first-generation cases 10^{-6} liveborn offspring 10 mSv^{-1}*
Autosomal dominant		
Severe	2500	5–20
Mild	7500	1–15
X-linked	400	<1
Recessive	2500	<1
Congenital abnormalities	20000–30000	10

*Adapted from table 2-1 of BEIR V[3].

Cataract of the eye lens

The threshold for induction of cataract of the eye lens ranges from about 2 Gy when the dose is received in a single exposure, to more than 5 Gy when the dose is received in multiple exposures over a period of weeks ([3] see p. 363). These thresholds are far greater than the dose received with contemporary dental radiographic techniques[13–15].

Heritable effects

Heritable (genetic) effects are those seen in the progeny of irradiated individuals. There is little information about the heritable effects of radiation exposure in man and, to date, such effects have not been clearly demonstrated. There is no statistically significant increase in genetically related disease in the children of atomic bomb survivors. Current knowledge of heritable effects following radiation exposure derives largely from work on mice. Table IV shows the estimated heritable effects in man following an exposure to the population of 10 mSv per generation. These estimates result primarily from human and mouse data. The BEIR V, ICRP and UNSCEAR committees estimate that at least 1 Sv of low dose-rate X-radiation to each member of the population is required to double the mutation rate in man[1–3]. The probability of heritable effects resulting from dental radiography is quite low, as the annual genetically significant dose* from dental radiography is 0.08 μSv in countries with a high level of health care and less in other countries ([2] see p. 289). The individual gonadal dose following a FMS is less

*The genetically significant dose is the dose that, if received by every member of the population, would be expected to result in the same total heritable injury to the population as do the actual gonadal doses received by the individuals exposed.

Table V Average annual effective dose of ionizing radiations to a member of the US population*

	Dose (mSv)	Population (%)
Natural		
Radon	2.0	55
Cosmic	0.27	8.0
Terrestrial	0.28	8.0
Internal	0.39	11
Artificial		
Medical		
X-ray diagnosis	0.39	11
Nuclear medicine	0.14	4.0
Consumer Products	0.10	3.0
Other		
Occupational		
Nuclear fuel cycle	<0.01	<0.3
Fallout	<0.01	<0.03
Total	<0.01	<0.03
	3.6	100

*Adapted from table I-3 of BEIR V[3].

than 0.01 μSv in an adult female[12] and 10 μSv or less in males[14]. The gonadal dose is so small from dental radiography that the risk of heritable defects is negligible in comparison with the somatic risk*.

Dental risk implications

To gain a perspective on the magnitude of dental exposure, it is instructive to review a listing of major sources of radiation. Table V shows the average annual effective dose of ionizing radiations to a member of the US population†. Diagnostic radiation accounts for only about 11% of all exposure. Only about 1% of this 11%, or about 0.1% of the total exposure, results from dental radiography ([2] see p. 288)‡. Compare this to radon, for instance, which is estimated to contribute more than half the human exposure. Estimation of risk from dental radiography in this discussion will focus first on cancer fatalities and then on the effective dose.

Fatal cancers

The risk of fatal cancers resulting from a radiographic exposure is the sum of the risks of individual radiosensitive organs. The ICRP 1990 report estimates the lifetime mortality coefficients for low dose exposure for 12 specific organs (Table III). The probability coefficients for fatal cancers for structures in the primary beam, e.g. bone marrow and thyroid, are now higher than in 1977 for the reasons described above. The product of these mortality coefficients and organ doses received during a radiographic examination yields fatality estimates for that examination. The remainder organs are those known to be radiosensitive but whose risk coefficient is too low, or not known with sufficient precision, to list separately. The cancer risk also depends on the age and sex of the exposed individual. The risk estimates presented here pertain to the general public, in that they are derived on the basis of typical age and sex distribution ([1] see p. 128).

The dental literature contains several studies reporting sufficient dosimetric data for radiosensitive sites in the head and neck to allow estimation of the risk of fatal cancers from intra-oral and panoramic radiography. To estimate the risk from intra-oral radiography and compare the results from various studies, it was necessary to define comparable exposure conditions. This study will first consider a FMS exposed at 70 kVp with D-speed film and round open-ended aiming cylinders as the basis for comparison of results. Table VI computes the probability of fatal cancers per million FMS made under these conditions. This table incorporates several adjustments to the primary data. First, the risk estimates were made using the original dosimetry, but with the current ICRP risk factors. Further, E-speed film dose values were doubled and C-speed dose values were halved to estimate comparable D-speed dose values. The dose resulting from one bitewing exposure was equated to one-twentieth of a FMS. When data from bone surface exposure was missing it was estimated to be 4.64 times the marrow exposure[16].

The average of the seven studies in Table VI shows that the highest estimated risks are for leukaemia (bone marrow), thyroid and bone surface cancer. The estimated risks for leukaemia (bone marrow) and thyroid cancer are greater than prior estimates because of the

Table VI Risk of fatal cancers per million FMS*

	References							
	10†	12	17	18	19†	15‖	16‖	Average
Gonads	—	—	—	—	—	—	—	—
Bone marrow	0.4	1.1	0.6	0.3	1.3	0.1¶	1.4	0.7
Colon	—	—	—	—	—	—	—	—
Lung	0.2	0.1	—	0.1	0.2	—	—	0.1
Stomach	—	—	—	—	—	—	—	—
Bladder	—	—	—	—	—	—	—	—
Breast	—	—	—	0.2	0.2	—	—	0.1
Liver	—	—	—	—	—	—	—	—
Oesophagus	—	0.5	—	—	—	—	—	0.1
Thyroid	0.2	1.3	0.1	0.4	0.1	2.2	1.0	0.8
Skin	—	0.1	—	0.1	—	—	—	—
Bone surface	0.3	1.1	0.7	0.1**	0.6	—	0.7	0.5
Remainder	0.8††	0.5	0.1	0.1	0.5	0.1	0.3	0.3
Sum	1.9	4.5	1.4	1.0	2.6	2.4	3.4	2.5

*D-speed film and round collimation.
†Data multiplied by 20 to equate one bitewing with a full-mouth examination.
‡Data multiplied by 10 to equate two bitewings with a full-mouth examination.
§Data divided by 1.7 to equate exposures of 70% C-speed film and 30% D-speed film to all D-speed film.
¶Data doubled to equate E-speed film data to D-speed film.
**Bone marrow in mandible assumed to constitute 1.3% of body bone marrow.
††Dose to bone surface assumed to be 4.64 times that of bone marrow.
‡‡Method of computation of remainder a modification of the ICRP method and used here as published.
—, <0.05.

*If the risk of heritable defects is taken to be 30 additional first-generation cases per million liveborn offspring per 10 mSv (Table IV) and the average exposure to every member of the population is taken as 0.5 μGy (one-tenth the average of the male and female gonadal exposure from a full-mouth set of radiographs) then the heritable risk is 1.5×10^{-9}. This is more than three orders of magnitude less than the somatic risk estimated on Table VI.

†The values shown in this table are consistent with those in UNSCEAR ([2] see p. 41) that reflect the greater range of exposures found in different regions of the world.

‡This value is representative of countries with a high level of health care. The dental fraction of total exposure will depend on the country, as both the rate of exposure ([2] see p. 273) and the mean effective dose ([2] see p. 286) vary by country.

elevated fatal probability coefficients (Table III). While the relative risk for bone cancer is lower than for bone marrow and thyroid, the relatively high dose absorbed at the bone surfaces gives this site a comparable risk. The risk of bone cancer following dental exposure, however, is especially suspect. Because of the lack of evidence relating low LET exposure below 4 Gy with osteosarcoma, it may be that this risk is considerably overestimated.

It is striking that even with the current higher risk coefficients, the average risk reported in Table VI, 2.5 fatal malignancies per million FMS, is generally less than previously reported. Gibbs *et al.* estimated the risk to be seven fatal cancers per million examinations in 30-year-old individuals[12]. Underhill *et al.*[22] concluded that for a FMS using round collimation and E-speed film there are about five fatalities per million examinations in 30-year-old individuals. Bengtsson[18] put it at 12 deaths per million FMS while Gregg[20] calculated three cases per million four-film dental examinations and thus 15 per million FMS. The difference in the risks computed in this report and those originally reported by the authors of the studies cited results from two competing effects. There is an increased risk estimated from organs known to be radiosensitive, listed in Table III, and a reduced risk estimated for the remainder organs whose radiosensitivity is less well established. The current ICRP method of computing the dose to the remainder organs (an average of the organs listed in footnote[‡] of Table III) results in a smaller estimated dose to the remainder organs than using the previous ICRP method. In the current report, the remainder organs account for only about 10% of the total risk. Gibbs *et al.*[12], for instance, found that the risk resulting from exposure to the remainder organs was about 10 times larger than in the current report and accounted for about two-thirds of their total risk estimate.

Use of E-speed film and rectangular collimation will substantially reduce the total risk. Velders *et al.*[10], Underhill *et al.*[16] and Gibbs *et al.*[12] compared the risk from round with rectangular collimation. The average risk is reduced by a factor of 2.8 using rectangular collimation. Since E-speed film is about twice as fast as D-speed film, the risk of dental radiography declines approximately five-fold by using rectangular collimation with E-speed film. The studies of Velders *et al.*[10] found that the risk is increased at 50 kVp but they and Gibbs *et al.*[12] found that the risk is largely insensitive to variation in kVp in the range 65–90.

It is possible to estimate the worldwide risk of fatal cancers from dental radiography. The United Nations reports that there were 340 million dental radiographic procedures performed in 1980 and that there was an average of four films per procedure ([2] see p. 274). Given a risk estimate of 2.5 fatalities per million FMS we may project that the risk of one radiographic procedure (four films) is about 0.5 fatalities per million procedures. Accordingly, the worldwide annual fatality rate may be about 170 cases. This estimate declines to 34 cases by universal adoption of E-speed film and rectangular collimation.

Published dosimetry for panoramic radiography allows risk estimation from this source of exposure. Table VII computes the risk of fatal malignancies per million individuals exposed for a panoramic radiograph using rare-earth intensifying screens. As in Table VI, the computation is based on original dosimetry and the current ICRP risk estimates. Original dosimetry data measured with calcium tungstate screens was halved to take into account the dose reduction. In this case, leukaemia (bone marrow) and thyroid cancer constitute the greatest risk, while bone surface cancers are also important. It is noteworthy that panoramic radiography carries about one-tenth the risk of a FMS.

