SB

160

HFIN

FILE

FISCAL NOTE

STATE OF ALASKA
1998 LEGISLATIVE SESSION

No. 1
Bill Version: CSSB160(L&C)
(S) Publish Date: 4/3/98

Revision Date:
Title: An Act relating to radiological equipment used in the practice of dentistry.
Sponsor: Senator Taylor by request
Requestor: Senate Labor & Commerce

Department: Commerce and Economic Development
BRU: Occupational Licensing
Component: Operations
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)

FUND SOURCE	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04
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

POSITIONS	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04
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
Division: Occupational Licensing
Phone: 465-2144
Date: 4/2/98
Approved by Commissioner: Deborah B. Sedwick
Agency: Commerce and Economic Development
Date: 4/2/98

PREPARER TO PROVIDE ALL DISTRIBUTION COPIES TO GOVERNOR'S LEGISLATIVE OFFICE
For further distribution information, call the Governor's Legislative Office

FISCAL NOTE

STATE OF ALASKA
1998 LEGISLATIVE SESSION

BILL NO.: **CSSB 160(L&C)**
#1

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

FISCAL NOTE

STATE OF ALASKA
1998 LEGISLATIVE SESSION

No. 2
Bill Version: CSSB 160 (L&C)
(S) Publish Date: 4-14-98

Revision Date: 04/03/98
Title: Testing radiological equipment
Sponsor: Senator Taylor
Requestor: Senate L&C

Dept. Affected: Health and Social Services
BRU: State Health Services
Component: Laboratory Services
COMPONENT SERIAL NO. 291
See also (SN#):

Expenditures/Revenues: (Thousands of Dollars)

OPERATING	FY99	FY00	FY01	FY02	FY03	FY04
PERSONAL SERVICES						
TRAVEL						
CONTRACTUAL						
SUPPLIES						
EQUIPMENT						
LAND & STRUCTURES						
GRANTS, CLAIMS						
MISCELLANEOUS						
TOTAL OPERATING	0.0	0.0	0.0	0.0	0.0	0.0

CAPITAL EXPENDITURES						

CHANGES IN REVENUES ( )						

FUND SOURCE (Thousands of Dollars)

1002 Federal Receipts						
1003 GF Match						
1004 GF						
1005 GF/Program Receipts						
1037 GF/Mental Health						
Other (please specify)						
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0

POSITIONS:

FULL-TIME						
PART-TIME						
TEMPORARY						

Estimate of any current year (FY98) cost: $0.0

ANALYSIS: (Attach a separate page if necessary)

With the proposed elimination of the on site inspection and certification of dental radiologic equipment, the Division will generate the revenue for supporting the existing Radiological Health Program by assuring responsibility for the Federally required inspection of mammography equipment.

4/3/97

Prepared by: Peter M. Nakamura, MD, MPH
Division: ~~Public Health~~
Phone: (907)465-3090
Date: 04/03/98

Approved by Commissioner: Karen Perdue, Commissioner
Agency: Department of Health & Social Services
Date: 4/2/98

PREPARER TO PROVIDE ALL DISTRIBUTION COPIES TO GOVERNOR'S LEGISLATIVE OFFICE
For further distribution information, call the Governor's Legislative Office

(Rev 10/96)fisnote xls/DAS_DHSS

adopted

NO | OBJ

0-LS0825\Q.2
Lauterbach
5/7/98

AMENDMENT 2

OFFERED IN THE HOUSE

TO: CSSB 160(L&C)

Page 4, following line 20:

Insert a new subsection to read:

"(c) Notwithstanding other provisions of this Act, a person is not considered to be in violation of AS 08.36.075(c) or (d), added by sec. 1 of this Act, unless the violation occurs more than one year after the effective date of regulations adopted by the Board of Dental Examiners to implement AS 08.36.075, added by sec. 1 of this Act."

