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ABSTRACT

This overview of dental radiology contains sections on demographics, equipment, dental radiology quality assurance, efficacy, dental radiology education curricula, professional organizations' guidelines for training and use, and state activities. In section 1 dental personnel, population of dental personnel, employment and earning prospects, dentist-to-population ratio, dental visits, dental radiographs, dental care and x-ray costs, and selected health characteristics are described. In section 2 conventional diagnostic x-ray equipment, performance standards, new technology, ancillary equipment, and an alternative modality are described. The Dental Surpak program, nationwide evaluation of x-ray trends, the Nashville Dental Project, the Dental Exposure Normalization Technique, and the present status of quality assurance in dental radiology are discussed in section 3. Section 4, which covers efficacy, contains information on examination frequency, trends, and costs; radiation exposures, doses, and risks; routine x-rays, referral criteria, and post-treatment radiographs. Dentists, dental auxilliaries, and continuing education are examined in section 5, which deals with dental radiology education curricula. Section 6 outlines professional organizations' guidelines for training and use. It presents comments on curriculum development and the findings and recommendations of professional organizations. State activities are described in section 7. A total of 134 references and 29 bibliographic citations are included. (MN)

AN OVERVIEW OF DENTAL RADIOLOGY

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FOREWORD

Medical technologies pose many complex and interrelated issues—for the health care professions, for patients, and for society. To help address these considerations, Congress established the National Center for Health Care Technology to conduct and sponsor assessments of health care technologies. Publ: Law 95-623 (the Health Services Research, Health Statistics, and Health Care Technology Act of 1978), which created the Center, defines health care technology broadly to include any means to prevent, diagnose, or treat disease or promote health. Furthermore, it calls for evaluation not only for safety and efficacy, but also for the social, ethical, and economic implications of technologies.

To provide medical and scientific background on certain selected technologies generally considered to be of particular significance, the Center has commissioned a series of overview papers, one of which follows. These were written by one or more authorities and are designed to review that state-of-the-art and identify, but not resolve, the key issues surrounding the subject. They are not intended to be comprehensive surveys of the literature. Each paper has been subjected to review by appropriate medical specialty societies, government agencies, and individual experts, and has been revised accordingly.

These overviews are likely to be of most immediate interest to clinicians and biomedical scientists; they also may provide valuable background for assessments undertaken by the Center and for exploring the broad societal implications of health care technologies.

This paper was prepared for the Center by experts at the Bureau of Radiological Health of the Food and Drug Administration. We are grateful for the time and effort they expended in the production of this comprehensive overview, and we look forward to other fruitful collaborations.

It is our hope that you will find this paper interesting and useful.

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November 7, 1980

PREFACE

This overview report has been prepared at the request of the National Center for Health Care Technology (NCHCT). It is one of several projects entered into jointly by the Bureau of Radiological Health (BRH) and NCHCT relating to the use of radiation for health care.

Dental radiation protection has been a long-time interest of BRH. Both our past and on-going efforts to minimize population radiation exposure from electronic products have included specific action programs directed at minimizing unnecessary radiation exposure to the population from dental radiology. Our current efforts in quality assurance and referral criteria are two aspects of our own assessment of this technology which are described within the larger picture presented in this overview.

The issues considered in this document go beyond the radiation exposure aspects of dental x-ray procedures. To be responsive to the informational needs of NCHCT, the assessment includes various other factors that influence the practice of dental radiology. We hope this analysis will serve as the basis for planning and conducting future programs to improve the practice of dental radiology.

I would like to express my appreciation to NCHCT for inviting and supporting our participation in development of this publication.

John C. Villforth
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INTRODUCTION

Intraoral and extraoral radiographs are an extremely valuable diagnostic tool in dentistry. Common chronic diseases such as caries and periodontal problems may present few physical symptoms during their early stages. Similarly, developmental abnormalities may remain hidden to direct clinical observation until well advanced. The consequences of failing to detect dental diseases range from relatively slight biologic disability to fatality in the case of malignant tumors or oral-source blood-borne infections. Radiographs can permit early detection, diagnosis, and treatment of many conditions.

Nonetheless, public concern about radiation exposure and health care costs is increasing. Recently, both the news media and Congressional hearings have focused substantial attention on the potential hazards of exposure to ionizing radiation. Accordingly, the present state of dental radiographic practice should be appraised. The scope of this report is a broad examination of the safety, efficacy, cost effectiveness, and economic, social, and ethical impacts of dental radiology.

Dental radiology is used extensively in delivering dental care. Approximately 145,000 dental x-ray machines are in operation in the United States, and according to 1976 information 335,702,000 dental visits were made by 102,620,000 individuals. In 1978, 82 percent of dental patients received radiographic services. Total 1978 expenditures for dental care amounted to $10 billion, $730 million of which was for dental radiographic services.

Another cost perceived to be associated with the use of ionizing radiation in diagnosis is the potential for detrimental effect on biological tissues. Although dental x-ray procedures contribute only about three percent of the average total adult active bone marrow dose for a year, sources of unnecessary exposure to dental radiation should be eliminated.

Several specific measures can minimize unproductive exposure to dental x rays; each has as its goal the enhancement of x rays as a safe, cost-effective method of diagnosis in dentistry. First, unnecessary examinations should be eliminated, since they increase both risk and consumer costs. Second, the diagnostic quality of dental radiographs should be improved, because poor quality can lead to misdiagnosis, repeat exposure, and added cost. Third, development and use of techniques to reduce dose without compromising diagnostic quality should be fostered.

Various factors influence radiation exposure and cost in dental radiology, and thus critically affect attainment of the above objectives. One is the practices of personnel who actually expose and process dental radiographs, which are largely shaped by the training they receive. The adequacy of equipment is another factor, but a more fundamental influence is the collective attitude of the dental profession regarding selection of patients for x-ray examinations.

In an attempt to understand these factors so that recommendations for improvement can be made, this review addresses a wide range of areas. The first section consists largely of data on dentists and allied professions, and on expenditures for dental care. A summary of conventional equipment and new technologies is then followed by a discussion of quality assurance in dental radiology, with special consideration given to the manner in which x rays are used in dentistry. This is followed by a section on the efficacy of dental radiographic practices. Curricula and training requirements are analyzed for their impact on performance. The remaining two sections outline existing guidance from professional organizations and State agencies for the practice of dental radiology, either voluntary or mandatory. Where feasible, recommendations have been included in relevant sections of the report.

Because the report refers to various Bureau of Radiological Health programs at several points, it is advantageous to define them at the outset. The X-Ray Exposure Study (XES) of 1970 is an important source of data regarding the volume and rates of x-ray examinations. NEXT (Nationwide Evaluation of X-Ray Trends), a joint FDA/State surveillance program, currently provides data on patient exposures for a set of specific projections in different facilities within the States. DENT (Dental Exposure Normalization Technique) is a quality assurance program designed to identify and correct exposure problems in individual dental offices.

DEMOGRAPHICS

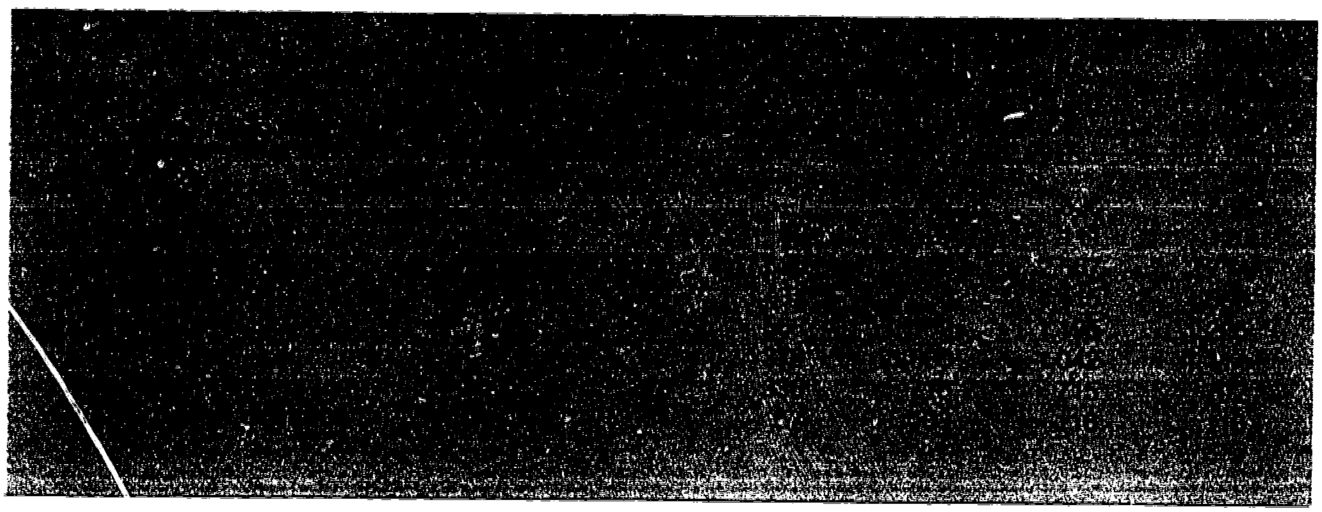
DESCRIPTION OF DENTAL PERSONNEL

Dentists

The key member of the dental health care team is, of course, the dentist. Most dentists are general practitioners who provide many types of dental care; only about 10 percent are specialists. The largest specialty group are the orthodontists, who correct dental malocclusions. The next largest group, oral surgeons, operate on the mouth and jaws. The remaining specialties are pedodontics (dentistry for children); periodontics (treatment of diseases of the gums); prosthodontics (the making of dentures); endodontics (root canal therapy); public health dentistry; and oral pathology (diseases of the mouth). (1) See Table 1.