Effective dose

The ICRP recommends use of the concept of radiation detriment in radiation protection. This is the total harm that would eventually be experienced by an exposed group and its descendents as a result of radiation exposure. It is appropriate to estimate detriment only

Table VII Risk of fatal cancers per million panoramic examinations*

	References and type of examination											
	21 Panoral	*21 OPS†*	*21 Orallx*	*19† §*	*16 Panoura*	*16 Panoral*	*16 Orallx*	*16 Panelipse*	*16 OPS*	*18† §*	*15† ‡*	*Average*
Gonads	—	—	—	—	—	—	—	—	—	—	—	—
Bone marrow	0.05	0.07	0.06	0.13	0.07	0.04	0.07	0.05	0.08	0.03	—	0.06
Colon	—	—	—	—	—	—	—	—	—	—	—	—
Lung	0.01	0.02	0.01	0.04	—	—	—	—	—	0.04	—	0.01
Stomach	—	—	—	—	—	—	—	—	—	—	—	—
Bladder	—	—	—	—	—	—	—	—	—	—	—	—
Breast	—	—	—	0.01	—	—	—	—	—	0.01	—	—
Liver	—	—	—	—	—	—	—	—	—	—	—	—
Oesophagus	0.05	0.07	0.06	—	—	—	—	—	—	—	—	0.02
Thyroid	0.03	0.10	0.05	0.03	0.05	0.03	0.04	0.03	0.04	0.04	0.24	0.06
Skin	—	0.01	0.01	—	—	—	—	—	—	0.01	—	—
Bone surface	0.02	0.04	0.03	0.05	0.03	0.02	0.03	0.03	0.04	0.01¶	—	0.03
Remainder	0.04	0.11	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.06	0.03
Sum	0.22	0.41	0.29	0.25	0.16	0.09	0.15	0.12	0.17	0.14	0.30	0.21

*Using rare-earth intensifying screens.
†Original data divided by 2 to convert from calcium tungstate intensifying screens to rare-earth screens.
‡Orthopantomograph, model OPS.
§Type unspecified.
¶Dose to bone surface assumed to be 4.64 times that of bone marrow.
—, <0.005.

Table VIII Tissue weighting factors*[1]

Tissue or organ	*Tissue weight factor, w_T*
Gonads	0.20
Bone marrow (red)	0.12
Colon	0.12
Stomach	0.12
Lung	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Oesophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surface	0.01
Remainder	0.05[a][1]

*From table 3, ICRP Publication 60, 1990[1].
[a]The values have been developed from a reference population of equal numbers of both sexes and a wide range of ages. In the definition of effective dose they apply to workers, to the whole population, and to either sex.
[1]For purposes of calculation, the remainder is composed of the following additional tissues and organs: adrenals, brain, upper large intestine, small intestine, kidney, muscle, pancreas, spleen, thymus and uterus. The list includes organs which are likely to be selectively irradiated. Some organs in the list are known to be susceptible to cancer induction. If other tissues and organs subsequently become identified as having a significant risk of induced cancer they will then be included either with a specific w_T or in this additional list constituting the remainder. The latter may also include other tissues or organs selectively irradiated.
In those exceptional cases in which a single one of the remainder tissues or organs receives an equivalent dose in excess of the highest dose in any of the 12 organs for which a weighting factor is specified, a weighting factor of 0.025 should be applied to that tissue or organ and a weighting factor of 0.025 to the average dose in the rest of the remainder as defined above.

Table IX Effective dose, E, for a full-mouth examination (μSv)*

	References							
	10[a]	*12*	*23*	*18*	*19*[b]	*15*[g]	*16*[h]	*Average*
Gonads	—	—	—	—	4	—	—	1
Bone marrow	10	25	14	6	30	2[e]	34	17
Colon	—	—	—	—	—	—	—	—
Lung	2	1	—	1	2	—	—	1
Stomach	—	—	—	—	—	—	—	—
Bladder	—	—	—	—	—	—	—	—
Breast	—	—	—	5	5	—	—	1
Liver	—	—	—	—	—	—	—	—
Oesophagus	—	8	—	—	—	—	—	1
Thyroid	13	80	5	25	5	138	63	47
Skin	1	4	—	3	—	1	—	1
Bone surface	5	21	14	2[f]	12	1[f]	13	10
Remainder	9[i]	5	1	1	5	1	3	3
Sum	44	144	34	44	63	142	113	84

[a]D-speed film and round collimation.
[b]Data multiplied by 20 to equate one bitewing with a full-mouth examination.
[c]Data multiplied by 10 to equate two bitewings with a full-mouth examination.
[d]Data divided by 1.7 to equate exposures of 70% C-speed film and 30% D-speed film to all D-speed film.
[e]Data doubled to equate E-speed film data to D-speed film.
[f]Bone marrow in mandible assumed to constitute 1.3% of body bone marrow.
[g]Dose to bone surface assumed to be 4.64 times that of bone marrow.
[h]Method of computation of remainder a modification of the ICRP method and used here as published. —, <0.5.

when the exposures are small and stochastic effects are being considered. Detriment includes not only the probability of fatal cancer but also the weighted probability of non-fatal cancer, the weighted probability of severe hereditary effects, and the relative length of life lost. To estimate detriment, first determine the equivalent dose to radiosensitive organs. The equivalent dose, H_T is the sum of the products of the radiation weighting factor, w_R, and absorbed dose, $D_{T,R}$ to each exposed tissue or organ. w_R is unity for all low LET radiations including X-rays of all energies. $D_{T,R}$ is the absorbed dose averaged over the tissue or organ T, due to radiation R. The unit of equivalent dose is the Sievert (Sv). Detriment is measured by the effective dose, E, the sum of the equivalent doses, H_T, to each organ of interest multiplied by the tissue weighting factor, w_T. The tissue weighting factors consider the relative contribution of each organ or tissue in terms of total detriment. Table VIII lists the tissue weighting factors that have been adopted by the ICRP in 1990. The effective dose calculated in this way for a particular radiographic examination may be expected to result in the same total detriment as that from a uniform whole-body exposure of the same amount. For example, a dose of 20 mSv limited to the thyroid gland ($w_T = 0.05$) yields an effective dose of 1 mSv and can be expected to provide the same detriment as a whole-body dose of 1 mSv.

Table IX shows the effective dose from a FMS using D-speed film and round collimation using the same data conversions as described above. The effective dose to the thyroid is approximately three times that to the bone marrow, while the risk expressed as fatal cancers is about the same. While the contribution of non-fatal cancers is twice that for thyroid compared with bone marrow, the relative length of life lost for leukaemia is twice that for thyroid cancer. The discrepancy results from the rounding used by the ICRP in assigning tissue weighting factors*. Because of these approximations, emphasis is placed on the total effective dose.

An average effective dose of 84 μSv for a full-mouth examination using D-speed film and round collimation is less than that previously estimated by most authors for the same reasons described above for estimation of the probability of fatal cancers. Gibbs *et al.*[12] computed an effective dose of about 400 μSv for a young adult. Wall and Kendall[19] reported 10 μSv per film, equivalent to 200 μSv for a FMS. Stenström *et al.*[23] give a comparable effective dose of 234 μSv. The reduced estimate of the effective dose in the present report results largely from the great reduction in the contribution from the remainder organs. The fairly wide discrepancies in effective dose to bone marrow and thyroid may relate in part to beam diameter. Stenström *et al.*[23] used a beam diameter of 5.5 cm, Velders *et al.* 6.0 cm[24], while Gibbs *et al.* used 7.0 cm[12]. Antoku *et al.* showed that when the beam diameter is increased from 6.5 to 8.0 cm, the thyroid dose is increased by a factor of four[15]. Underhill *et al.*[16] estimated an effective dose of 514 μSv for a FMS with E-speed film and round collimation, equivalent to about 1000 μSv for D-speed film. This effective dose, as with that computed from the data of Stenström *et al.* using the current ICRP method, is a slight underestimate as it does not include skin and the remainder organs. Velders *et al.*[10] estimated the effective dose for one bitewing at 75 kVp with round collimation as 2.3 μSv, or 44 μSv for a FMS. They modified the ICRP method for determining the effective dose resulting from exposure to abdominal and remainder organs to the

*The ratio of the relative contribution of bone marrow to thyroid in terms of total detriment (' see table B-20) is 6.8, virtually the same as the ratio of the probability of fatal cancer for these tissues. After rounding to assign the tissue weighting factors, however, the bone marrow to thyroid detriment ratio is reduced to 2.4. This raises the relative weight assigned to the thyroid gland by a factor of 2.8, almost exactly the relative increase seen in Table IX.

Table X Effective dose, E, for a panoramic examination (μSv)*

	References and type of examination											
	21 Panoral	21 OPS†	21 Oralix	19‡ §	16 Panoura	16 Panoral	16 Oralix	16 Panelipse	16 OPS	18‡ §	15‡ §	Average
Gonads	—	—	—	0.5	—	—	—	—	—	—	—	—
Bone marrow	1.2	1.7	1.4	2.0	1.6	0.8	1.7	1.2	1.9	0.6	—	1.4
Colon	—	—	—	—	—	—	—	—	—	—	—	—
Lung	0.2	0.2	0.2	0.6	—	—	—	—	—	0.6	—	0.2
Stomach	—	—	—	—	—	—	—	—	—	—	—	—
Bladder	—	—	—	—	—	—	—	—	—	—	—	—
Breast	—	—	—	0.3	—	—	—	—	—	0.3	—	—
Liver	—	—	—	—	—	—	—	—	—	—	—	—
Oesophagus	0.9	1.2	1.0	—	—	—	—	—	—	—	—	0.3
Thyroid	2.2	6.0	3.0	1.8	3.1	1.7	2.3	2.1	2.6	2.5	15.0	3.8
Skin	0.2	0.4	0.4	—	—	—	—	—	—	0.3	—	0.1
Bone surface	0.5	0.8	0.6	1.0	0.6	0.3	0.7	0.6	0.7	0.2	—	0.6
Remainder	0.4	1.1	0.7	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.6	0.3
Sum	5.5	11.4	7.3	7.2	5.3	3.0	4.7	3.9	5.3	4.6	15.6	6.7

*Using rare-earth intensifying screens.
†Data divided by 2 to convert from calcium tungstate intensifying screens to rare-earth screens.
‡Orthopantomograph, model OP5.
§Type unspecified.
—, <0.05.

extent that it differs from a strict application of the ICRP method by 7%*.