Conceptual Amendment 2

Page 4 following line 20:

(C) Notwithstanding other provisions of this Act, dental radiologic equipment which has been registered under AS 08.36.075 (c) before January 1, 1999 shall be issued an initial inspection seal valid until July 1, 1999 after payment of the fee

Conceptual so legal can improve wording

HOUSE COMMITTEE REPORT

(11)

Date Referred to Committee: May 5, 1998

FURTHER REFERRALS:

Date of Committee Action: 5/7/98

The FINANCE Committee considered: CSSB 160(L&C)

CS FOR SENATE BILL NO. 160(L&C)

DENTAL RADIOLOGICAL EQUIPMENT

"An Act relating to radiological equipment used in the practice of dentistry."

recommends it be replaced with the following committee substitute HCSCS SB 160(FIN) [X] the same title [ ] a new title

[ ] additional referral to ____________ Committee

[ ] attached amendment(s)

ADOPTS: ____________ Letter of Intent

ATTACHES NEW FISCAL NOTE(s): (Dept)

[ ] fiscal note(s) ____________

[ ] zero fiscal note(s) ____________

APPROVES PREVIOUS: (Dept/Date)

[✓] fiscal note(s) DCED 4/3/98

[✓] zero fiscal note(s) DHSS 4/14/98

SIGNING WITH RECOMMENDATIONS		DP	DNP	NR	AM
[signature]	Therriault			X	
[signature]	Mulder			X	
[signature]	Martin			X	
[signature]	Kohring		X		
[signature]	J. Davies		X		
[signature]	Grussendorf		X		
[signature]	Moses			X	
[signature]	G. Davis			X	
[signature]	Kelly	✓			

CHAIR'S SIGNATURE [signature] Therriault

0-LS0825\Q.1
Lauterbach
5/1/98

AMENDMENT

OFFERED IN THE HOUSE

TO: CSSB 160(L&C)

Page 1, following line 8:

Insert new paragraphs to read:

"(1) satisfactorily completed a United States Department of Defense biomedical equipment technician's course;

(2) a biomedical equipment technician certificate issued by the International Certification Commission for Clinical Engineers and Biomedical Technology;"

Renumber the following paragraphs accordingly.

adopted w/o

A M E N D M E N T 1

OFFERED IN THE HOUSE

TO: CSSB 160 (L&C)

Page 1, line 9 through 15 and page 2, lines 1 through 2:

Delete all language

Insert:

"qualifications equivalent with the qualifications established in Applicant Profile and Job Qualification Summary for a state Radiological Health Specialist I on the effective date of this Act."

Kate Coleman
923 D Street
Juneau, Alaska
99801 USA

EXPERIENCE

Alaska Radiological Health Director

- register and inspect x-ray equipment and accelerator produced radioactive materials
- investigate and respond to incidents involving possible over exposure to radiation
- maintain emergency response capability within the state and internationally
- represent the state to the Conference of Radiation Control Program Directors and federal agencies
- develop and manage grants and contracts
- provide information to government entities, industry and the citizens on the health effects of radiation exposure
- revise regulations

Washington State Radiological Health Manager

- supervise statewide radiological health section
- administer quality assurance and training program
- direct the radon program working with federal, state and local agencies to educate the public in the detection and mitigation
- serve on a national and international policy development committee

Washington State Emergency Response Coordinator

- coordinate planning activities between counties, the utility, and multiple state agencies
- write procedures
- conduct training and exercises
- represent the region on a national committee to develop training and communication
- coordinate regional conferences

Washington State Technical Support Program Manager

- coordinate office-wide activities such as audits, regulation revisions and contracts
- liaison with federal agencies
- develop and implement the radiation safety program and technical library

Washington State X-ray Compliance Inspector and Manager

- direct and supervise professional staff engaged in the inspection of x-ray facilities

- field inspector of x-ray facilities
- generate compliance action and evaluate corrective actions
- conduct federal contract on computer tomography

New Mexico State Uranium Mill Licenser

- develop guidelines and policies for licensing of uranium processes
- review license applications for new uranium processes
- provide public information services via press release, brochures and television shows

Washington State University Engineering Extension Graduate Assistant

- coordinate engineering short courses by developing program format, obtaining speakers, securing funding and advertising
- key word indexing