About 4 percent of all dentists teach in dental schools, engage in research, or administer dental health programs on a full-time basis. Additionally, many dentists in private practice participate in these activities on a part-time basis. (1)

Table 1. Number of Dental Specialists: Selected Years 1955 through 1973 (2)



[1] Endodontics was not recognized as a dental specialty in 1955 or 1960, and data are unavailable for 1965.

Dental Hygienists

In general, dental hygienists scale, clean and polish teeth, and instruct patients in proper oral hygiene. They are the only dental auxiliary personnel required by each State to be licensed, although specific responsibilities vary depending on the law of the State where the hygienist is employed. Among the tasks usually performed by hygienists are removing deposits and stains from teeth, counseling and instructing patients in care of teeth and in nutrition, applying fluoride for prevention of tooth decay, and performing radiographic services. In addition, dental hygienists often take medical and dental histories and make model impressions of teeth. (1)

Most hygienists work in private dental offices and many are employed part-time. Others work in school systems, public health agencies, government, industrial plants, hospitals or clinics, or are involved in teaching or research. (1)

Dental Assistants

The dental assistant helps the dentist treat the patient by performing such tasks as handing the dentist instruments, keeping the patient comfortable and the operating field clean, and preparing materials for the restoration of teeth or the making of impressions of teeth. Many dental assistants also expose and process dental radiographs. Dental assistants frequently perform non-chairside duties such as receiving patients, arranging and confirming appointments, keeping records, sending bills, and ordering supplies. (1)

Most dental assistants work in private offices for dentists in either individual or group practices. Others work in dental schools, hospital dental departments, or public health departments. Unlike dental hygienists, only about one out of 10 works part-time. (1)

POPULATION OF DENTAL PERSONNEL

As might be expected, the number of dental personnel in the U.S. is increasing (see Table 2). Hygienists, for example, more than doubled their ranks over the past decade. Concomitantly, there has been an influx of practitioners into specialty areas (see Table 1). Immigration is also a source of additional dentists. According to data prepared by the U.S. Immigration and Naturalization Service, 421 dentists entered the U.S. in fiscal year 1973, in contrast to 182 in fiscal year 1965. (2)

Table 2. The Population of Dental Personnel by Selected Years

	Dentists	Hygienists	Assistants	Reference
[illegible]	[illegible]	[illegible]	[illegible]	(3)
1970	[illegible]	[illegible]	[illegible]	(4)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	(2)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

***1970	MALE	FEMALE
Dentists	87,691 (97%)	3,110 (3%)
Hygienists	942 (6%)	14,863 (94%)
Dental assistants	1,866 (2%)	86,309 (98%)

As Table 3 shows, most dentists and hygienists are practicing in private offices. Although pertinent data are lacking, the concentration of dental assistants follows the same pattern. Among auxiliaries, assistants far outnumber hygienists (see Table 4), a significant fact for the radiological process, because although both hygienists and assistants commonly perform radiographic examinations, educational and testing requirements to monitor and promote competence have received far less emphasis for dental assistants than for hygienists.

Table 3. Employment Distribution (1970) (4)

Location	*Dentists*	*Hygienists*	*Dental Assistants**
Dentist offices	83,430	12,863	
Physician offices	1,246	154	
Chiropractic offices	10	—	
Hospitals	2,049	246	
Convalescent institutions	157	24	
Office of practitioners (other)	11	5	
Health service	1,172	1,479	
Total	88,075	14,771	

*Breakdown of dental assistants not available; however, almost all are in dental offices (see above).

Table 4. Percent of Independent Dentists Who Employ Auxiliaries: Selected Years 1955-1975 (5)

Year	*Type of Auxiliaries* *Dental Hygienists*	*Dental Assistants*	*All Types*[1]
1975	41.3	92.5	96.1
1972	36.9	90.2	93.6
1970	30.8	85.6	89.9
1967	25.2	86.6	92.4
1964	20.2	82.4	89.9
1961	15.0	76.7	82.6
1958	14.0	75.5	81.8
1955	10.3	70.7	77.1

[1]Includes dental laboratory technicians and secretary-receptionists, as well as dental hygienists and dental assistants. These employees may be either full-time or part-time.

EMPLOYMENT AND EARNING PROSPECTS

Dentists

After graduation, many dentists open their own offices, purchase established practices, or go into group practice. Others enter the Armed Forces or the Public Health Service. Some go on for advanced specialty or academic training. Employment opportunities for general practitioners look very good through the mid-1980s. Dental school enrollment has grown in recent years, but without further expansion the number of dentists is expected to fall short of the demand for services. Population growth, increased public awareness of the role of regular dental care in preventing and controlling dental diseases, and the expansion of prepayment arrangements are expected to increase the demand for dental services. (1)

Based on the limited data available, the average income of dentists in 1976 was about $39,500. Urban areas have greater demands for dental services, and therefore afford larger incomes for dentists than do smaller communities. Most dentists work 5 days a week, averaging 40 to 45 hours per week. Some offer evening hours. Many dentists practice part-time well beyond the average retirement age. (1)

Dental Hygienists

Employment opportunities for dental hygienists are expected to be good through the mid-1980s. Although the number of graduates is increasing, demand is expected to exceed supply. Opportunities should abound for those seeking part-time employment or location in rural areas. (1)

Earnings of dental hygienists are affected by type of employer, education, experience, and geographic location. According to the limited data available, a full time dental hygienist working in a private office earned an average salary of about $12,900 in 1977. Dental hygienists employed by the government earned somewhat less. Usually, dental hygienists employed in private offices work from 35 to 40 hours per week. (1)

Dental Assistants

The employment outlook for dental assistants also is excellent through the mid-1980 s. Salary is largely dependent on education, experience, duties and responsibilities, and geographic location. In 1977, the average salary for a dental assistant ranged from $7,400 to $8,300. The prevailing work week is 40 hours. (1)

DENTIST-TO-POPULATION RATIO

Public demand for dental care has been increasing as the population, standard of living, and level of education have risen, and as private and Federal mechanisms for providing payment for dental services have become more widely available and accepted. (2)

Between 1940 and 1975, the number of dentists increased from 76,000 to more than 100,000. However, this increase failed to keep pace with population growth, so that the dentist-to-population ratio actually decreased from 57 per 100,000 to 52 per 100,000. (6)

By 1990, the ratio of dentists per 100,000 population is projected to rise 24 percent. Approximately 850 geographic areas, with a total population of about 13 million, have been identified as having critical shortages of dentists (generally indicating fewer than one dentist per 5,000 persons); about nine-tenths of these areas are rural. (5)

DENTAL VISITS

In 1976, an estimated 335,702,000 visits to dentists were made by 102,620,000 persons. (4) Despite overall increases in utilization of dental services, the number of visits per year has remained relatively constant for the various age groups (see Table 5). The greatest percentage of visits occurred within six months of a prior visit (see Table 6).

Table 5. Number of Dental Visits Per Person Per Year

Year	[illegible]
[illegible]	[illegible]

Table 6. Interval Since Last Dental Visit

	Under 6 mos.	6-11 mos.	1 yr.	2-4 yrs.	5 yrs.+	Never	Unknown	Total	Ref.
1977	35.7%	14.1%	13.1%	12.9%	13.9%	9.3%	1.1%	100%	(7)
1976	34.9%	13.8%	13.2%	13.2%	14.1%	9.7%	1.0%	100%	(8)
1975	STATISTICS NOT AVAILABLE FOR 1975								
1974	34.3%	15.0%	10.9%	14.2%	13.8%	10.3%	1.5%	100%	(9)
1973	33.8%	15.1%	11.0%	14.0%	13.9%	11.2%	1.0%	100%	(10)
1972	32.7%	14.5%	11.7%	14.3%	13.9%	11.8%	1.1%	100%	(11)
1971	32.4%	14.7%	11.7%	13.9%	13.4%	12.3%	1.6%	100%	(12)
1970	32.3%	14.5%	11.6%	13.8%	13.7%	12.7%	1.4%	100%	(13)
1969	32.1%	12.8%	11.8%	14.2%	13.2%	13.3%	2.5%	100%	(14)

DENTAL RADIOGRAPHS

In 1978 over 417 million packets of dental film were sold, (15) among which intraoral films were the most frequently used. Nearly all dentists now use high-speed film. (16) The use of panoramic radiographs is increasing, but statistics are not available. Statistics from the Bureau of Radiological Health, however, do indicate an average of 4.1 exposures per x-ray experience per patient. (17)

COST OF X-RAY EXAMINATIONS

In 1969, Americans spent an estimated $268.4 million for dental radiographs. (18) A sampling of a population with dental insurance showed that radiographic services accounted for 7.3 percent of total dental charges in 1978. (19) Extrapolation from this figure leads to an estimate of $730 million for the annual national expenditure for dental radiography. Table 7 presents the costs for various dental x-ray examinations as a function of dental specialty.