Table X shows the estimates of the effective dose for panoramic radiography. The thyroid effective dose is relatively high compared to the bone marrow dose for the reason described above. The effective dose estimates for panoramic radiography in this report, an average of 6.7 μSv, are smaller than many recent estimates for the reasons identified above for risk estimates. As with the risk estimate, the effective dose of panoramic radiography is less than 10% of a FMS made with D-speed film and round collimation.

By way of comparison, the current BEIR estimate of the average effective dose from natural sources (based on fatal cancers) is 3 mSv per year ([3] see p. 18). To include non-fatal cancer and severe hereditary effects (the probability of stochastic effects) multiply this value by 1.45 to yield 4.4 mSv ([1] see table B-20). We may then estimate that a FMS made with D-speed film and round collimation (84 μSv) is equivalent to 1 week of background exposure. Table XI shows equivalent background times for other common dental examinations. For instance, a panoramic radiograph made with rare-earth screens corresponds to about half a day of background. It may also be instructive to observe that the effective dose for a FMS (84 μSv) is well within the range of natural variation in cosmic and terrestrial background exposure between different populated geographic sites.

Table XI Equivalent background exposure from dental radiography

Examination	Film	Collimation	Background equivalent*
Full mouth†	D	Round	1 week
	E	Round	4 days
	D	Rectangular	3 days
	E	Rectangular	1 day
Bitewings‡	D	Round	1 day
	E	Round	17 h
	D	Rectangular	13 h
	E	Rectangular	7 h
Panoramic§	Calcium tungstate screens		1 day
	Rare-earth screens		12 h

*Based on an environmental effective dose of 4.4 mSv (see text). Time rounded to the nearest whole unit.
†Data derived from average effective dose from Table IX.
‡Data derived from average effective dose from Table X.

*The effective dose for 75 kVp, round collimation as calculated by Velders *et al.*[10] for one bitewing is 2.22 μSv, including a remainder of 0.463 μSv. With the strict ICRP method for computing the remainder, the effective dose drops to 2.06 μSv, including a remainder of 0.09 μSv, a reduction of 7.2%.

Conclusions

The estimates above represent extrapolations to the low dose range beyond the availability of data. As such, we cannot consider they demonstrated that diagnostic exposures cause cancers at the rate estimated. Nor, on the other hand, is there reason to presume that dental radiography is without risk. While the risk from dental radiography is certainly small in terms of other risks we readily assume during our daily lives (e.g., from driving, smoking or eating fatty foods), there is no basis to assume that it is zero. Although radiation appears to be a weak carcinogen, prudence suggests we should be cautious because of the large numbers of people exposed to dental radiography.

It is our responsibility to assure that our patients avoid receiving even the smallest unnecessary dose of radiation. While there is evidence that the dental profession has made considerable progress in reducing patient exposure over the years (Figure 1), there is still opportunity for improvement. Certainly, dentists should use selection criteria for ordering films. As there is no consensus on exactly what such criteria should be, we need continued research in this field. The use of E-speed film and rectangular collimation should be routine, as should time-temperature processing and the use of rare-earth screens for all extra-oral radiography. We should use thyroid collars, especially with children, as they halve the thyroid dose[17]. As Lauriston Taylor has observed: 'Today we know about all we need to

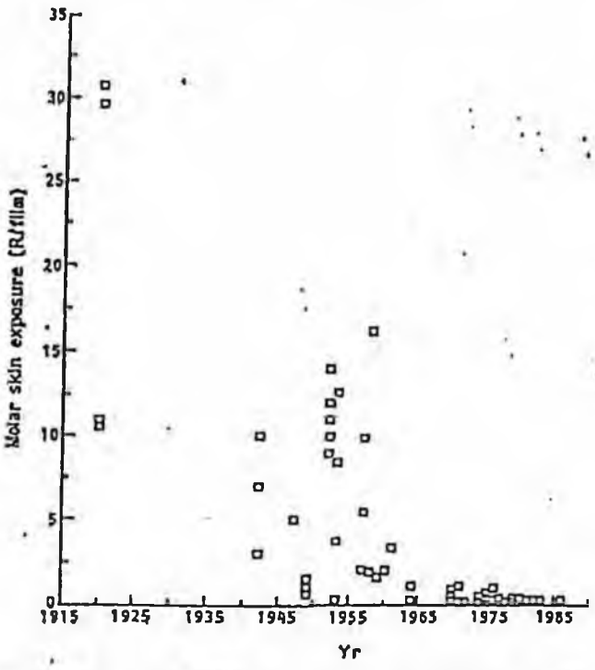

Figure 1 Values for skin exposure for an intra-oral radiograph of the first molar derived from review of the English-language literature. The 1920 values are reconstructions. The higher value in each pair results from the use of a 9.2-cm beam diameter rather than 7.6 cm. The higher pair has no added filtration, often the case in these years, while the lower pair reflects the use of 1.0 mm added aluminium filtration. Note great reduction of surface skin exposure resulting primarily from introduction of faster films, use of added filtration, and restriction of beam size. The sources used to gather these data points are listed in ref. 9

know for adequate protection from ionizing radiation'[25]. While dentistry can rightfully take pride in how far we have come, as a profession we still have further opportunity to implement our knowledge of radiation protection.

Acknowledgements

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Senator Robin L. Taylor
Senate Majority Leader

SPONSOR STATEMENT

SENATE BILL 160

Senate Bill 160 changes the procedures for inspecting and registering dental radiological equipment. Current procedures are erratic and inutile. On-site inspections by the Department of Health and Social Services are unnecessary because the incidence of x-ray overexposure is so insignificant as to be non-existent. Some states do not even have a requirement for registration or inspection of dental radiological equipment.

SB 160 will transfer the registration of dental radiological equipment to the Board of Dentistry. Inspection activities will be done by the private sector. The owner or lessee of the equipment will be responsible for providing documentation to the Board that the equipment is registered and has been inspected within the past five years by an individual who meets the criteria established by the Board.

Inspections and needed adjustments are routinely performed by trained dental supply company technicians who are far more qualified to perform such inspections than representatives from the Department of Health and Social Services. SB160 will establish the criteria required for technicians who will be acceptable inspectors under this legislation.

Under SB 160, if a dentist or their employees use equipment that is not registered or equipment that does not have a current inspection sticker, they will be subject to a civil penalty in the form of a fine, levied by the Board, not to exceed $5000 for each violation.

Gentle Dental Care

FLOYD R. "FRED" BOUSE, DDS
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March 5, 1998.

Senator Robin L. Taylor
State Capitol - Room 516
Juneau, AK

Dear Sirs,

We in the dental profession very much appreciate your efforts regarding SB160.

I personally wrote letters of protest about this matter several years ago and again recently. The letters were sent to the Department of Health and Social Services in Juneau.

The last time my office was inspected was seven years ago or so - fees paid to the Department of Health & Social Services have increased to 250% of original fees, yet helpful inspection of my facility has been sporatic-to-non-existent. Only after a recent letter I wrote, in which I protested a lack of services (from Health and Social Services Radiology Dept.) did I have my radiological equipment examined by a state employee. I personally desire and invite intelligent, helpful involvement of the appropriate parties in the maintenance of my equipment in first-rate, state-of-the-art condition.

The State of Alaska has been woefully negligent in its duty to the dental profession regarding radiological inspections: negligent not because we need inspections, but because we were promised inspections, we paid for inspections and then never or hardly ever get what we are paying for.

A much more effective and responsive solution to this matter is addressed by SB160. Let me encourage you to proceed and prevail in this matter.

Thank you for taking time to read my note.

Yours in service,

Floyd F. Bouse, DDS

Geist Professional Building
3745 Geist Road
Fairbanks, Alaska
99709
(907) 479-2208

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Chiropractors	63
Dentists	241
Educational	5
Hospitals	19
Industrial	50
Medical	116
Veterinary	47

Dentists inspected since May 1995 133

Kate Coleman began inspecting 25% in May 1995. Clyde Pearce began inspecting 100% in May 1997. It is now possible to inspect all of the facilities on a three-year cycle.

Helmbrecht Dental
MICHAEL J. HELMBRECHT, D.D.S.

421 Third Street Fairbanks, Alaska 99701 (907) 456-1237 FAX (907) 452-4778

February 23, 1998

Senator Robin Taylor
State Capital
Juneau, AK 99801

Dear Senator Taylor,

Once again I want to thank you for affording me the opportunity to respond to the Department's claims reguarding dental x-rays.

This time, however, I am in agreement with most of the information they sent you. The body of scientific literature we have today concerning dental x-rays seems to agree that there could be a cancer risk on the order of one in a million associated with a full series of dental x-rays just as I reported to you in my last letter to you. It should be pointed out, however, that there has never been a case of cancer diagnosed that could be attributed to dental x-rays. Let me explain:

Background Information:

Cancer was not regarded as a population risk from sublethal radiation doses until excess leukemia began to appear in Japanese war survivors in the late 1940's. Since then, epidemiologic studies have shown excess lung cancers in uranium miners. Numerous studies since have shown increased cancers in populations using very high therapeutic doses of radiation to treat various anomalies in the late 1940's and 1950's. Some of these therapeutic modalities required the patient to endure up to 400 treatments with extremely high does of radiation.

All of the studies of cancer risk from small (diagnostic) doses of radiation have had to extrapolate from the data acquired on the high dose cases since there has never been any study which could show a link between diagnostic doses and cancer. Obviously there are many problems in the estimation of cancer risk from small radiation doses using the extrapolation technique. Consider for a moment, a study of liver cirrhosis on Second Avenue (Fourth Avenue if you live in Anchorage). Can we accurately extrapolate to show the risk of liver cirrhosis to the person who has one glass of champagne a year on New Years Eve form data showing the incidence of liver cirrhosis in a population that drinks to excess on a daily basis?

Noone has yet proven we can, so to be on the safe side lets assume the cancer risk from dental x-rays to be one in a million even though we get more radiation from traveling in an airplane for 6000 miles (JADA, vol. 105).