US Environmental Protection Agency Information Specialist Intern

- prepare congressional correspondence for congressman and their constituents
- organize a public information center to categorize and distribute all incoming documents

EDUCATION

Master of Science, Environmental Science, Washington State University, 1977

Bachelor of Science, Broadcast Journalism, University of Idaho, 1975

Alaska State Legislature

Chairman,
Judiciary Committee

Member,
Resources Committee
Rules Committee
Committee on Committees

State Capitol
Juneau, Alaska 99801-1182
(907) 465-3873
Fax: (907) 465-3922

50 Front Street, #203
Ketchikan, Alaska 99901
(907) 225-8088
Fax: (907) 225-0713

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.

Alaska State Legislature

Chairman,
Judiciary Committee

Member,
Resources Committee
Rules Committee
Committee on Committees

State Capitol
Juneau, Alaska 99801-1182
(907) 465-3873
Fax: (907) 465-3922

50 Front Street, #203
Ketchikan, Alaska 99901
(907) 225-8088
Fax: (907) 225-0713

Senator Robin L. Taylor

Senate Majority Leader

TO: Rep. Gene Therriault, Co-Chair
House Finance Committee

FROM: Senator Robin Taylor RLT

DATE: May 6, 1998

RE: SB 160 "Relating to dental radiological equipment."

SB 160 was introduced to address an ongoing problem relating to the inspection of dental radiological equipment. Inspections have been under the Department of Health and Social Services Radiological Health Division. According to the dental community, some dentists have gone as long as ten years between inspections by the department.

Senate Bill 160 will put in place a more meaningful inspection program that will both serve the dental community and the public more effectively and efficiently. There is one amendment I would like added to the bill that deals with the inspectors. We inadvertently omitted two groups of qualified persons that routinely perform these types of inspections. A copy of the amendment is attached.

SB 160 is revenue neutral as the costs of administering the program will be paid for by the owners or lessees of the equipment.

Thank you in advance for your consideration.

Post-it® Fax Note 7671	Date 3-10	# of pages ▶ 18
To M. HELMRRECHT	From J. MALONE	
Co./Dept. ALASKA	Co. ADA 1-800-	
Phone #	Phone # 621-8099	
Fax # 9074524775	Fax # 3124402536	

Article 4

Continuing Education

X-Radiation: Potential Risks and Dose-Reduction Mechanisms

Kenneth Abramovitch, DDS, MS
Associate Professor

Lisa P. Thomas, RDH, DDS
Clinical Assistant Professor

Section of Radiology
Department of Oral Diagnostic Sciences
Dental Branch
University of Texas Health Science Center at Houston
Houston, Texas

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 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.[2] 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]