Table 7. Cost of X-ray Examinations (1975) by Dental Specialty (20)

Procedure	Dentists (General) Mean	Dentists (General) Ranges	Pedodontists Mean	Pedodontists Ranges	Oral Surgeons Mean	Oral Surgeons Ranges	Orthodontists Mean	Orthodontists Ranges
Intraoral radiographs (complete series including bitewing)	$22.11	$16-30	$20.74	$14-30	$22.63	$15-35	$21.75	$15-30
Intraoral radiographs (single first film periapical or bitewing)	3.69	2-6	4.06	2-8	4.38	2-7	3.08	0-8
Each additional radiograph	2.03	1-4	2.20	1-5	2.47	1-5	2.09	0-5
Bitewing radiographs (4 films)	9.07	6-15	9.07	5-14	-	-	-	-
Bitewing radiographs (2 films)	6.39	4-10	6.51	4-10	-	-	-	-

COST OF DENTAL CARE

During 1975 the average family spent $134 for dental bills, and as family income rises, so does out-of-pocket expense. However, out-of-pocket health spending takes a larger share of family income in lower income groups than in higher income groups. (21) The average per capita expense for dental service in 1975 was $41. (22)

Dental Service Corporations, known as the Delta Dental plans, were the first providers of dental care coverage. By the end of 1974, an estimated 23 million people were covered by some form of dental insurance by more than 140 carriers offering dental prepayment. (23, 24) During the years 1969 to 1977, the number of Americans with dental insurance increased from 7 million to 48 million. Between 1970 and 1977, the money spent annually for dental care more than doubled from $4.4 billion to $10 billion. (19) By 1982, 70 million Americans are expected to be covered by dental insurance. (19) The Health Care Financing Administration's Medicare program provides some dental care, as do cooperative State programs. Additionally, thirty-three of the total fifty-three States/jurisdictions provide some dental coverage through Medicaid.

For each major category of dental service, Table 8 indicates the proportion of patients in a selected, insured population who receive the service, and also the contribution of that service to total charges during a 1-year period. Radiography accounts for 7.3 percent of all charges, and is the service most frequently provided.

Table 8. The Percentage of Patients Receiving a Service and the Percentage of Total Charges for the Service in an Insured Population (19)

[illegible]

*Approximately 17% of total charges are for services not included in this table.

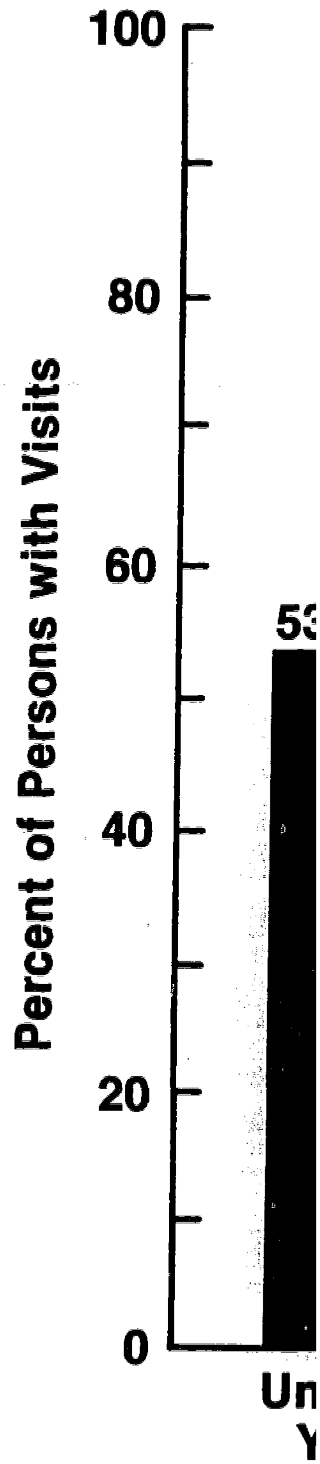
SELECTED HEALTH CHARACTERISTICS

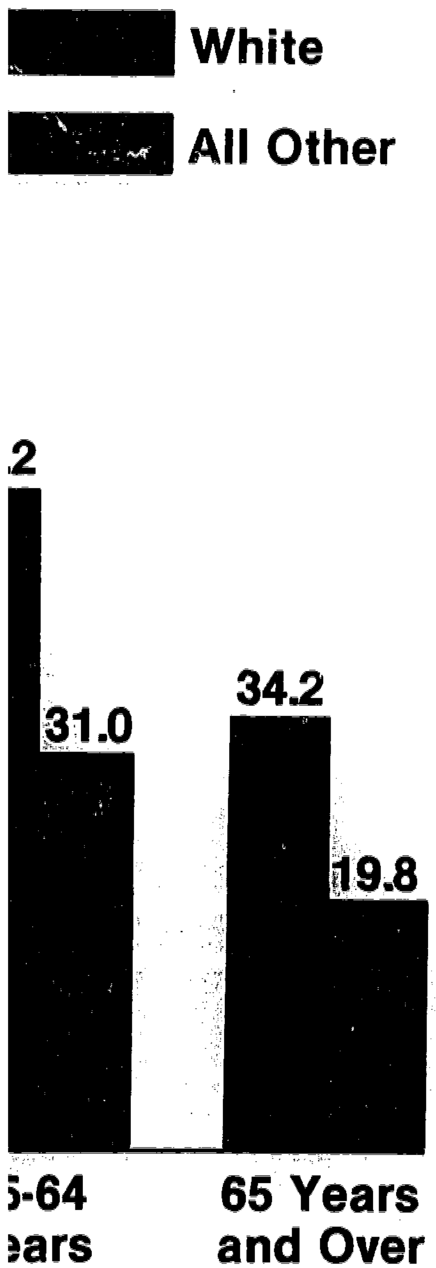
Utilization of dental care services depends upon a number of variables, the most significant of which are income and education. As family income increases, so does the use of dental services. Educational level has a similar effect. Fewer years of schooling are associated with lower utilization of services, even when financial barriers are disregarded. (19)

Proportion of Persons Making an Annual Dental Visit

Based on 1979 data, an estimated 50 percent of the population sees a dentist during a given 12-month period. This proportion decreases with advancing age, with slightly over one-half of the people 17-44 years old seeing a dentist, compared to about one-third of the population over 65. The percentage of the population making dental visits increases as family income rises. Among the 6-16 year age group, the percentage rises from 52 at a family income under $7,000, to 79 at a family income of $25,000 and over. Racial differences are also noted; the proportion of caucasians making dental visits was 52 percent compared to 36 percent for non-caucasians. This difference in utilization of dental services by race is striking (see Figure 1).

Between 1964 and 1979 the proportion of the population making at least one annual dental visit rose from 42 to 50 percent, with females making a higher percentage of visits than males during both years. The proportion of caucasians who made dental visits was twice as high as for all other persons in 1964, but the difference had decreased somewhat by 1979.


Percent of Persons with Visits
100
80
60
40
20
0



visits

25)

Visits by Residence and Age

Children 6-16 years of age and young people living in standard metropolitan statistical areas (SMSA) visited dentists more frequently than did children and young people living outside SMSAs. Among children 6-16 living outside SMSAs, those living in both nonfarm and farm areas visited the dentist at the same rate (see Figure 2).