As I've mentioned in previous correspondence, the risk of getting cancer from dental x-rays would then be the same as the risk of dying in an accident if you spent six minutes in a canoe (JADA, vol, 105). What dentistry has done in acknowledging this potential risk is to put outriggers on the canoe. Through the various safety measures (eg. collumnation, lead aprons, high speed film, filtration, use of film holders, etc...) we have minimized this risk.

As the Department's article states, "the risk is small because of the efforts by the dental community, manufactures, and state radiation control programs."

S.B. 160 would not change any of this. What it would do is change the way the state is administering its control program in that the Board of Dental Examiners would be in charge. Through this change dentistry would be held to routine and predictable inspections and calibrations of equipment, not just the hit and miss "inspections" as they are done now. This would then relieve the Department of over 50% of their case load and give them the opportunity to concentrate their inspections on the more potentially hazardous machines used in medicine, veterinary, chiropractic, and industry without any budget increases.

I hope this letter will clarify not only the risks, but what we are doing to lessen them even more. Please contact me if there are any further questions. I am enclosing several up-todate articles from the current literature available on dental radiation risks.

Sincerely,

Michael J. Helmbrecht D.D.S

Mike Helmbrecht

enclosure/MH/bb

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December 19, 1996

Senator Robin Taylor
P. O. Box 1441
Wrangell, Alaska 99929

Dear Senator Taylor,

Thank you for the considerable amount of time you spent listening to our concerns regarding the state - government sanctioned x-ray inspection bureaucracy.

First of all, allow me to define the problem and give a brief history of the program in our state.

The entire matter of state sanctioned registration fees for each x-ray tube in dental offices remains of considerable importance to many members of the Alaska Dental Society. In 1986, the authority to collect fees for registration and inspection of radiological devices was established by Alaska Statute 44.49.022. An accompanying schedule was established by regulation. The per tube rate for dental offices was $20.00. The Alaska Dental Society did have opposition, however, it was felt the possibility of providing a better service to dental patients was sufficient cause to cooperate.

In 1993, there was an increase in registration fee to $50.00 per tube. This was a 150% jump and the sole purpose of the increase was to cover increased costs for the radiological physicist traveling state wide to inspect x-ray equipment in various offices. It is interesting to note that by this time the physicist had left the state and no other expert has been hired to replace him. Today the Division of Radiological Health for the Department of Health and Social Services for the State of Alaska is an "Environmental Scientist" by training. As an additional point of interest, she was at our last State Dental Society meeting in Homer stating her case for another large fee increase.

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I understand that science cannot be solely based on personal testimonials, but permit me to relate one to you. My wife and I are general dentists occupying a small building in Fairbanks. Between us we utilize five Gendex GX1000's, four Gendex GX770's and two panelipse machines. Those 11 sources are costing our patients $650.00 per year. Also we have not had any inspections for at least ten years. My question to you remains - how effective are state sanctioned registration/inspection bureaucracies? Also, is the cost/benefit ratio to the public worth all the excess bureaucracy?

In a nutshell, dentistry's concerns are:

1) "On-site" inspections are truly unnecessary because the incidence of x-ray overexposure has been so insignificant as to be non-existent.
2) The dental society knows of no history of documented over-exposure in Alaska's dental offices.
3) Inspections and any needed adjustments are routinely performed by trained dental supply company technicians.
4) Manufacturers of dental x-ray equipment must go through rigorous requirements by the FDA to fulfill 510 K and Initial Report guidance documents to prove safety and effectiveness. These guidance documents may be acquired through the FDA by calling 1-800-638-2041. It should be noted that the design engineers at Gendex are sympathetic with our cause but were unable to formally help us because their corporate lawyers feared repercussions by the various government agencies.
5) The State of Alaska is expanding a position that is well taken care of through the private sector. This is not cost containment or responsible government.

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Although our society never did poll our members directly, there were individual incidents cited where the inspector, when she did come, gave little notice, disrupted the practice, and in general seemed arrogant and unaware that her actions were embarrassing and inappropriate. These were not positive experiences.

As you know, our efforts were not successful. Increased registration fees are once again on the horizon.

Lets work together to rid ourselves of this unnecessary and obtrusive bureaucracy.

Robin, please let me know if I can be of help in any way. I have scientific literature on x-ray safety. Also, the Alaska Dental Society has just completed a national survey of the State Dental Societies to acquire data on how other states administer x-ray inspections if they do at all. If the survey results would help you, please let me know.

Thank you for your time in reviewing this important matter. If I can be of any further assistance, please let me know.

Yours in Dental Health,

Michael J. Helmbrecht, D.D.S.

Helmbrecht Dental
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March 6, 1997

Senator Robin Taylor
State Capitol
Juneau, Alaska 99801-1182

Dear Senator Taylor,

I have received a copy of the letter sent to your office by Dr. Peter Nakamura of the Department of Health and Social Services. I am certainly grateful for this opportunity to reply.

I firmly believe we can modernize x-ray inspection techniques to reflect the current technology used in x-ray equipment and film processing while maintaining the same high standards for public safety that the dentists in this state have always had. At the same time we can cut the unneeded expense and bureaucracy that has been a burr in the saddle of dentistry since inspections began in 1988.

The following text dissects each of Dr. Nakamura's paragraphs to point out the ambiguities in his claims which may lead the uninformed to the wrong conclusion.

Paragraph #1

In the first paragraph of Dr. Nakamurs's letter he has made an attempt to demonstate that Alaska's x-ray inspection fees are commensurate with other states in the Northwest. Each of these figures he sites is either wrong or misleading.

Here is the correct breakdown:

1) ALASKA:

As we know, the fee we pay in Alaska is $50.00/x-ray source/year. To compare accurately, lets see what our office with eleven x-ray sources would pay in each state.

Currently we pay $550.00 /year to Alaska

2) WASHINGTON:

Dr. Nakamura reported the fee accurately for Washington, however, he told you it was an annual fee when in fact it is a bi-annual fee. This in effect cuts the cost in half.

Cost for our office: $255.00/year

3) OREGON:

Here Dr. Nakamura reports an 87.00/control panel/two years fee. Of course the layman would not distinguish between "control panel" and "x-ray source". In actuality one control panel can control up to four x-ray sources. Our office has three control panels. Most dental offices have one control panel.

Cost for our office: $261.00/year

4) MONTANA:

Dr. Nakamura reports a $100/tube/year fee for Montana. With a little checking, one finds that Montana has no routine inspection nor do they have an annual fee. They will inspect a newly installed x-ray head before it is put in service. The fee for this is a one-time fee of $100.00.

Cost for our office: $000.00/yr

I'd like to know where Dr. Nakamura is getting his data.

Paragraph #2

This paragraph from Dr. Nakamura's letter basically deals with two different topics. The first is Ms. Coleman's educational qualifications. Dr. Nakamura states that Ms. Coleman exceeds the qualifications necessary for her job, but he falls short of giving us her qualifications. Recruitment Bulletin #122-94 for the State of Alaska lists minimum educational qualifications for a Radiological Health Specialist as: Bachelor's degree or the equivalent in radiological health, health physics, physics, chemistry, environmental science, or closely related field. The state would not provide us with Ms. Coleman's curriculum vitae, but we are reasonably sure she holds a degree in "environmental science". In checking with several universities, we found that this is a liberal arts degree with a curriculum emphasis in humanities. It should be noted that Ms. Coleman's predecessor, Syd Hydersdorph, is a radiological physicist. It certainly would be preferable to have an inspector who has a thorough scientific background in radiology, not one who has been educated in ravages of pollution and mans desecration of the earth. Its kind of like having the IRS prepare your taxes in that interpretation of regulations becomes a point of contention. Perhaps it would be advisable to make some changes in the minimum qualifications for the position of Radiological Health Specialist if we are to maintain state-sponsored x-ray inspections.

The second topic in paragraph #2 deals with Ms. Coleman's presentation to the Alaska Dental Society meeting in August (see enclosed minutes). Although she did not directly speak of an imminent fee increase, the minutes reflect the current planned expansion of her office to include a full-time inspector for the Anchorage area. Also, Ms. Coleman reported that there hasn't been a consistent pattern of inspection for the last six years since Dr. Hydersdorph left. Naturally the question becomes how does she plan on meeting her objectives without additional funding. The current fees provide her office with $72,000 - $75,000 per year and this supports Ms. Coleman, a second inspector, and a clerk. Instead of helping build another bureaucratic dynasty with their dental fees, I think the citizens of Alaska deserve a safer more predictable and efficient means of x-ray inspection.

Paragraph #3

The third paragraph in Dr. Nakamura's letter deals with an x-ray inspection of our office in 1993. I mistakenly reported no inspection for at least ten years in an earlier letter. In fact an inspector visited while we were at a continuing education course in August of 1993. Our biomedical equipment technician, Dan Anderson, handled the "items of non-compliance" as stated in the September 10, 1993 report. Since Mr. Anderson couldn't find any "unattached chords" or "drifting tube heads" as the report indicated, he responded that no corrective measures could be taken. The matter was never brought to my attention and thus the inaccurate report in my first letter for which I apologize. It should be noted that the inspection described above cost my patients $2750.00 if we assume one inspection every five years.

Paragraph #4

This paragraph is misleading because it doesn't adequately define the term "overexposure". X-ray dose equivalents are measured in rems. Currently the federal government standards allow for an individual to receive 5 rems per year with no harmful effects. Most "overexposures" are measured in mrem (millirems). If one millirem is used to expose a film more than is necessary, then an "overexposure" has occurred. However, it would take more than 5000 of these millirems just to receive the dose equivalent allowed by the federal government. So we are talking about extremely small amounts of radiation here. In fact, the amount of x-radiation a patient receives for a full mouth series of x-rays (20 films) has been compared to the amount of x-radiation received by standing outside on a sunny day with ones shirt removed. According to the head design engineer at Gendex (the leading manufacture of dental x-ray equipment) the types of x-ray sources used in dental offices are incapable of emitting harmful doses of radiation. This is also according to the strict performance standards set by the FDA.

Also in this paragraph Dr. Nakamura lumped dental x-rays with medical x-rays. The graph he provided speaks only to medical x-rays. It should be noted that x-ray dosage for diagnosis is tiny compared to that used for therapeutics (eg: treating leukemia). In dentistry, we only use x-rays for diagnosis (very small doses).