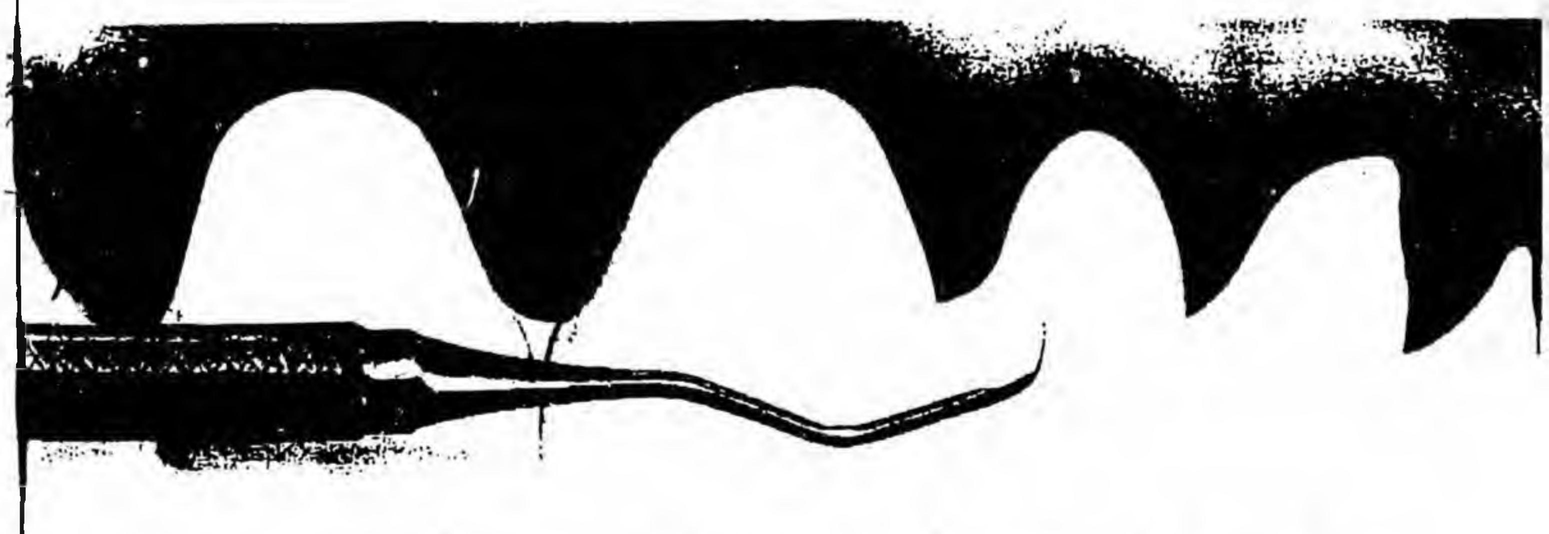
	mRem	mSv
Natural		
Radon	200	2.0
Cosmic	27	0.27
Terrestrial	28	0.28
Internal	39	0.39
Artificial		
Medical		
X-ray diagnosis	39	0.39
Nuclear medicine	14	0.14
Consumer products	10	0.1

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).[4] 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.[4] 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.[4] 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.[6] 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.[6] 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 a ded 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 psycholo gical or comforting effect on the pat ent.

Thyroid collars simil rly reduce radiation exposure to the thyroid gland. These collars ar 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%.[28,27]

Quality Assurance

A quality-assurance program is also needed to re uce 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

Feature

X Rays: What is the Risk?

By Neil L. Frederiksen, D.D.S., Ph.D.
Director, Oral and Maxillofacial Radiology
Department of Diagnostic Sciences, Oral and Maxillofacial Radiology
The Baylor College of Dentistry, Dallas, Texas

Introduction

If it hasn't happened already, it will. It's simply a matter of time before one of your patients will ask: "How much radiation is involved with these x rays?" or "Aren't these x rays harmful?" or, "Are you using the latest methods to reduce my exposure to x rays?" Dentists and their office personnel are continually asked questions pertaining to the use of x rays. Your response, or that of your staff, may have a profound effect on your practice. To respond with a clear and concise answer will serve to increase their confidence in you as a practitioner. On the other hand, to simply ignore these questions, or treat them lightly, may create the impression of a lack of concern for their overall well being. This may not only result in a loss of the patient's confidence in your ability, but also the loss of a patient.

There is no question that ionizing radiation in general, and x rays in particular, have a potential harmful effect on humans. It is known beyond a shadow of doubt that if exposed to sufficient quantities of radiation, humans will experience an increased risk of nonfatal and fatal cancer, hereditary disease, or loss of life expectancy. It is the purpose of this article to provide you with the information to put these risks into perspective, allowing you to use x rays when needed for diagnosis.

Frederiksen

Radiation in our Environment

No matter who we are or where we live, we are subjected to quantities of radiation exposure from a variety of sources. Because not all of these sources are responsible for exposure of the whole body, the quantities of radiation they deliver are expressed in terms of effective dose. This unit, effective dose, is calculated from both whole- and partial-body exposures. It is the dose that may be expected to result in the same total risk of harm as that from a uniform whole-body exposure of the same magnitude. Effective dose is then a useful term that allows comparisons to be made between sources of radiation exposure which expose only portions of the body, such as radiographic techniques, and whole-body exposures, including those resulting from natural or background radiation. The unit of effective dose is the sievert (Sv). A millisievert (mSv) is one thousandth of a sievert.