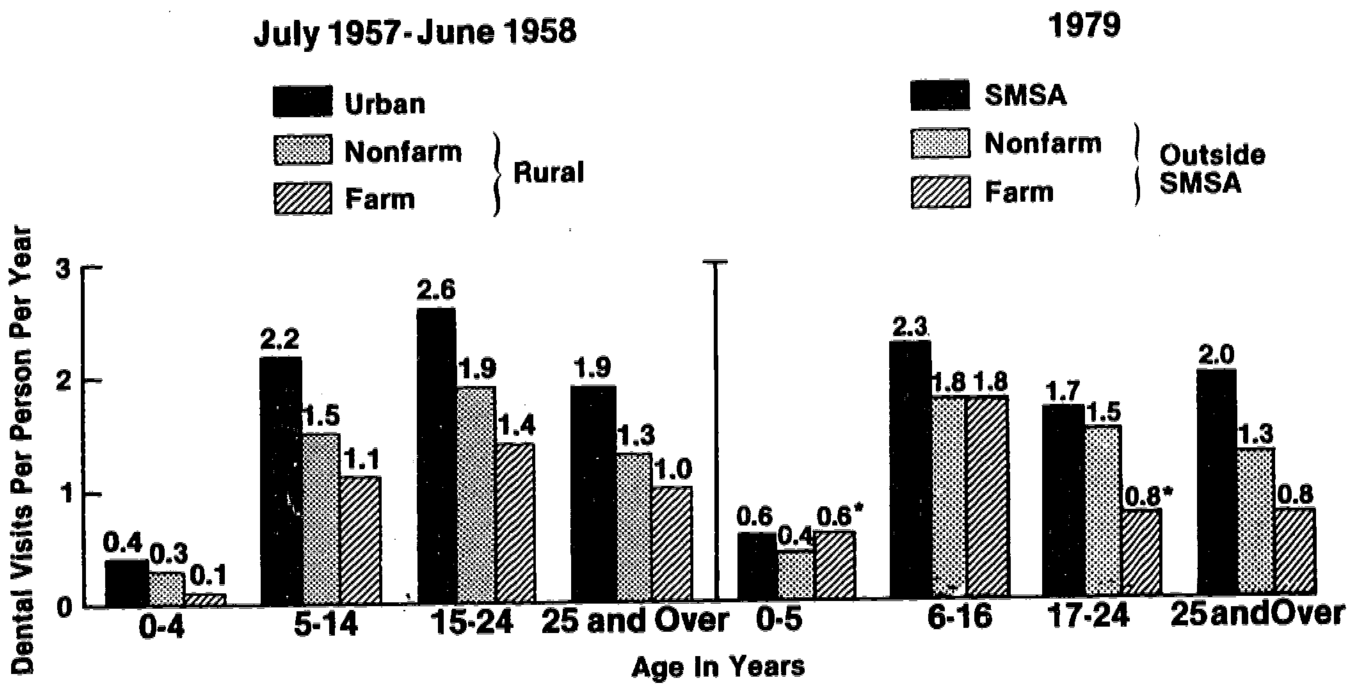


*Figure does not meet standards of reliability or precision.

Figure 2. ***Number of dental visits per person per year, by place of residence and age: July 1957-June 1958 and 1979.*** (25, 26)

Visits by Place of Residence and Geographic Region

In 1979, the average number of dental visits per person per year was 1.7 for the total population, 1.9 for those in a Standard Metropolitan Statistical Area (SMSA), and 1.3 for those living outside an SMSA. The Northeast had the highest per capita number of dental visits (2.1), followed by the West (1.8), North Central region (1.6) and South (1.4). (27)

Visits by Income and Age

Family income substantially affected the rate of dental visits. Among children 6-16 years of age, those living in families with incomes of $7,000 or more visited dentists about 40 percent more frequently during 1979 than those living in families with lower incomes. Similar differences were also found on the basis of family income as shown in Figure 3 for July 1957-June 1958 and for 1979.

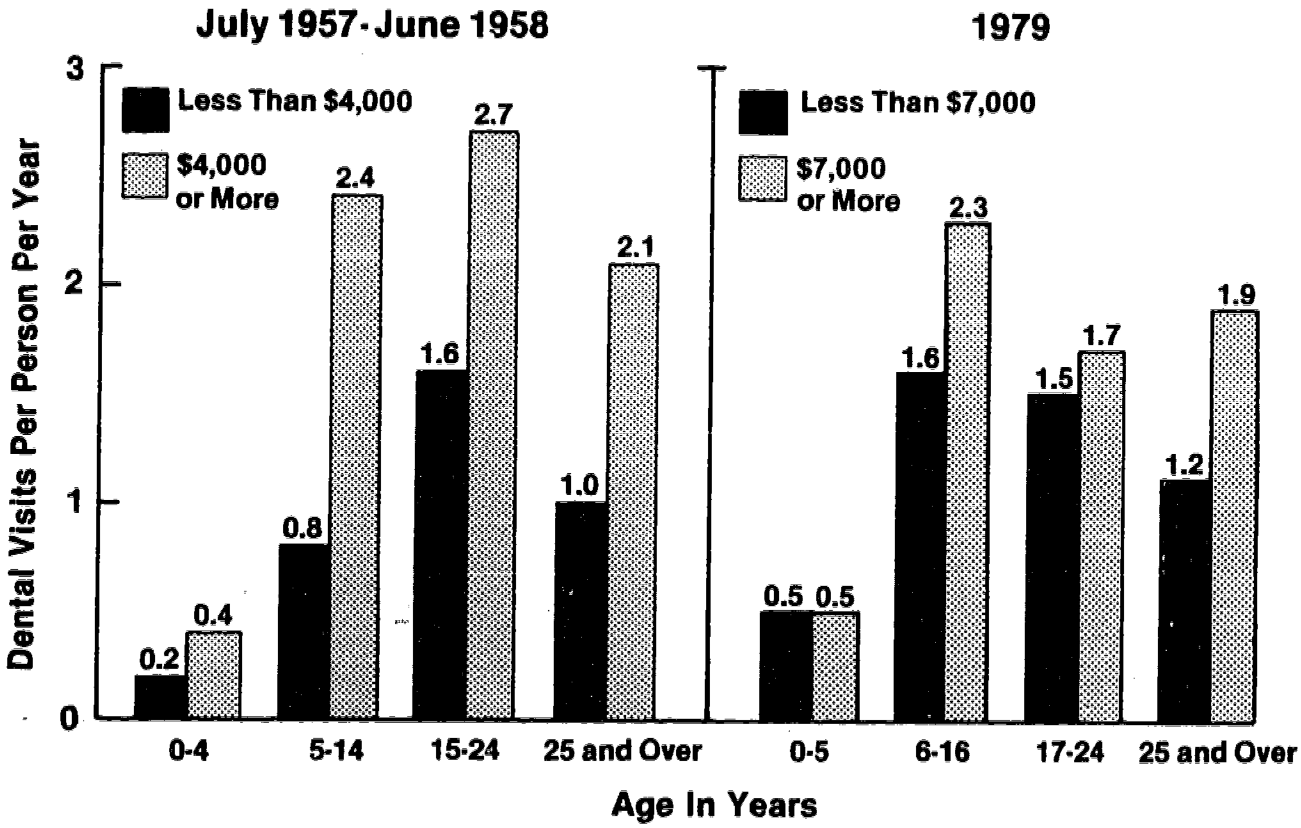


Figure 3. ***Number of dental visits per person per year, by family income and age: July 1957-June 1958 and 1979.*** (25, 26)

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EQUIPMENT

INTRODUCTION

In assessing the efficacy, safety, and cost aspects of dental radiographic practice, the influence of x-ray equipment must be considered. This chapter will therefore attempt to discuss current applications of dental x-ray equipment. In addition, newer technologies that promise to reduce x-ray exposure and/or improve the quality of radiographic images will be reviewed.

CONVENTIONAL DIAGNOSTIC X-RAY EQUIPMENT

Conventional dental x-ray machines are typically self-rectified, with both x-ray tube and transformer contained within the tube housing. Modern conventional dental units employ an open-ended position-indicating device (cone) used primarily for aiming the tube head prior to making an x-ray exposure. Many newer position-indicating devices also help reduce scatter radiation by incorporating a metal cylindrical collimator within the open-ended plastic cone. Some older dental units are still equipped with plastic pointed cones. Since they may lead to decreased image quality and increased scatter radiation, their use is strongly discouraged. Position-indicating devices, commonly 4 to 16 inches in length, are designed to insure that a minimum source-to-patient skin distance is maintained during the exposure. Conventional dental units typically operate between 45 and 100 peak kilovolts (kVp), but most examinations are performed at 60 to 75 kVp. Although machine tube currents typically range from about 5 to 15 milliamperes (mA), most modern radiographic techniques specify 10 or 15 mA. Conventional dental units are generally wall- or ceiling-mounted, but may be used as mobile units as well.

Radiographic films are of two basic types: screen and direct exposure. Direct exposure films are exposed directly to the x rays. Screen films are exposed primarily by the fluorescent light given off by intensifying screens following absorption of x rays. Radiographic films can also be classified as intraoral and extraoral, according to their placement during use. Intraoral projections usually employ direct exposure film whereas extraoral projections generally use screen film.

Intraoral dental film is a direct exposure film consisting of an emulsion spread on both sides of a relatively rigid but flexible film base. It is supplied in individual light-tight packets ready for use. These film packets may be placed in film holders and held in place by the patient during the radiographic exposure. Intraoral films are manufactured as single or double packets, the latter being used when duplicate radiographs are desired.

Extraoral films are exposed while positioned outside of the oral cavity. They are screen or (rarely) direct exposure film and are usually 5″ x 7″ or larger.

The x-ray machine market has undergone steady growth, both in the number of x-ray units assembled and in the number of manufacturers. A Bureau of Radiological Health (BRH) study in 1967 reported 9 manufacturers of dental x-ray equipment, (28) whereas BRH recorded 31 manufacturers in July, 1979. (29) In addition, Bureau data collected for the years 1975 through 1977 indicated slow growth in the number of yearly assemblies of conventional radiographic equipment. (29)

PERFORMANCE STANDARDS

History

Numerous reports of studies conducted from the late 1950s through the early 70s indicate that many dental x-ray units were operated without adequate provision for patient (or operator) safety. (30-34) For example, Miller reported that prior to 1960 approximately 75 percent of the dental units in the U.S. would not meet recommended standards. (30) In a sample of almost 34,000 medical and dental x-ray facility surveys, Fess, et al. found that in 1962, 36 percent of dental machines were inadequately collimated and 46 percent were inadequately filtered. (21) During the mid-sixties, a large percentage of dental x-ray machines did not meet the recommendations of the National Committee on Radiation Protection and Measurements (35) or of the American Academy of Oral Roentgenology. (36) Responding to the need for a national dental radiological health program, the Bureau of Radiological Health initiated a dental quality assurance program that was successful in eliminating much of the unnecessary x-ray exposure from dental x-ray units (see p. 18).