Dr. Nakamura goes on to state that the over exposure potential in Alaska is "extreme" since we lack regulation requiring dentists to post proper x-ray technique guidelines in our offices. The State of Alaska already tests each dentist on their knowledge and skill in dentistry when we take the State Dental Board Examination. Since each participating dentist in this state have passed the exam, there should be no need to duplicate the function of the exam with further regulations and inspections. Proper technique in taking x-rays is the only way to get a good result so it is in our best interest as well as the patients to follow proper procedure. To date, not one instance of any adverse reaction to dental x-rays has been reported in the state of Alaska before or after x-ray inspection was began in 1986. In fact if there was a risk it would be to the dental office personnel who are around dental x-rays everyday. The National Council on Radiation Protection and Measurements (NSRP) currently recommends a maximum permissible dose equivalent from occupational sources of 5 rem per year as described earlier. When 231 dental personnel in 72 private offices were studied, a mean one month exposure of .01rem (range of .005 to .06 rem) was reported in the study. This means it would take approximately 100 to 5000 months to exceed the current annual 12 month federal standard of 5 rems if you worked in a dental office. It should be noted that this study was done before Alaska even had a dental inspection program. I remain curious as to the problem that the bureaucracy was trying to fix.

Clearly there is ample evidence of adverse effects of radiation in sufficient doses. There is at present no proof of such effects from doses employed in dental practice. Most experts now agree that there may be a small, difficult to quantify risk of cancer or genetic mutation from diagnostic exposure during work. Prudence dictates acceptance of this position until proof to the contrary is available. However, these risks are not "extreme" as Dr. Nakamura suggests. Recent analysis suggest that cancer risk to a patient from a dental radiographic examination is on the order of one in a million; the genetic risk is substantially less, about one in a billion. So lets look at other things people do in their daily life that have an order of magnitude of risk similar to a series of dental x-rays.

Table 9 ■ Situations in which a person has a one in a million risk of dying.*

Risk situation	Cause of fatality
Being a man, age 60, for 20 minutes	Cardiovascular disease, cancer
Living in New York for two days	Air pollution
Living in Denver for two months	Cosmic radiation
Living in a stone building for two months	Natural radioactivity
Drinking water in Miami for one year	Carcinogens
Living near a polyvinyl chloride plant for ten years	Carcinogens
Riding in a canoe for six minutes	Accident
Riding a bicycle for ten miles	Accident
Riding in a car for 100 miles	Accident
Traveling by airplane for 1,000 miles	Accident
Traveling by airplane for 8,000 miles	Cosmic radiation
Working in a coal mine for one hour	Black lung
Working in a coal mine for three hours	Accident
Working in a typical factory for ten days	Accident
Smoking cigarettes, 1.4	Cardiovascular disease, cancer
Drinking wine, 500 cc	Cirrhosis
Drinking diet soda, 30 cans	Carcinogens

*Data from Pochin[9] and Wilson.[4]

Paragraph #5

Here Dr. Nakamura is again less than accurate when he describes the maintenance capabilities of technicians typically hired to work on dental equipment. Dan Anderson is the biomedical equipment technician I referred to earlier. He runs a very small operation compared to most but he uses a $3000.00 meter capable of 2% resolution on kV measurements that he uses on our x-ray equipment. According to Dan, he doesn't know of any equipment technician who doesn't have instrumentation for measuring kVP as Dr. Nakamura states.

Also, Dr. Nakamura leads one to believe that a dentist would intentionally alter his x-ray equipment to perform differently that the stringent federal requirements I eluded to earlier. This simply does not happen. There is not one case to support this claim. A dentist would have no reason to alter his x-ray equipment nor would most dentists be technically capable of altering x-ray equipment.

To address quality assurance for x-ray film processing, these days its all automatic with state-of the -art processors that maintain proper temperature and replenish solutions automatically. These processors on occasion require some service in which case dentists typically rely on a biomedical technician never an environmental scientist.

Paragraph 6

The following is a direct quote from the conclusion of Dr. Nakamura's letter which the author presents to justify bureaucratic fees for x-ray inspection. However I feel that it supports my case much better than it supports his.

> "Presuming that one million x-ray procedures are performed each year in Alaska and as a result of state inspection each exposure is reduced by 10 millirem (.01 rem): then 10,000 rem are saved each year, the equivalent of one theoretical life. The question becomes how much is it worth to save a life? Fifty dollars per tube soon becomes a very insignificant investment."

Certainly you can understand dentistry's frustration when we are dealing with this type of reasoning. Basically what he is saying is that if 10,000 mosquito bites could kill you, and the average person receives six mosquito bites on an average evening in Alaska, then we should have a bureaucrat fly around the state picking one mosquito off of the 10,000 Alaskans to save one

"theoretical life." Also the fifty dollar cost he refers to translates into $2750.00 per inspection for our office, or $2,250.00 for the dental patients in Alaska to pay during my practicing career.

CONCLUSION:

There has got to be a reasonable solution to our problem - there is. Current federal guidelines require each x-ray machine be registered by the state in which it is used. If you recall, Montana has a one time $100.00 on site inspection to register a newly installed x-ray machine. This would solve both dentistry's problem and governments problem and everyone would be satisfied.

If the concept of periodic inspections is too difficult for government to give up, a biomedical equipment technician could do it in a fraction of the time and cost every five years just as we redo our CPR training every two years. The technician is on site from time to time anyway. He could just fill out a form and mail it to a clerk.

If some folks in government still need "government inspection" there is a thermolhuminescent device (TDL) which California mails to its dentists every 5 years. It is then exposed and returned to the government agency for inspection.

Respectfully Yours,

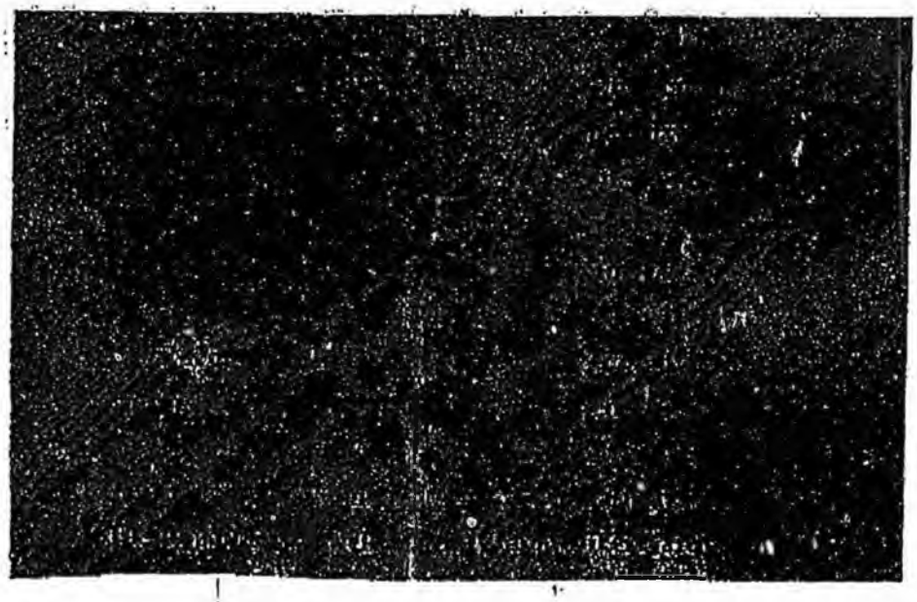
Michael J. Helmbrecht, DDS

Oral Radiology

Risks From Dental Radiation in 1995

Robert P. Langlais DDS, MS and Olaf E. Langland DDS, MS

When an individual is exposed to ionizing radiation from a dental X-ray machine, the postulated risk from this procedure is the induction of damage to either the somatic or genetic tissues of the exposed person. Somatic tissues include all tissues of the body except the sperm and ovum, which are genetic tissues responsible for transmitting specific traits from one generation to the next. The most radiosensitive somatic tissues exposed to dental sources of radiation and the type of damage induced, are: bone marrow and leukemia; thyroid gland and thyroid cancer; the lens of the eye and cataract formation. According to White, salivary glands, especially the parotid gland, also are at risk for the development of malignant salivary gland disease.[1-3] In a review of current methods of estimating risk, White found that low doses of radiation, in the range of 0.2 Gy or less, carry more risk of causing cancer than was previously thought.[1]



The agencies most frequently cited for estimating the risks from radiation are the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR),[4] the committee on the Biologic Effects of Ionizing Radiation (BEIR) of the United States National Research Council[5] and the International Commision on Radiological Protection (ICRP).[6]

When genetic tissues are exposed to radiation, there is a risk of a congenital or heritable defect. The gonadal dose following a full month survey (FMX) is less than 0.01μSv in an adult female; for males, it is 10μSv or less.[1] Hiroshima survivor data indicate that damage to newborns did not occur in doses below 200 mSv.[7] to the genetic tissues.[7] White concluded that the risk of heritable defects from dental radiology is negligible.[1] It is thought that exposure to dental radiation of the fetus in utero could result in mental retardation of the newborn at threshold doses of 0.12-0.2 Sv; however, since the uterine dose from an FMX is less than 0.01μ SV, the risk of mental retardation from dental radiology is considered nonexistent.[1]

Therefore, the risks from dental radiation are essentially to the *somatic* tissues, rather than the *genetic* tissues, and the risk may be higher than previous estimates. Risks are defined differently depending upon whether the person is occupationally exposed, as for a dental healthcare worker (DHCW), or whether the exposure results from being a patient. Because we will be referring to quantities of radiation in several different radiation units, table 1 is included to illustrate the various equivalent doses.

NEXT PAGE → TABLES

Table 1. Dose Conversion Table

(m = Milli or 1,000th) (μ = micron or 1,000,000th)
(100 rem = 1 Sv) (100 rad = 1 Gy)
(1 rad = 1 rem) (1 Gy = 1 Sv)

mrad/mrem	rad/rem	Gy/Sv	mGy	μGy
1	0.001	0.00001	0.01	10
1000	1	0.01	10	10000
1000000	100	1	1000	1000000
100	0.1	0.0001	1	1000
0.1	0.0001	0.000001	0.0001	1

Maximum Permissible Doses

The National Council on Radiation Protection and Measurements (NCRP)[8] and the International Commission on Radiological Protection (ICRP)[6] have defined MPD as the maximum permissible dose equivalent that an occupationally exposed person or parts thereof shall be allowed to receive in a stated period of time. The definition embodies the principle that cells can repair radiation damage and that different tissues have varying radiosensitivities. Stated more simply: MPD is the maximum dose of radiation sustained over a period of time that a person can absorb without appreciable injury. The MPDs for both occupationally and non-occupationally exposed persons excludes radiation received from environmental/natural background sources, for which the annual effective dose is 3 mSv, and artificial radiation (such as medical and dental exposures), for which the annual effective dose is 0.6 mSv.[9] These exposures are excluded because they cannot be controlled.