Estimates of the radiation exposure of all persons living in the Unites States resulting from all sources have been made. By totaling these individual exposures and then dividing by the population, an average dose has been determined (1) (Table 1). In this manner, it has been estimated that an average individual living in an average location in the United States receives an effective dose of 3.6 mSv of radiation every year. Of this total, over 80 per cent (3.0 mSv) is the result of natural or background radiation. This means that every day of a person's life, they receive 0.008 mSv of radiation exposure from natural sources or sources over which they have no control. We are all concerned with the human contribution to radiation exposure; however, it is estimated that in total, this amounts to only 0.6 mSv. Including everything from the medical uses of radiation to consumer products (including some smoke alarms, airport inspection systems, and dental porcelain) to nuclear reactors, this category subjects an average individual to less than one third the radiation delivered by naturally occurring radon (2.0 mSv).

Dental x-ray examinations are estimated to be responsible for an average annual effective dose of less than 0.01 mSv (2). This figure, equal to only 2.5 percent that of medical x-ray diagnosis and 0.3 percent of the total average annual effective dose, is surprising when it is considered that dentists own over half of the x-ray machines in this country and perform an estimated 105 million examinations per year using 380 million pieces of film. In spite of these figures, the use of x rays in dentistry is not considered as a source of exposure and for that reason not listed in Table 1. The exclusion of dental x rays as a source may have resulted in part from the introduction of the term "negligible individual dose" (3). Formulated by the National Council on Radiation Protection and Measurements, a private, nonprofit organization whose findings are made into law by most states, the negligible individual dose is that quantity of radiation that can be dismissed. Currently, this dose is established at 0.01 mSv per year, a quantity equal to that of the estimated average annual effective dose resulting from dental x-ray examinations.

Exposure From Dental X Rays

Occupational Exposure.

Within twenty-five years of Roentgen's discovery of x rays, it had been estimated that over 100 early pioneers in radiology had died of cancer caused by their exposure to radiation (2). This finding, among others, has resulted in the establishment of limits on the amount of radiation a person may be exposed to in the course of their occupation. The Texas Regulations for the Control of Radiation state that each registrant shall control the occupational dose to individual adults such that it will not exceed an annual effective dose of 0.05 Sv (4). This limit has been set in an attempt to ensure that the lifetime fatal cancer risk as a result of exposure to x rays will be similar to the risk of accidental death in "safe" industries where there is no exposure to radiation. Because even this dose carries with it some risk, all individuals are further urged to follow the principles of ALARA (As Low As Reasonably Achievable) which recognize that no matter how small the dose, there may be some risk of effect. The fact that the dental profession follows these principles may be illustrated by the fact that most recent data show that the annual effective dose of those occupationally exposed in the operation of dental x-ray equipment was 0.2 mSv (2). This figure is only 1/250 the allowable limit. This finding is perhaps one of the reasons that the State of Texas no longer requires radiation monitoring of dental employees.

Patient Dose. The dose delivered to the patient as a result of an x-ray examination is dependent in part on the specific area exposed, the size of the area exposed, and on the type of image receptor used. The latter may be either intraoral direct-exposure film, extraoral screen-type film, or some form of solid state detector as used in digital radiography, including computed tomography. Table 2 (5,6,7,8) lists the effective dose patients may receive by undergoing both some common and more specialized dental and medical radiographic examinations. By comparison of figures in the table, a lower GI series (barium enema) can be seen to deliver 27 times more radiation to the patient than a full-mouth series of oral radiographs and a radiograph of the chest about three times more than a panoramic film.