Equipment Performance Standards

In March, 1970, the National Council on Radiation Protection and Measurement (NCRP) published Report No. 35, which provided radiation protection guidance in the use of ionizing radiation in dentistry. (27) Specifically, it offered user recommendations for the dentist and safety recommendations for persons conducting radiation protection surveys. The report also provided manufacturers' standards for the design of equipment, including standards for collimation, filtration, leakage radiation, and source-to-patient distance.

The diagnostic x-ray equipment performance standard was issued by the Bureau of Radiological Health, FDA, and became effective on August 1, 1974. (38) The x-ray standard requires that all new dental x-ray equipment meet certain minimal performance requirements before being installed for use by the dentist. The standard specifies minimum filtration requirements and limits the maximum x-ray beam to no more than 7 centimeters in diameter (2.75 inches) at a source-to-skin distance of 18 cm (7.1 inches) or more. It is important to note that this standard only applies to the exposure of intraoral films, except for occlusal-size films. Minimum source-to-skin distances are also specified to reduce absorption of lower energy x rays in facial tissue. Other provisions of the standard call for "beam-on" indicators and methods to insure termination of exposures at preset time intervals. In addition, standards for exposure accuracy and reproducibility are specified.

In 1974 the American Dental Association, in cooperation with the American National Standards Institute, issued ADA Specification No. 26. These specifications closely paralleled the requirements of the diagnostic x-ray equipment performance standard and were issued as guidance to all dentists for implementation, effective August 1, 1975. (39)

NEW TECHNOLOGY

Panoramic Dental X-Ray Units

Panoramic radiography is relatively new to the dental radiologist's armamentarium. Panoramic units first became commercially available in 1959, and their use has grown over the last two decades. Panoramic units include both extraoral tomographic units (40, 41) and intraoral source units. (42) For purposes of this overview, however, the term "panoramic unit" refers to an *extraoral* tomographic unit. A discussion of intraoral source machines is presented in the next section.

During a panoramic x-ray examination, both the x-ray tube and the radiographic film move about the patient's head on two or more common centers of rotation. The resultant radiograph is a tomographic view of a curved plane through the dental arches. The anatomic structures shown include a broad view of the dental arches, the mandible, the maxilla, the nasal fossa, and each zygomatic arch. The panoramic radiograph provides a limited trough of focus in the area of the dental arches. (43, 44) Objects lying outside this trough are blurred by the tomographic process and may not be visualized. In addition, tomographic motion and the use of screen film limits available detail. Thus, these radiographs may be a useful adjunct to conventional dental films or a technique for examination of a wider area of teeth and jaws. The ADA's Council on Dental Materials and Devices (now the Council on Dental Materials, Instruments, and Equipment), has prepared a brief summary discussing the advantages and disadvantages of dental tomographic radiography. (45)

Since their introduction 20 years ago, panoramic x-ray units have steadily increased in popularity. White estimates that there are about 25,000 panoramic machines in the United States. (46) Most are located in the offices of general practitioners and many are found in those of oral surgeons and pedodontists. Generally, panoramic radiographs are used at a patient's first visit and periodically thereafter.

Several investigators have studied the amount of radiation exposure to patients during panoramic and conventional intraoral dental radiographs. (47) White and Rose have determined that the bone marrow dose from a panoramic unit is approximately 20 percent or less than that received from full mouth intraoral periapical radiography. (47) Other studies performed during the last several years indicate that the thyroid gland may receive a significant dose during panoramic procedures. Antoku suggested that panoramic procedures deliver a greater thyroid dose than intraoral radiography since the thyroid is irradiated during the entire procedure. (49) Block, Goepp, and Mason reported that large potential thyroid exposure hazards are associated with panoramic examinations. (50) Knowledge is still incomplete regarding thyroid hazards during panoramic procedures, however radiation exposure could be reduced significantly by use of smaller film sizes and by careful patient positioning.

Intraoral Source X-Ray Units

Much of the development and growth of intraoral source dental x-ray machines has occurred within the last decade. The intraoral source machine employs a miniature rod-anode x-ray tube positioned inside the mouth to expose a film mounted extraorally. X rays are emitted from a region near the end of the cylinder and radiate outward from the anode tip. The anode target is shielded except for a filtered window permitting transmission of the primary beam.

The first rod-anode unit, Westinghouse Corporation's "Panoramix," was marketed in the United States in the early 1960's and was designed to take panoramic full-mouth radiographs of the upper and lower arches with a single exposure. (52) The rod-anode source was positioned intraorally in the mid-sagittal plane (mid-line plane) and radiographs of the entire maxillary (upper) and entire mandibular (lower) arch were radiographed onto films bent in a curved plane around the patient's face.

The Panoramix failed to become a commercial success in the United States. The major factors contributing to the failure included:

- lack of patient and practitioner acceptance;
- a large and expensive generator;
- nonuniform magnification of image structures because of very short source-subject distances;
- radiological risks, since the unit could be operated without the shielding or collimator;
- large rod-anode diameter, interfering with intraoral positioning;
- inconvenience in maintaining an aseptic environment;
- use of nonscreen films, since the output of the unit could not be sufficiently reduced. Radiation dose was, thus, believed to be greater than necessary;
- strong competition from extraoral panoramic equipment;
- high doses of radiation to those tissues closest to the anode.

Recent innovations in imaging technology, however, have helped to overcome these early problems. For example, x-ray generators have been made smaller, less costly, and more flexible; better collimators and shielding have significantly improved radiation safety; recently developed high-speed film/screen combinations have been coupled with microfocus x-ray sources to substantially lower patient doses; and hygienic control has been improved to prevent intraoral-source contamination.

Practical Considerations of Intraoral Sources

In a paper entitled "Practical Considerations for the Application of Rod-Anode Sources in Dental Radiography," Schoenfeld compares intraoral source radiography with conventional periapical bitewing radiography and with curved surface tomography (extraoral panoramic units. (53) The three modalities were compared using five criteria: image quality, radiation dose, clinical convenience, economics, and compliance with Federal performance standards. Schoenfeld concluded that "the intraoral use of rod-anode sources appears to provide image quality advantages for many diagnostic tasks along with a well-documented reduction in patient radiation dose. Also, intraoral source radiography compares favorably with conventional extraoral source techniques with regard to clinical convenience and economics. Compliance with (Federal) regulations does not appear to create an inordinate barrier to the initiation of clinical studies of the concept of intraoral source."

In August 1978, Lieberman and Webber published the results of a clinical evaluation of a prototype intraoral source x-ray system consisting of a modified intraoral source machine and a Polaroid film/screen combination. (54) The researchers found that although incipient enamel lesions were identified less often than by conventional nonscreen techniques, larger lesions were reliably detected. The intraoral source technique was predicted to reduce total patient dose by as much as 98 percent and produced positive dry prints in 15 seconds, precluding the need for darkroom processing. The clinical tests confirmed that the intraoral source device offered potential advantages over existing technology for certain specific applications such as presurgical examinations and endodontic procedures. The authors concluded that most of the clinical objections encountered were largely technical and could be corrected by modifications to the prototype design.

Xeroradiography

Among the most promising new dental x-ray imaging technologies is intraoral xeroradiography. Xeroradiography is the recording of x-ray images by using xerographic copying principles. The process involves exposing a positively charged selenium plate to x rays. X rays transmitted through the patient are absorbed by the selenium plate, causing selective discharge. The amount of discharge is proportional to the amount of radiation striking the plate, therefore information in the transmitted x-ray beam is recorded as a residual charge pattern on the plate, known as the latent image. Development of the image is accomplished by the deposition of a fine, blue, negatively-charged powder, called toner, on the latent electrostatic image. The final image is prepared for viewing by transferring the toner from the selenium plate to paper by a heat fusion process.

Dental Applications

The principles and early applications of xeroradiography have been described in detail by Wolfe, (55, 56) McMaster, (57) and Rawls and Owen. (58) More recently, Lopez (59) and Hyman and Bakker (60) have described the potential uses of xeroradiography in dentistry. Both studies stated that the xeroradiographic images obtained were in some respects more detailed and of higher quality than those obtained with conventional radiographic techniques. Hyman and Bakker reported that the xeroradiograph was slightly superior to the conventional radiograph in its ability to depict carious lesions and bony radiolucencies. This advantage was more clearly demonstrated in certain applications than in others; for example, root canals and periodontal ligaments appeared particularly well-defined. Other advantages of xeroradiography include elimination of darkroom requirements, decreased development time, and ability to make cephalometric tracings directly on the xeroradiograph. In their early studies, Gratt and associates at the University of California, San Francisco, demonstrated that extraoral xeroradiographic techniques could produce high-quality images of soft tissue, bone, and teeth at radiation exposures 7 times less than for conventional intraoral-film radiography. (61) Despite these merits, the need to develop semiconducting plates small enough to be placed inside the patient's mouth remained.