Different MPDs have been developed for occupationally exposed persons than for patients. According to the most recent guidelines provided by the NCRP,[9] the maximum permissible effective whole body dose to an occupationally exposed dental healthcare provider is 50 mSv; for the general public, it is 1 mSv. However, because different tissues and organs have varying sensitivities to radiation, the equivalent dose limits vary among these tissues. For example, the MPD to the lens of the eye for occupationally exposed persons is 150 mSv; it is 500 mSv each for the skin, hands and feet. For the general public, the MPD is 15 mSv for the lens and 50 mSv for the skin.

For occupationally exposed pregnant workers, the MPD is 1/10th the normal recommended MPD.[9]

Dental HCWs who are not occupationally exposed have the same MPD as for the general public. At doses equal to the MPD, the risk is not zero, but it is small and consistent with risks encountered in other occupations. Thus, no matter how small the dose, there may be some effect.[10]

According to ICRP, no ill effects or injuries have been encountered as a result of exposures within the limits defined by the MPD.[6] It should be noted that NCRP and ICRP are private nonprofit organizations; therefore, their recommendations do not carry the force of law. However, most federal and state radiation regulatory bodies follow these recommendations.

Risk From Dental Radiation

Risk from dental radiation, often referred to in terms of absolute risk, is expressed as the number of extra fatal cancers in a given tissue or organism per million X-ray examinations. According to the BEIR V and the 1990 ICRP reports, the relative risk model is the most appropriate way to estimate risk. In 1992, White[1] compared the risk of fatal cancers per million full mouth surveys (FMX) to that of panoramic radiographs (PAN). His data were based on FMXs exposed at 70 kVp, D speed film and round open-ended cones (PID) and PANs using rare earth screens. For bone marrow, he reported 0.7 extra cancers per million FMXs and 0.06 extra cancers per million PANs. He also noted 0.1 and 0.01 extra cancers of the lung respectively for the FMX and PAN examinations; 0.1 (FMX) and 0.02 (PAN) extra cancers of the esophagus; 0.8 (FMX) and 0.06 (PAN) extra cancers of the thyroid. Overall, when all tissue sites were considered, White found 2.5 extra cancers per million FMXs and 0.21 extra cancers per million panoramic examinations. Danforth and Gibbs[11] have stated that the risks from dental radiation compare with similar one in a million risks that we take every day; for comparison, see table 2.[12]

According to several reports,[1-3] there may be an increased risk of malignant parotid salivary gland tumors associated with dental radiation. In his review, White[1] reported an overall 10-fold

Table 2: One in 1 million risk of fatal outcome

Risk	Outcome
20 minutes as 60-year-old male	natural death
2 months in Denver, CO	cosmic radiation
10 miles by cycle	accident
300 miles by automobile	accident
10 days typical factory work	accident
1 cigarette	chemical carcinogens
500 ml wine	alcohol-related death
125 ml whiskey	alcohol-related death
1600 ml beer	alcohol-related death

increase in the risk of developing cancer from the intraoral full mouth survey as compared to the panoramic examination. Underhill and colleagues[13] included the salivary gland data in their study, and found a 15-fold increase in the risk of developing a radiation-induced cancer using FMXs as compared PANs.

The risk of radiation damage to the eye is cataract formation. The type of dose response curve used in estimating this risk is the threshold type as opposed to the linear type. This means very little damage can be detected at doses less than the threshold dose, which for radiation-induced cataracts of the eye is about 2 Gy when the dose is received in a single exposure.[14-16] According to BEIR V, it is more than 5 GY when the dose is received as multiple exposures over a period of weeks.[5] When long round open-ended cones are used, the single film dose to the eye is 0.5 mGy, whereas for the panoramic it is 0.09 mGy per PAN.[14-16] Thus, the risk of producing damage to the eye in dental radiology is remote.

The reported gonadal dose from an FMX ranges from 2 to 20μGy with the protective apron in place.[17] The gonadal dose in panoramic radiology is much less than the FMX dose when the protective apron is in place, as the narrow slit beam of radiation is directed from below at an upwards angle of 5-7 degrees.[18]

Reducing Patient Dose

Advances in technology, greater patient awareness and the application of new devices by dentists offer many opportunities for reducing the dose of radiation to patients.

The use of higher kVp results in less radiation absorbed by the patient. In general, higher kVp radiation is more penetrating, resulting in less of the radiation being absorbed by the superficial soft tissues. Therefore, a lesser amount of the higher kVp radiation is needed to expose the film. In one study, there was a reduction of up to 23 percent between comparable density radiographs (overall darkness) with an increase in kVp from 70 to 90.[19] Today, many x-ray machines have fixed kilovoltages of 70 kVp or less. These devices are less desirable than those capable of settings up to 90/100 kVp.

The use of the long cone (PID) has always produced a lesser absorbed radiation dose to the patient than the short cone (PID).[20] This is because the collimator on an eight-inch short PID is about the size of a nickel, while the collimator for a long 16-inch PID is about the size of a dime. Thus, with the smaller collimator, less of the patient's tissues are irradiated, reducing the secondary radiation doses to the patient. Secondary radiation occurs when photons of radiation bounce off dense tissues such as bone and are redirected to another part of the body to produce exposures at distant sites, such as the gonads. Because this redirected radiation is internal, the use of protective aprons is of limited value in shielding patients against this type of radiation. Because of the inverse square law,[21] the exposure time for the long cone will be four times longer than for the short cone to produce films of the same density if the film speed, kVp and mA are kept constant. However, though the radiation exposures to the film are the same, as stated previously, more tissue is exposed with the use of the short cone.

Though the short cone may be more convenient, the selection of a machine with a recessed anode design has the convenience of a short cone and the dose reduction advantages of the long PID. To assess true cone length, study the machine specifications or measure from the dot representing the location of the focal spot on the tubehead to the tip of the cone. However, recessed anode tubeheads are difficult to find at the present time.

Using the long PID with rectangular collimation will further reduce patient doses from those received with the long round PID. Rectangular collimation can be achieved by Precision film holders, Rinn or Masgraf rectangular PIDs or the Rinn stainless steel rectangular collimator attached to the end of the round PID. Underhill reported the dose to the thyroid gland for a 20-film FMX using the long round cone is 628 μGy, while the dose using the long rectangular cone was 270 μGy. For the parotid gland, the dose for the FMX was 5,236 μGy, and for the rectangular cone, 859μ Gy, a considerable savings in dose.[22] Underhill reported a risk of 7.1-17 extra cancers for the FMX using the long round cone, while the risk using the long rectangular cone was 2.5-6.6 extra cancers per million FMXs.[13]

The leaded apron is useful in protecting the patient from scatter radiation. Scatter radiation occurs after the primary beam passes through the patient and bounces off dense objects in the room, reexposing the patient. Thus, the leaded apron designed for intraoral radiography should cover the thorax and abdominal area. In panoramic radiology, the poncho type, which hangs from the shoulders and protects both the front and back sides of the patient, is preferred. This is because both the front and back of the patient are exposed in panoramic x-ray projections.[22]

The thyroid shield can be used for intraoral radiography, but should not be employed in panoramic radiology as it will absorb portions of the lower part of the primary beam and produce voids in the image. It is interesting to note that in spite of the thyroid shield being in place for the FMX, Underhill reported doses of 628 μGy for the FMX using the long round cone, 270 μGy for the FMX using the long rectangular cone and only 47 μ Gy for the panoramic without the thyroid shield.[22]

Using faster film can reduce exposure by a factor of 40 percent to 50 percent.[23] In the United States, this will mean using the new KODAK EKTASPEED Plus film instead of KODAK D speed film. The recommended processing solution for this film is the KODAK Readymatic chemicals. The recommended darkroom safelight is a 7 1/2 watt bulb with the KODAK GBX II filter at the usual four feet from the countertop.

PAN vs FMX

Selecting a panoramic radiograph in lieu of the intraoral full mouth survey will result in a significant savings in radiation dose to the patient without

necessarily compromising the diagnostic benefit of the radiographs. White estimated that there is about 10 times less radiation dose to the patient from the panoramic radiograph than the FMX.[1]

White has advocated including the salivary glands, particularly the parotid, as tissues at risk for the development of extra cancers as a result of dental radiography. In 1988, Underhill and colleagues compared doses to the salivary glands from FMXs to those from PANs. They used E speed film, 90 kVp and the long round open-ended PID for the FMXs and rare earth screens for the PANs. They reported the following doses: for the parotid gland, the FMX delivered an average dose of 5,236 µGy versus 670 µGy for the PAN, nearly seven times less radiation for the PAN. For the submandibular gland, the FMX delivered an average dose of 8,984 µGy versus 375 µGy for the PAN, 24 times less radiation for the PAN. For the sublingual gland, the FMX delivered an average dose of 7,833 µGy versus 134 µGy for the PAN, nearly 59 times less radiation for the PAN.

Langlais and colleagues[24] have discussed in some detail evidence which indicates that a properly exposed panoramic radiograph may, in many instances, be used to interpret interproximal caries, especially in the posterior region; the level of alveolar bone in the assessment of periodontal disease; and periapical disease of pulpal or periodontal origin. Diagnosis of these dental diseases previously was believed by most to require full mouth survey and/or bitewings. While this recommendation may not be appropriate in all cases, there is mounting evidence that such diagnoses can be made with the aid of properly exposed panoramic radiographs. This phenomenon may be explained in part by the reports of several investigators who compared direct exposure intraoral film to intraoral screen/film images. They found that clinical judgement seemed to be affected more by contrast than by sharpness[25] and the higher contrast of the screen/film image over E speed film seemed to compensate for the inherent reduction in sharpness.[26] Panoramic films and rare earth screens are capable of producing sufficient contrast to distinguish both bony and soft tissue details, as well as the difference in densities between enamel, dentin and pulp.