Risk

Risk is the chance or possibility of loss or injury. The probability of loss or injury may be considered in both relative and absolute terms. Relative risk can be illustrated by comparing doses received as a result of exposure to x rays for diagnostic purposes with natural or background radiation. Table 2 lists the days of equivalent natural exposure. It can be seen from these data that a panoramic radiograph delivers a dose to the patient equal to 3.3 days of natural radiation exposure, a bitewing examination 4.8 days, and a full-mouth survey 18.8 days. Additionally, by comparison, radon in our environment (2.00 mSv, Table 1) is responsible for an annual exposure of over 13 times that of a full-mouth survey of intraoral films. These figures can also be used to make comparisons between persons living in various locations of the U.S. For example, it has been estimated that the effective dose from cosmic radiation in Denver, Colorado, is 0.24 mSv higher than the U.S. average (2). This is because of Denver's higher elevation. This would mean that a patient living in an average location of the U.S. who had almost four panoramic and bitewing examinations every year (total effective dose for these examinations is 0.064 mSv, Table 2) would incur the same risk of potential harm from radiation as a patient living in Denver who was not exposed by these examinations.

In absolute terms, risk can be described by calculation of detriment. Detriment is a term used to represent a combination of the probability of occurrence of an unfavorable health effect resulting from radiation exposure and a judgment as to the severity of the effect (9). Thus, radiation detriment can be expressed as the total harm that would eventually be experienced by an exposed population of individuals and their descendants as a result of radiation exposure. This includes the probability of fatal cancer, the weighted probability of nonfatal cancer, the weighted probability of hereditary effects, and the relative length of life

X rays: What is the Risk?

lost. Detriment can be calculated on the basis of the probability of incidents per million of exposed population, the population at risk (Table 2). For some of the more common examinations, this probability ranges from less than 0.1 per million for a single-film tomogram that may be made for oral implant diagnostics, to 11 per million for a full-mouth survey, to 296 per million for a lower GI series.

Calculation of risk per million from the use of x rays allows for comparison with risks patients are subjected to in the course of their everyday lives. Table 3 lists some of these risks compiled from various newspaper and news magazine articles over the years. These data, expressed as the probability of either death or developing cancer, show that patients have about the same risk of choking to death (13 per million) as expressing some detriment from having a full-mouth survey (11 per million) made during the course of an oral examination. In all fairness, however, diagnostic x rays involve a risk generally much higher than that of being killed by falling airplane parts or in a shark attack.

Minimizing the Risk to Patients and Personnel

Although the risk from exposure to x rays may be compatible with everyday life, according to the principles of ALARA we should always try to employ techniques, equipment, and materials that will allow us to produce radiographs with the least amount of radiation. As an added benefit, everything we do to reduce patient exposure will reduce the possibility of exposure of ourselves and our personnel.

The following is a summary of methods of exposure reduction that can be used in oral radiography (2). Patient selection is probably the single most effective way in which exposure can be reduced (See *Guidelines*, this issue). If the decision is made that radiographs are not necessary, this represents a 100 percent reduction in patient exposure. An almost 50 percent reduction in patient exposure can be realized by using E-speed film rather than D-speed film. The use of digital intraoral imaging techniques also requires less radiation. Digital imaging has been found to require only 40 percent the radiation of E-speed film and 23 percent that of D-speed film (10). Rare-earth intensifying screens, such as Lanex® (Eastman Kodak Co., Rochester, NY), which may be used in extraoral radiography, are up to eight times more sensitive to x rays than conventional screens, resulting in a significant reduction in patient exposure. Long-cone instead of short-cone techniques for intraoral radiography may result in a 32 percent reduction in exposed tissue volume. Rectangular collimation will reduce the area of the patient's skin surface exposed by 60 percent over that of round collimation. Leaded aprons and collars can reduce the amount of scatter radiation to the patient's abdomen by 98 percent and to the thyroid gland by 92 percent. And finally, good darkroom techniques, including time-temperature processing, may contribute to exposure reduction. Six percent of dental radiographs may not be readable because of poor darkroom techniques. Radiographs that must be remade because of inadequate exposure or processing techniques result in a doubling of patient exposure.

Finally, to ensure that a dental office consistently produces high quality radiographs with a minimum of patient exposure, the American Dental Association recommends the establishment of a quality assurance program in each dental office (11). Such programs include inspection of the x-ray unit, darkroom, and ancillary equipment such as leaded aprons at suitable intervals and the establishment of written procedures for safe operation, exposure and processing techniques, and maintenance. Many of these items are required by the Texas Regulations for the Control of Radiation (4) (See *Message*, this issue).