In an effort to overcome this problem, researchers at Xerox Corporation developed a new xeroradiographic system designed specifically for intraoral use. (62) This system included image receptors small enough for intraoral positioning and a self-contained, portable, daylight operating processor that differed in several respects from the Xerox 125 System used for medical xeroradiograpy. (63) Gratt, White, Sickles, and Jeromin evaluated the imaging properties of the prototype unit and demonstrated its substantially superior image quality, which resulted mainly from the wide latitude and edge enhancement properties of the xeroradiographic process. (64) Radiation doses of one-third those received from conventional intraoral films were measured.

Most recently, White and Gratt conducted the first clinical trials of the newly-designed xeroradiographic processor at UCLA and UCSF, respectively. (65) During three months, twelve hundred clinical xeroradiographs were compared to the conventional radiographs of the same patients for their ability to depict both hard and soft tissues. White and Gratt reported that the dental xeroradiographic images allowed visualization of oral tissues with greater clarity and more detail. They found that small structures differing in density from surrounding structures, e.g., the periodontal ligament, pulp canals near the root apex, and thin plates of trabecular bone tended to be more easily seen on the xeroradiographs because of the edge enhancement properties of the xeroradiographic process. Carious lesions could be seen equally well on the xeroradiographs as on conventional images, and in patients being treated for periodontal disease, the alveolar bone could be seen better on xeroradiographs. The University of California researchers also found that, with the xeroradiographic process, exposure times could be reduced by one-half to one-third compared to conventional "D" speed film. Lastly, they found that their image receptors could be comfortably and conveniently used intraorally.

Thus, many of the technical problems associated with dental xeroradiography appear to have been minimized or eliminated. A remaining problem is that of a higher incidence of artifacts than with conventional radiography. Although White and Gratt call for additional controlled evaluation, particularly comparisons of the incidence of disease detection by xeroradiography and conventional radiography, they are optimistic that xeroradiography will play an important role in the future of dental radiology.

Field-Emission Units

Field emission x-ray tubes most differ from conventional x-ray tubes in their mode of electron production. In conventional units, electrons are produced by heating a cathode (thermionic emission); in field emission tubes the electrons are drawn off the cathode by high-potential electric fields. Field emission x-ray units can produce very short pulses of x-ray energy, thereby essentially stopping all patient motion. In addition, slight movement of film and/or tube/head can be tolerated without loss of radiographic quality.

Manson-Hing evaluated the Fexitron 845 portable field emission unit and found its short pulse, small size, and battery-operated capability offered distinct advantages over conventional machines for portable use. (66) However, he determined that the x-ray source size was large and the pulse rate slow relative to conventional dental x-ray machines, thus precluding sharp images at short exposure times. Current-day image recording devices are considerably more sensitive, however, and may offer a solution to the problem of poor image quality.

The Low Intensity X-Ray Imaging Scope (Lixiscope)

The lixiscope is a fully portable, compact x-ray imaging system. It consists of three basic components: a photon-emitting radiation source; a photocathode or scintillator screen which converts the photon image into a visible light image; and a microchannel plate, image intensifier tube. This hand-held device produces real-time fluoroscopic images that can be viewed directly, photographed, or coupled to other imaging devices.

The lixiscope has generated much interest since its development was first reported by Dr. Lo I. Yin of the Goddard Space Flight Center in November, 1977. Because of its small size and portability, many potential medical, dental, and industrial applications have been suggested. (67) To date, however, because of various design characteristics, only a prototype device has been built. Several researchers have tested the lixiscope on a limited scale, but no formal, large-scale clinical evaluations have yet been performed. (68)

Dental Applications

Dental investigations of the lixiscope are directed by Dr. Webber of the National Institute of Dental Research, NIH. There, researchers have replaced the x-ray generating source with a 50 millicurie source of iodine-125. In this configuration, the complete lixiscope fluoroscopic system is lightweight, rugged, and fully portable. The ^{125}I source is housed in a lead capsule 3-mm thick, which in turn is contained in a stainless steel housing lined with a lead wall 3-mm thick. Photons are directed toward the detector by means of a spring-loaded push button "trigger." Depressing the "trigger" rotates the source capsule until it is aligned with a hole in the housing, producing a collimated x-ray beam that illuminates the detector screen.

The lixiscope permits the dentist to irradiate small volumes of tissue. Unnecessary radiation outside of the image receptor is eliminated. necessary radiation outside of the image receptor is eliminated.

Although a number of potential dental applications employing the lixiscope have been identified, several remaining limitations severely reduce the device's usefulness:

- The 28 keV average energy gamma emission of the iodine-125 source has insufficient energy to penetrate thicker dental structures (other higher energy radionuclide sources are unsuitable because of unacceptable half-lives or secondary emission problems);
- Geometric conditions such as small source-object distances relative to object-receptor distances cause image unsharpness and magnification problems which seriously degrade lixiscope images;
- The user must obtain a Nuclear Regulatory Commission (NRC) or agreement State license to possess radioactive material. He must also comply with all safety procedures for leakage testing and radioactive source disposal;
- Replacement of the ^{125}I radioactive source every 3 to 4 months is costly.

Because of these limitations, use of a portable fluoroscopic device does not appear to be a viable alternative for use in general dentistry. However, technical modifications such as intraoral source imaging and improvements in image receptor storage capabilities are being investigated. (69) Such devices offer special promise for applications in dental research, and possibly for endodontic root-canal procedures.

Another promising technology is digital image processing. Image enhancement techniques may eventually result in significant gains in resolution. (69).

ANCILLARY EQUIPMENT

Modern film-screen combinations and collimators designed to attenuate all but the useful portion of the x-ray beam can greatly reduce patient radiation exposure. The use of rectangular collimation in intraoral radiography significantly decreases the exposed area and thus patient dose. Rectangular collimation has been available for about 10 years in the form of a metal shield sold by Precision X-Ray Company. (70) More recently, rectangular position indicating devices have become available from the Rinn Corporation. (71) In an April, 1979, study of absorbed bone marrow dose in various dental techniques, White and Rose demonstrated that the use of rectangular collimation reduced the bone marrow absorbed dose from an intraoral series by 60 percent. (47) Much of this exposure reduction derived from dos. vings in the anterior region of the mandible. Thus, the use of rectangular collimation is a radiation dose reduction technique particularly well-suited for periapical radiography.

The choice of appropriate film and screen speed can reduce patient radiation exposure during extraoral radiography. The film or screen speed refers to the relative amount of exposure needed to produce a given degree of density. Thus, a "fast" speed screen requires less exposure than a "medium" speed screen. In general, the use of a "slow" speed screen results in somewhat improved image quality at the expense of patient radiation exposure.

White and Rose compared bone marrow doses from three extraoral panoramic techniques to those from intraoral techniques and found that the former gave a dose of approximately one-fifth or less than the latter during periapical radiography. (47) While the presence of intensifying screens in panoramic units permits the use of lower doses, Reiskin et al. suggest that the use of rare earth intensifying screens could reduce doses still further. (72)

AN ALTERNATIVE MODALITY

The fiber optic transilluminator, a technology involving the use of a nonionizing radiation source, is worthy of mention at this point. This device produces a pencil-thin beam of light that shines through the teeth and highlights decay, fractures, calculus, and other tooth damage without exposing patients to ionizing radiation.

The advantage of transillumination is that some oral areas such as proximal tooth contacts can be examined without x rays. However, transillumination does not provide a lasting record for study, although development of a recording system, probably electronic, should be possible.

Marketed in 1976, the fiber optic transilluminator is used in about 5 percent of dental offices. The device could serve a useful adjunctive service by identifying areas to which x-ray examination can be limited.

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DENTAL RADIOLOGY QUALITY ASSURANCE

INTRODUCTION

The meaning of the term "quality assurance" has rapidly evolved as scientists and clinicians have come to appreciate the importance of reproducible, reliable systems to generate radiological images. Quality assurance can improve the overall radiographic process and thus reduce both costs and patient radiation exposure. The Bureau of Radiological Health began developing methods of quality assurance for medical radiology facilities in 1974. In 1979, the Bureau published recommendations for quality assurance programs in diagnostic radiology facilities in the *Federal Register.* (73) These general recommendations pertain to both dental and medical diagnostic facilities.

The term "dental radiology quality assurance" as used here means any systematic action to ensure that a dental office will produce consistently high quality images with minimal exposure to patients and personnel. A complete quality assurance program includes not only administrative procedures, but also quality control techniques to monitor the components of an x-ray system. That system includes, at a minimum, the high voltage generator, the x-ray control, the tube-housing assembly, the beam-limiting device, and the necessary supporting structures. Accompanying components,such as image receptors, image processors, view boxes, and darkrooms are also considered parts of the system.