Traditionally, resolution, which is a measurement of sharpness, has been used as the primary criteria to assess the efficacy of an image; adequate resolution has been the principal reason for advocating intraoral radiographs for the aforementioned diagnoses.[27] Scarfe and colleagues[28] calculated the horizontal angle of incidence of the panoramic beam required to routinely avoid interproximal overlap, especially as often occurs in the premolar area. They state that there are several machines with improved orthogonal projections available, though none of these machines were specifically designed on the basis of newer projection geometry data. However, since most of these newer machines are based on robotic principles and controlled by a specific computer chip, even older models can be updated when newer panoramic projection beam geometry becomes available. When there is a reduction of posterior interproximal overlap and sufficient contrast, then caries and many other subtle density changes will be readily dectecteable in panoramic radiographs.[29]

In a recent report using narrow beam panoramic radiology (Scanora/Soredex), Tammisalo and colleagues[30] found the panoramic image was better than intraoral radiographs for detecting periodontal and periapical pathology. Langlais and colleagues[24] reported that some investigators have observed that periapical rarefaction of bone is detected more easily on the panoramic radiograph than the corresponding periapical, though the reason for this so far defies full explanation.

Radiation doses from panoramic x-rays can be further reduced by approximately 40 percent by placing a filter of rare earth screen material over the narrow slit panoramic collimator without appreciably affecting image quality.

Direct Digital Imaging

The integration of direct digital x-ray imaging may reduce the radiation dose to patients. Intraoral direct digital systems average about 50 percent less radiation than the fastest current film-based images. Narrow beam digital panoramic devices have the potential of reducing radiation dose by at least 50 percent when these new machines are introduced to the market, most likely in 1995.

Several reviews on digital imaging have been presented.[31-33] Two types of intraoral digital systems currently are available. The first involves a screen-producing fluorescence transmitted by a fiberoptic bundle to a charge coupled device CCD and then to the computer or a direct exposure CCD type of detector. CCDs transmit the image information to the computer by a line similar to a telephone wire, thus allowing instantaneous viewing of the image. These CCD detectors are narrower than number 2 periapical film, so more exposures may be required for the full mouth survey. Therefore, the reduction in radiation from taking an FMX with a CDD digital device may be misleading.

The second type of detector is an image storage phosphor plate. This type of detector has no wire, but must be placed into the computer via a read-out device which processes the stored image electronically into a digital image format.

Each of these digital intraoral systems has advantages and disadvantages, but both have the following features in common: less primary radiation and diminished scatter per image; no film or chemical processing and associated devices, chemicals, maintenance and space needed; long-term savings as there is no need for materials and supplies such as film, mounts, chemicals for processing, processor maintenance and infection control; simplified infection control procedure requirements; rapid image acquisition; improved convenience and labor cost savings; fewer retakes because the density or contrast can be altered by digital image adjustments in the computer; expanded diagnostic yield by image

subtraction to detect early caries or periodontal disease; rapid consultation by a faxlike transmission to one or several colleagues with compatible equipment; and better patient patient communications by use of television monitors to explain the patient's oral condition. Several panoramic systems also are available or are under development and will have digital features similar to those of the direct digital systems described.

Whatever system is in use, retaking any radiograph doubles the radiation dose to the patient for that image. The obvious answer to this problem is to strive for perfection in techniques by continued learning. Dental healthcare workers have become adept at intraoral radiography over the century since Roentgen's discovery of x-rays in Germany in 1895. Intraoral film-positioning and beam-indicating devices are helpful, as is strict adherence to the manufacturer's instructions with regard to automatic processor operation and maintenance.

It is the authors' belief that panoramic radiology equipment, first introduced 35 years ago, although very popular, is less well understood than conventional intraoral radiography. The panoramic system is generally unforgiving of patient positioning and other technical errors, yet troubleshooting the image is very simple to learn. The first step in using panoramic radiography properly is to recognize deficiencies in image quality and projection geometry. Once that is accomplished, training of dental x-ray technologists becomes a rather simple procedure. As a result, the diagnostic quality of your panoramic radiographs will improve immensely.

Reducing Operator Risk

The following recommendations, as iterated by Preece,[34] have been in practice for many decades.

- Stand at least 6 feet away from the patient and in the safe quadrant, which is a position between 90 and 135 degrees to the primary beam.
- When distance and position requirements cannot be met, stand behind an impermeable barrier, such as a leaded wall or other similarly effective material such as concrete, cinderblock or a double thickness of sheetrock.
- Do not hold the film or other devices, such as the tubehead, during exposure.

For personnel who are worried about being exposed in a dental office, monitoring devices are available which accurately measure the exposure. Monitoring devices should not be worn when dental personnel have radiographs taken on themselves as patients. Under normal circumstances, personnel radiation monitoring is neither recommended by the authors nor is it required by most states.

The risk from exposure to radiation has always been a consideration in what we do for our patients and staff. The risk to patients for the very small doses received in dental radiology, although still acknowledged as slight, is believed to be greater (UNSCEAR 1988, BEIR V 1990 and ICRP 1990) than indicated in previous reports. With currently available devices and material, further decreases in patient exposure are possible. The risk of occupational exposure in dental radiology is virtually nonexistent when appropriate radiation hygiene practices are in force.

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SAFETY

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Article 4
Continuing Education

X-Radiation: Potential Risks and Dose-Reduction Mechanisms

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Learning Objectives

After reading this article the reader should be able to:

- define and list the maximum permissible dose for occupationally and nonoccupationally exposed individuals.
- list four sources of naturally occurring background radiation.
- discuss the dose and risk considerations for each critical organ with regard to dental x-radiation exposures.
- list methods available to reduce dental x-radiation to the patient.
- describe how collimation affects patient exposure to dental x-radiation.

Table 1—Annual Maximum Permissible Radiation Doses[1]

Occupationally exposed (includes dental workers who take x-rays)	5,000 mRem (50 mSv)
Nonoccupationally exposed (the general public)	500 mRem (5 mSv)

Nearly a century after its discovery in 1895, x-radiation remains a controversial diagnostic modality. It has been associated with several risks and side effects, some of which are difficult to substantiate. Despite the controversy, radiography is a reliable and convenient diagnostic aid for the dental profession. This article will discuss relative risks associated with dental x-rays and the mechanisms available to reduce those risks.

Radiobiologic Risks

Biologic Risks and the Maximum Permissible Dose

X-radiation is an ionizing form of electromagnetic radiation. When absorbed in human tissues, energy levels of this magnitude alter the electrostatic charges and molecular bonding of complex structural and regulatory proteins. Such changes can affect the basic conformation of cytoplasmic and nuclear organelles. These alterations increase the risk of permanent, demonstrable damage to the tissues by slowing, accelerating, altering, or stopping their normal biologic function.

Because of these risks, the International Commission of Radiological Protection (ICRP) has defined a safety limit for tissue exposure to ionizing radiation below which the risks are considered minimal. The safety limit is referred to as the maximum permissible dose (MPD). More specifically, this dose can be summarized as the amount of radiation received chronically or acutely over a lifetime, which, in light of present knowledge, is not expected to cause appreciable body injury.[1] The annual MPD values are listed in Table 1.

The MPDs for individuals working with radiation (ie, occupational exposure, which includes dental personnel) is 10 times higher than

Exposure comparisons on next page at top.

for the general population (ie, nonoccupational exposure). Occupationally exposed personnel are assumed to be willing to accept a higher risk of radiation exposure for the lifestyle attained by their employment. Yet, if all radiation workers were to realize this tenfold increase in radiation exposure, it is not expected to affect the mutation rate of the whole population for any pathologic entity.

The ICRP has a lower MPD for occupationally exposed women who are pregnant. They have the same MPD as the lay population. This is to protect the fetus, which should not be considered occupationally exposed.

The ICRP has recently suggested lowering the MPD values to 200 mRem(2mSv)/y.[3] This limit is presently being reviewed by several organizations.

Environmental and Diagnostic Radiation

MPD values were established because people are regularly exposed to naturally occurring environmental sources of ionizing radiation (Table 2). Consequently, biologic systems are constantly exposed to these sources of radiation, which must be considered within the range of tolerance. Radon and its decay products are the major sources of naturally occurring background radiation. Note: the average whole-body exposure limits are below the MPD values for occupational and nonoccupational individuals.

Medical and dental diagnostic x-radiation exposures can also contribute to the annual whole-body exposures. However, these values are not considered in MPD calculations because diagnostic x-rays are assumed to be beneficial to the life span of an individual. Note the relatively low dose equivalent for diagnostic radiation compared to the naturally occurring sources of background radiation. The sum of all of these procedures remains below MPD values.

Table 2—Average Individual Annual Effective Dose Rate of Ionizing Radiations[1]

	mRem	mSv
Natural		
Radon	200	2.0
Cosmic	27	0.27
Terrestrial	28	0.28
Internal	39	0.39
Artificial		
Medical		
X-ray diagnosis	39	0.39
Nuclear medicine	14	0.14
Consumer products	10	0.1

Table 3—Critical Organs and Their Potential Risks

Organ	Risk
Skin	Carcinoma
Bone	Leukemia
Gonads	Mutation
Eye lens	Cataracts
Thyroid gland	Carcinoma
Embryo/Fetus	Congenital defects

Critical Organs

Critical organs affected by dental x-radiation are defined as the tissues that, by virtue of their radiosensitivity or proximity to the dental beam, are possibly vulnerable to pathologic or life-threatening sequelae.[3] These critical organs and their potential risks are listed

in Table 3. The dose and risk considerations for each of the critical organs are discussed separately.

Skin

Dental exposures for a full mouth series of x-rays vary considerably, depending on the technique used. The type of film speed, kilovoltage, filtration, collimation, etc, all affect the amount of exposure. Several dosimetry studies have shown that a trend for decreasing exposures is evident.[4] According to current ICRP data, a full mouth x-ray series using 70 kV, D-speed film, and round collimation yields an average effective dose of 840 mRems (8.4 mSv).[5] A full mouth x-ray series procedure taken with D-speed film, round collimation, 80 to 90 kV, and a 16-inch long-cone focal distance, has a maximum cumulative skin dose at any one site of approximately 1,250 mRem (12.5 mSv).[6] The approximate skin dose from the intraoral exposure of one diagnostic-quality radiographic image with D-speed film is 200 mRems (2 mSv).[6] Increased risk to the earliest type of skin cancer is not evident below dose levels of 25,000 mRems (250 mSv).[6] Keeping the proper risk perspective (according to these numbers), carcinoma induction from dental radiographic exposures that are approximately 1% to 5% of acute threshold doses seems very low.