The practice of dentistry requires lifelong learning. Every practitioner should keep in mind that developing and maintaining skills and acquiring knowledge is a continuous process. Every effort should be made to be aware of improvements in techniques in radiology and every field of dentistry so that patients may receive quality care.

References

1. National Council on Radiation Protection and Measurements: Ionizing radiation exposure of the population of the United States. NCRP Report 93,1987.
2. Frederiksen NL: Health physics. In Goaz PW, White SC: Oral radiology: Principles and interpretation, ed 3. St. Louis: Mosby, 1994.
3. National Council on Radiation Protection and Measurements: Limitation of exposure to ionizing radiation. NCRP Report 116, 1993.
4. Bureau of Radiation Control, Texas Department of Health: Texas regulations for the control of radiation, 1993.
5. Avendanio B, Frederiksen NL, Benson BW, Sokolowski TW,

Estimate of radiation detriment: Scanography and intraoral radiography. J Dent Res 1994;73: 2109.

6. Frederiksen NL, Benson BW, Sokolowski TW. Effective dose and risk assessment from computed tomography of the maxillofacial complex. Dentomaxillofac Radiol 1994, In press.
7. Frederiksen NL, Benson BW, Sokolowski TW. Effective dose and risk assessment for film tomography used for dental implant diagnostics. Dentomaxillofac Radiol 1994, 23: 123-127.
8. National Council on Radiation Protection and Measurements: Exposure of the U.S. population from diagnostic medical radiation. NCRP Report 100, 1993.
9. International Commission on Radiological Protection: Radiation Protection, ICRP Publ 60, 1990.
10. Frederiksen NL: Specialized radiographic techniques. In Goaz PW, White SC: Oral radiology: Principles and interpretation, ed 3. St. Louis: Mosby, 1994.
11. American Dental Association, Council on Dental Materials, Instruments, and Equipment. Recommendations in radiographic practices: An update, 1988 J Am Dent Assoc 1989; 118: 115-17. ■

Table 1.

Average Annual Effective Dose of Ionizing Radiations to a Person in the United States

Source	Effective Dose (mSV)	
Natural		
External		
Cosmic	0.27	
Terrestrial	0.28	
Internal		
Radon	2.00	
Other	0.40	
Total		3.00
Man-Made		
Medical		
X-ray diagnosis	0.39	
Nuclear medicine	0.14	
Consumer products	0.10	
Other		
Occupational	<0.01	
Nuclear fuel cycle	<0.01	
Fallout	<0.01	
Miscellaneous	<0.01	
Total		0.60
Total= Natural plus Man-Made		3.60

Dental not listed

X rays: What is the Risk?

Table 2.

Effective Dose by Radiographic Technique

Technique	Effective Dose (mSv)	Days Equivalent Natural Exposure	Probability (per million)
Dental			
Intraoral			
Periapical (15 films)	0.111	13.9	8.1
Bitewing (4 films)	0.038	4.8	2.8
Full-mouth survey (19 films)	0.150	18.8	11.0
Extraoral			
Panoramic	0.026	3.3	1.9
Film tomography *	<0.001-0.030	<0.1-3.8	<0.1-2.2
Computed tomography.			
Maxilla	0.104	13.0	7.6
Mandible	0.761	95.1	55.6
Medical			
Lower GI series	4.060	507.5	296.4
Upper GI series	2.440	305.0	178.1
Chest	0.080	10.0	5.8

* Scanora® integrated imaging system (Orion/Soredex, Helsinki, Finland). The effective dose is dependent on the region of the jaws exposed and the collimation option used, i.e., round or rectangular.

Table 3.

How Safe ?

End Result And Cause	Probability of Occurrence (per million)
Cancer	
Exposure to termicide (Chlordane)	100-300
Herbicides and fungicides on fruits and vegetables	278
Death	
Choking	13.0
Boating accident	4.6
Tornado	2.2
Bathtub accident	0.6
Struck by lightning	0.5
Overseas terrorist attack	0.1
Falling airplane parts	0.1
Shark attack	0.003