The status of quality assurance in dental radiology can be summarized briefly by reviewing past and present programs and by describing prospective efforts.

DENTAL SURPAK PROGRAM

The Dental Surpak Program was an early venture (1961-1965) in quality assurance initiated by the U.S. Public Health Service. The term Surpak is derived from the two words SURvey and PAcKet. The packet was a light-tight envelope containing a sheet of Kodak Industrial X-Ray Film backed with a sheet of lead. A 2 mm Al filter and a 0.5 mm Cu filter were centered on the front side of the film. The outside of the envelope listed general instructions for the dentist. The following parameters could be estimated from a properly exposed Surpak: beam size at cone tip, exposure, total filtration, beam symmetry, and leakage radiation in the direction of a patient's face. The Surpak program was designed and carried out by the Division of Radiological Health, the forerunner of the Bureau of Radiological Health. Surpaks were supplied to State health agencies, which were then responsible for their distribution and use. This program aided in screening large numbers of radiographic installations for gross defects such as improper collimation and filtration. After identifying machines lacking sufficient filtration and collimation, the State health department would send the dentist corrective devices such as aluminum disks and lead washers to bring the machine into compliance with established standards.

The following numbers indicate the success of this early program: In 1960, 45.2 percent of the machines surveyed had a beam diameter of 3.00 inches or less. By 1963, the figure had increased to 63.6 percent. At that time, the recommended standard of the Public Health Service stated that the beam diameter should be 2.75 inches at cone tip (regardless of length) and should not exceed 3 inches. (30) Similar improvements were seen for filtration. In 1960, 42.2 percent of the machines surveyed had total filtration of 1.5 mm Al equiv. or greater. In 1963, the proportion had increased to 60.2 percent. The recommendation at the time was 1.5 mm of Al equiv. for equipment capable of operating up to and including 70 kVp, and 2.5 mm total for equipment operating above 70 kVp. (30)

Most machines produced in the 1930s and 1940s without proper collimation or filtration had been identified and corrected by the mid-1960s, and the Dental Surpak Program was terminated. Beginning in the mid-1950s, new dental x-ray machines were sold with at least 1.5 mm Al equivalent filtration and a beam size not greater than 3.0 inches in diameter at cone tip.

The X-Ray Exposure Studies (XES) of 1964 and 1970 documented the continuing improvement in collimation. (17) Table 9 below shows the percentage distribution of dental films by beam diameter as estimated from these studies.

Table 9. Estimated Percent Distribution of Dental Films by Beam Diameter (17)

[illegible]

Today, the maximum beam diameter at cone tip recommended by the National Council on Radiation Protection and Measurements (NCRP) is 3 inches, (37) and that recommended by the American Dental Association is 2.75 inches when the source-to-skin distance is greater than 7 inches. (74)

In 1970, all dental machines surveyed that operated below 50 kVp had at least 0.5 mm Al equiv. filtration, 87.8 percent of those that operated between 50 and 70 kVp had at least 1.5 mm Al equiv. filtration, and 70.7 percent of those that operated above 70 kVp had at least 2.5 mm Al equiv. (75)

The 1960 and 1963 values for filtration and collimation were based on an analysis of dental x-ray equipment, whereas the values for 1964 and 1970 were derived from population-based studies (XES). Nevertheless, the figures indicate a continuing upward trend in the proportion of dental x-ray machines operating within recommended parameters.

A reduction in patient radiation exposure paralleled this improvement in collimation and filtration. The mean exposure at skin entrance per film for the dental bitewing examination was 1249 mR in 1964 and 910 mR in 1970. (8, 76) It must be remembered, however, that these were average values. Later studies such as the Nationwide Evaluation of X-Ray Trends (NEXT) showed wide latitude in the amount of radiation used.

NATIONWIDE EVALUATION OF X-RAY TRENDS

In the Nationwide Evaluation of X-Ray Trends (NEXT), a current program coordinated nationally by the Bureau of Radiological Health, State radiation control agencies measure x-ray output using a standardized field survey technique. This allows determination of radiation exposure to the patient from standard dental examinations. NEXT first began collecting data in 1972. Some statistical parameters for NEXT data collected during 1978 for the posterior dental bitewing film are shown in Table 10. (77)

The wide range shown in Table 10 indicates that the amount of radiation received by patients during this examination varied from facility to facility. NEXT is an on-going program that continues to collect data useful to professionals in the field of radiological health; however, the survey protocol was not designed to determine the causes of overexposure.

Table 10. Statistical Parameters Based on 1374 Posterior Dental Bitewing Surveys Performed During January 1, 1978 to December 31, 1978 (77)

	Exposure at Skin Entrance (mR)
[illegible]	47
[illegible]	187
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	325

NASHVILLE DENTAL PROJECT

The Nashville Dental Project was conducted by the Bureau of Radiological Health during 1972 and 1973 in Nashville, Tennessee. (78) The objectives of the Project that relate to quality assurance were:

1. to provide additional data detailing causes of unnecessary exposure in the everyday practice of dental radiology;
2. to determine what changes could and should be made in the practice of dental radiology to eliminate unnecessary exposure and maximize information derived from radiographic procedures.

The project consisted of three phases. During the first, a team visited each participating dental office to make a radiographic survey and obtain related information. During the second, each dental office was visited by a consulting team, which recommended changes to improve radiographic practice. The third phase was a replication of the first.

The study showed that 28 percent of the facilities surveyed before the educational phase sight-developed their films. The average skin exposure at those facilities was calculated to be 720 mR/film. The average exposure for films processed by the established time-temperature basis was 404 mR/film. Inadequate darkroom facilities were frequently encountered.

When the facilities were surveyed one year later, after the educational phase, the percentage that were sight-developing had dropped to 18 percent and the average exposure for properly processed films had decreased to 325 mR/film.

The initial survey also indicated that timers were inaccurate in half of the x-ray machines and showed poor reproducibility in one-fourth. Accuracy of timers changed little from 1972 to 1973 because the consultants concentrated more on establishing a correct timer setting for the exposure factors than on correcting timer inaccuracies.

It can be said that the sources of overexposure related to equipment now are more subtle than filtration and collimation. As indicated above, one equipment-related problem is the timer. The faster or more sensitive dental films require shorter exposure times, usually of the order of a fraction of a second, at which timer accuracy becomes more critical. Likewise, timer unreliability can necessitate repeat radiographs, thus causing needless exposure to the patient. The Nashville Dental Project found significant problems with the accuracy of both mechanical and electrical timers, and with reliability of the former.

The Nashville project revealed other areas not directly related to x-ray equipment which can lead to unnecessary radiation exposure to the patient. One such area is film processing procedure. Five minutes are required to fully develop a film at the recommended temperature for most conventional developer solutions (68 degrees F). Then, following development, films must be fixed for 10 minutes and washed for 20 minutes. Some operators save darkroom time by overexposing and then underdeveloping the film. This procedure subjects the patient to unnecessary radiation. However, the use of rapid processing solutions or automatic processors may reduce the total processing time considerably.

A study by Pennsylvania Blue Shield pointed to similar problems in processing. In that study, 1,000 preauthorization radiographs submitted to the Pennsylvania Blue Shield were evaluated by a simplified quality rating system developed specifically for the study. Twenty percent of the films were judged unsatisfactory because of poor density or improper processing. (79)

Automatic film processors, which are receiving greater acceptance, present their own set of problems. A processor that is not properly cleaned, or that does not contain the proper quantity of fresh chemicals, will produce poor quality radiographs. (80, 81)

The Nashville Dental Project was designed to test the feasibility of using an educational approach for voluntary improvement of dental radiographic practices. Based upon the success of that project, the Bureau of Radiological Health promoted adoption of a similar methodology, known as the Dental Exposure Normalization Technique or DENT program, for use by health agencies nationwide.

DENTAL EXPOSURE NORMALIZATION TECHNIQUE (DENT)

The Dental Exposure Normalization Technique (DENT) program was developed to identify dental x-ray facilities where patient exposure is outside an accepted range. (82) The DENT program consists of three phases. In the first phase, the State health agency mails dosimeter cards to all dental x-ray facilities within the State. Dentists then expose the cards and return them for analysis. In the second phase, facilities showing excessive exposures are visited to determine the cause of the high exposure and to recommend correct procedures. Phase III is directed at identifying and surveying any new dental x-ray machines, as well as resurveying those contacted in Phase. I.

Data from the first phase of the DENT program showed that about 40 percent of the dental x-ray units surveyed used exposures in excess of the recommended ranges. Much of this overexposure was caused by poor darkroom practice, inadequate equipment or conditions, or depleted processing chemicals. In many cases the film was overexposed in order to compensate for deficiencies in processing or darkroom design. After a subsequent visit by a trained surveyor (Phase II), the exposure was reduced by an average of 200 mR/film. (83) The quality of the dental radiographs did not decrease and in many cases improved.