Bone Marrow

Leukemia induction is the major risk associated with x-ray exposures of bone marrow. Approximately 5% of the body's bone marrow gets exposed from dental radiographic procedures. The bone marrow dosage ranges from 1 to 3 mRems (.01 to .03 mSv) for 1 exposure and 9 to 14 mRems (.09 to .14 mSv) for a full mouth x-ray series.[6] Whole-body exposures of 5,000 mRems (50 mSv) are reported to increase the risk of leukemia induction. Linus[7] showed no significant increase in leukemia risk from long-term (chronic) fractionated doses of up to 30,000 mRems (300 mSv).

Table 4—Quality-Assurance Measures

- x-ray equipment testing and maintenance
- good radiographic technique (ie, film placement, reversed film, etc)
- using film holders
- proper exposure parameters
- proper film handling before and after exposure
- proper time/temperature film processing
- darkroom maintenance to prevent film fogging (ie, checking for light leaks, storing film at proper temperature, etc)

Gonads

Dental x-ray exposure to genetic tissues in the gonads results primarily from secondary scatter radiation off the skull. The gonadal scatter exposure from a standard full mouth x-ray series is about 0.5 mRems (0.005 mSv).[6] This dose can be reduced by 95% by using a lead apron. The average daily gonadal radiation exposure from natural background radiation is 0.15 to 0.3 mRems (.0015 to .003 mSv).[6] The full mouth x-ray series gonad exposure with lead apron protection is about seven times less than the average daily gonadal exposure of the US population from background radiation. At higher elevations (ie, Denver, Colo), these doses double because of the earth's proximity to the cosmic sources of background radiation.[8] Radiation doses of this low magnitude have very little effect on the genetically significant dose of the US population, ie, the dose of radiation required to affect genetic mutation rates.

Eye Lens

Cataract formation is very debilitating and can eventually cause blindness. Exposures of greater than 200,000 mRems (2,000 mSv) are required to induce cataract formation.[6] The standard full mouth x-ray series yields a lens dosage of 60 mRems (0.6 mSv). Again, it seems highly unlikely that dental exposures, which are 0.0003% of the threshold, contribute to this problem. They do contribute to a cumulative dose for cataract formation. However, fractionating the dose to this degree decreases the harmful effect.[9]

Thyroid

Radiation doses of 5,000 to 7,000 mRems (50 to 70 mSv) are required for thyroid carcinoma induction.[6] The thyroid exposure during a standard full mouth x-ray series is about 23 mRems (0.23 mSv). Again, carcinoma induction from a dental x-ray beam is very unlikely. It is also significant to note that of all the neoplasias affecting humans, thyroid cancer has only a 10% incidence of mortality.[10]

Harmful effects to the thyroid gland in children may be more significant because growing children have more active metabolic rates. The use of the lead thyroid collar diminishes the exposure to a negligible amount.

Embryo/Fetus

Dental x-ray exposure of pregnant patients is not recommended except in an acute emergency where the benefit of the diagnostic information far exceeds the radiation risk to the fetus. The National Council of Radiation Protection and Measurements (NCRP) has reported that the production of congenital defects is negligible from gonadal exposures of 5,000 mRems

(50 mSv) or less.[11] Danforth and Gibbs'[12] calculation of relative risks has shown that the chances of having a first-generation defect from a dental x-ray examination is 9 in 1 billion (ie, 0.000,000, 9% or 9.0×10^{-7}%).

The ALARA Principle

It is evident from the preceding discussion that risks of long-term biologic damage from dental x-ray exposures are extremely low.

However, it remains very difficult to scientifically document the long-term (30 to 50 years) cumulative effects of low-dose chronic exposure. Recently, it was reported that dental x-ray exposures may be causing higher incidences of salivary gland and brain tumors.[13,14] This risk estimate was based on several assumptions and estimations of the number of dental radiation exposures and the type of equipment used on the patients in their past dental treatment, all of which are difficult to prove. Consequently, a direct cause-effect relationship between previous dental radiation exposure and future cancer could not be made.

Regardless of the accuracy of these risk associations, radiobiologic damage does occur from exposure to x-radiation, so the ALARA (as low as reasonably achievable) principle[15] should be followed. This principle recognizes that knowledge of the cumulative long-term effects of exposure to low levels of diagnostic radiation may be minimal, but it still remains a risk entity. Scientific data is not available that can demonstrate a threshold radiation dose below which no harmful effect will ever occur. It is therefore prudent that we adhere to the ALARA principle, whereby all diagnostic radiographic procedures use the maximum amount of dose *reduction* possible. This would minimize the potential risks and any adverse sequelae to diagnostic radiation.

Various techniques are available to reduce radiation exposure from dental radiography. Incorporating these techniques into dental practice will have a profound effect on patient dose reduction.

Techniques for Reducing Radiation Exposure

The NCRP is a private organization composed of experts in various aspects of radiation. They operate under a congressional charter as an advisory group that makes recommendations governing the use of x-radiation. It is the responsibility of each individual state to make its own rules and regulations regarding radiation exposure based on these recommendations. The Texas Radiation Control Act, enforced by the Texas Department of Health, is based on many of the NCRP recommendations. Some of these regulations will be alluded to in the following discussion.

Beam Collimation

Based on an NCRP recommendation, it is mandated in most states that the dental x-ray beam be no larger than 7.0 cm in diameter (2.75 inches) at the patient's skin surface. Most dental units are sold with a 2.75-inch, lead-lined cylindrical cone (ie, BID or beam indicating device) collimation. However, smaller rectangular-shaped collimators are also available that further restrict the size of the beam. This kind of enhanced collimation can reduce the scatter radiation by 45% to 95%, depending on the site in question.[4] Scatter radiation is so dramatically diminished that the gonadal scatter from a 20-exposure full mouth x-ray series with rectangular collimation is the same as the scatter from 4 bitewing exposures with the size 2.75-inch-diameter, round collimation.[4] An earlier study[16] showed that rectangular collimation reduced the bone marrow dose by 60%.

Wood et al[17] went so far as to recommend that the scatter to the gonads is so minimal with rectangular collimation that a lead apron is not needed when rectangular collimators are used. Using the smaller-size beam from rectangular collimation may be more technically demanding, but Parks[18] concluded that radiography with rectangular collimation is no more difficult a technical skill for novice dental hygiene students to learn than dental radiography with round collimation.

Film Speed

E-speed film is the fastest, most sensitive, commercially available film speed. This film speed reduces dental radiation exposures by up to 50% when compared with D-speed film.[19] These are the only two film speeds available commercially for intraoral radiography. Exposure parameters for diagnostic dental films deliver a skin entrance dosage of 100 to 200 mRems (1 to 2 mSv).[4] The suggested exposure limit set by National Evaluation of X-Ray Trends (NEXT) is 400 mRems (4 mSv), which is a very lenient limit. Although images on E-speed film have less contrast than regular D-speed film images, there is no loss of diagnostic detail for caries and periodontal evaluations and endodontic procedures.[20-22]

The American Academy of Oral and Maxillofacial Radiology strongly recommends that the dental profession use E-speed instead of the slower D-speed film. E-speed film reduces exposure to both the patient and operator by reducing the number of retakes necessary as a result of patient or machine movement.[23]

Constant Potential X-Ray Generators

In the last 10 years, several new dental units have become available that produce x-radiation with a steadier stream of higher kilovoltage x-ray photons. Because the x-ray beam from this machine has a greater proportion of high-energy photons, shorter exposure cycles can be used. In addition, fewer of the lower kilovoltage (ie, lower energy) x-ray photons are produced. The lower energy x-ray photons are those in the beam that are too low in energy to contribute to the x-ray image, but are of sufficient energy to contribute to the patient's radiation dose. Constant potential dental x-ray machines can reduce radiation dose by up to 30%. Intrex®[a], Castle® HDX®[b], and Heliodent®[c] MD are examples of commercially available machines with this capacity. The only drawback to these units is that they are more expensive, costing approximately twice the amount of a regular dental unit. Fortunately, the price is not a major deterrent for many dental offices.

High-Energy Beams

Commercially available dental units range in their kilovoltage capacity from 60 to 100 kV. Machines with higher range kilovoltage potentials, ie, 80 to 90 kilovoltage, have larger generators with clinically larger tube heads. These larger units also have a higher purchase price. However, higher kilovoltage beams with the appropriate filtration and increased focal distances (16 inches) reduce the radiation exposure to the patient.[24] Higher kilovoltage beams produce long scale contrast images with many shades of gray that demonstrate more information on tissue density. This is extremely helpful for the early detection of caries and crestal bone changes in periodontal disease. Higher kilovoltage beams are also better for producing images for skull cephalometry.

Filtration

Filtration removes low-energy x-ray photons from the x-ray beam. The low energy photons do not contribute to the image but still affect the radiation dose. Radiographic units are manufactured with built-in filtration, which is dependent on the tube voltage. The greater the tube voltage the more the filtration. Adding extra filters made with rare earth metals to the x-ray unit has been shown to reduce radiation from 25% to 71%.[25] Added filtration with niobium decreases radiation exposure by up to 47%.[26] In each study, diagnostic images were produced with minimal loss of image information. However, the benefits of added filtration have yet to be determined because use of added filtration also increases the exposure time, and hence, the tube load.

Lead Aprons

Lead aprons are generally required for all patients exposed to dental radiation. For example, it is a regulation of the Texas State Board of Dental Examiners (Chapter 113.2) that all patients wear a lead apron during direct exposure to dental radiation. Scatter radiation to the thoracic, abdominal, and gonadal areas is reduced by up to 94% with a lead apron.[27] The apron also has a positive psychological or comforting effect on the patient.

Thyroid collars similarly reduce radiation exposure to the thyroid gland. These collars are highly recommended, provided they do not interfere with the image. This precludes their use during panoramic exposures. Thyroid collars reduce dental x-ray exposure to the thyroid gland up to 94%.[28,29]

Quality Assurance

A quality-assurance program is also needed to reduce radiation ex-

[a] KEYSTONE X-RAY, Inc, Dental Div. Neptune, NJ 07753
[b] MDT Diagnostic Co. North Charleston, SC 29411
[c] Pelton & Crane, A Siemens Co. Charlotte, NC 28224