PRESENT STATUS OF QUALITY ASSURANCE IN DENTAL RADIOLOGY

The state of quality assurance in dental radiology presently appears to lag behind that of medical radiology. Most of the current dental quality assurance programs are in dental schools. The DENT program is the one widely available quality assurance program, and has been quite successful as a public health program conducted by health departments on a Statewide basis. At present, however, no office-based comprehensive quality assurance "package" is available to dentists.

In order to encourage the development of office-based quality assurance programs, the Bureau of Radiological Health issued a Request for Applications (RFA) on March 16, 1979, (84) the object of which was to fund grant research for the development of a simple and effective system to be used in a dental office by dentists and/or dental auxiliaries to identify exposure and processing problems. It was requested that the system be as inexpensive as possible, with the cost not to exceed $200.

At present, the literature contains little information regarding dental radiology quality assurance programs. Dr. Manson-Hing recently has published a book, *Fundamentals of Dental Radiography,* that contains a chapter entitled "Quality Control in the Dental Office." (85) This chapter presents simple and inexpensive tests that can be performed in the dental office to identify some problems in dental radiology. Information is given on how to check solution strength, darkroom integrity and safelight conditions, timer accuracy, machine output, collimation and beam alignment, and focal spot size. Moreover, several papers given at the Annual Session of the American Dental Association, October 21-25, 1979, discussed radiographic quality assurance in dentistry. (86)

The *Diagnostic Radiology Quality Assurance Catalog* published by the Bureau of Radiological Health lists publications, such as that on the Nashville Dental Project, that pertain to quality assurance. (87) Most of the material in the catalog relates to medical radiology, but some of the references address dental radiology.

The "Recommendations for Diagnostic Radiology Facilities Qulity Assurance Programs," promulgated by the Bureau of Radiological Health, appeared in the *Federal Register* on December 11, 1979. This recommendation, which applies to both medical and dental radiology facilities, contains guidelines for specifying responsibility for the program, purchase specifications, parameters to monitor, standards for image quality, and aspects of program administration. This recommendation, and increased concern about the effects of repeated exposure to low doses of ionizing radiation, will no doubt increase the demand for quality assurance programs in dental radiology.

INTRODUCTION

Any attempt to describe the role of radiography in dentistry must address efficacy. Efficacy can be defined in several ways. One is simply "the potential of a given type of examination to provide information useful to the practitioner in the care of the patient." A more specific definition would require the inclusion of such concepts as benefit and risk. A consideration of patterns of x-ray utilization makes possible the construction of a general profile of dental radiographic practice. The major question to be addressed in connection with the patterns of utilization is whether or not x-ray examinations are used in an optimal fashion and only when necessary. A precise definition of such use may be difficult to formulate but would have to include such factors as diagnostic yield and patient management. Regardless of these conceptual problems, concern regarding possible overutilization of dental x rays has been expressed. (16, 88)

Some of the reasons often cited for the performance of unnecessary examinations relate directly to efficacy. Testimony presented on behalf of the American Dental Association before the Subcommittee on Health and the Environment of the Committee on Interstate and Foreign Commerce, pointed out that "some dental settings, schools, clinics, and practitioners still routinely conduct x-ray examinations on all new patients regardless of indicated need." (16) This practice persists despite the ADA's official recommendation that x-ray examinations be conducted only when there is an indicated need for each patient. (74) Another dentist at the same hearings alleged that, "Overexposure and overutilization occur because of inadequate education and the lack of meaningful guidelines or controls." (88) Other potential causes of overutilization might include the monetary incentive of self referral, third party payments, post-treatment radiographs, non-uniform criteria for taking dental x rays, and excess reliance on new technologies (e.g., panoramic units). For example, it was recently observed that from 1969 to 1977, the number of Americans with dental insurance as an employment benefit increased from 7 million to 48 million. (19) The same report stated that national expenditures for dental care went from $4.4 billion to $10 billion from 1970 to 1977. According to this source, x-ray examinations in the population sampled accounted for 7.3 percent of total charges and were received at least once in the course of a year by 82 percent of all patients presenting for services. Thus, it appears likely that third-party payment influences the utilization of dental services.

To analyze the impact of these elements on dental radiology, this chapter will attempt to delineate the extent to which dental x rays are used, look at trends in examination rates and consequences of dental radiation exposure, and survey the literature pertaining to the efficacy of various procedures.

EXAMINATION FREQUENCY AND TRENDS

The 1970 X-Ray Exposure Study has provided the basis for most of the estimates of examination rates found in the literature. (17) It was stated during the previously mentioned Congressional Hearings that 59.2 million persons received dental x rays in 1970. (88) Moreover, at that time 67 percent of all dental visits included x-ray exposure. In 1978, by contrast, 82 percent of all patients received one or more radiographs. (19)

As part of an Environmental Assessment Report supporting the performance standard for diagnostic x-ray systems and their major components, the Bureau of Radiological Health developed the following data relating to the frequency of specific types of dental x-ray procedures in 1970: (89)

Table 11. Estimated Relative Frequency of Various Dental Radiographic Examinations, 1970*

Examination type	*Number of exams (millions)*	*Number of films (millions)*
1. bitewing	27.2	67.5
2. bitewing and periapical	8.9	48.4
3. full mouth series	7.4	109.7
4. periapical	19.9	41.7
5. other (panoramic, cephalometric, etc.)	4.4	11.9
6. total	67.8	279.2

*Unpublished data obtained from 1970 XES study. (17)

Because some individuals received multiple examinations, the total number of exams (67.8 million) exceeds the number of persons receiving x-rays. The number of films exposed increased 23 percent, from 227 million to 279 million, during the interval 1964 to 1970. (17) Meanwhile, the U.S. population increased by 8 percent. This figure corresponds to 4.9 films per patient, or approximately 1.3 films per member of the total population. (90, 91) Like other radiographic examination rates, the dental exam rate exhibits an age correlation. (92) A peak is reached in the 15 to 24 year age group, and then a sharp decline commences.

A survey of 72 private dental offices established an average workload of 80 films per week per office. (93) Those offices producing the most films appeared to yield the lowest radiation exposures.

Number of Films per Examination

Considerable variability exists in the number of films employed per examination by different dental practitioners. Consequently, the number of exams alone does not adequately reflect either radiation exposure or cost incurred for a specific procedure. Some estimate of total films exposed is therefore necessary. Such information also provides insight into the range of attitudes within the dental profession regarding the diagnostic value and utility of x rays.

The American Dental Association, through its Council on Dental Materials and Devices (now known as the Council on Dental Materials, Instruments and Equipment), recommends that a minimum number of exposures be made. (74) More professional judgment should be applied in each case, so that exposure is confined to instances in which there is a reasonable expectation of gaining information useful to diagnosis or treatment. The general injunction to limit exposure can be found throughout the literature on this topic. However, at least one researcher has cautioned against "overzealousness while striving to achieve maximum radiographic efficiency." (43) This dentist contended that if all films taken produced positive findings, not enough radiographs were being made.

Data on this aspect of dental radiography illustrate the prevailing diversity of practice and instruction. One survey of private offices showed an average number of films per full mouth series to be 15, with a range of 12 to 21. (93) Interproximal examinations were done with two films in nearly 75 percent of these offices. Unpublished XES data show little variation in the number of films per full mouth examination on a regional basis. (17)

It is probably more instructive to look at what is being taught in dental schools, because this will affect future use patterns. In a 1968 study eliciting responses from 42 dental schools queried about the number of films used in intraoral surveys of average adult patients, (94) the figure varied from 14 to 32 films (periapicals plus bitewings).

Guidance given to students in dental radiology texts is frequently inconsistent with the professed position of the American Dental Association. For example, a text of recent vintage states that no less than 14 films should be used for a complete periapical exam. (95) An older text asserts that, "No examination should be considered complete without a full series of roentgenograms." (96)

EXAMINATION COSTS AND TRENDS

The inflationary pressures operating elsewhere in the economy have been experienced in the delivery of dental care as well. The expansion of dental insurance has also contributed to an escalation of costs. A 1979 publication provided data leading to an estimate for annual expen-ditures for dental radiography of $730 million. (19) Testimony given at the July, 1978, Congressional hearings assigned a cost of $22.11 for a complete full mouth series. (88) This estimate, based on the ADA's latest review of dental fees, was tied to an opinion that the overall cost of conducting an x-ray exam would be under $10.00, although this figure probably did not take into account the dentists' professional fee component for radiographic interpretation.

RADIATION EXPOSURES, DOSES, AND RISKS

Another cost associated with the use of x rays in dentistry is the potentially detrimental effects of radiation exposure. Growing public awareness and concern can be seen in all matters involving radiation. As a result, an inquisitive public is forcing the scientific, medical, and dental communities to carefully scrutinize the use of x rays in diagnosis, and to search for ways to optimize that use. Moreover, efforts to define more accurately the risks and benefits of diagnostic x rays are continuing.

Although an extensive body of literature on radiation biology has accumulated, this discussion will be restricted to a consideration of doses and their implications in dental radiology. Numerous researchers have made exposure and dose measurements and various risk assessments have been derived from them. For the most part, the latter have their origin in the 1972 *Biological Effects of Ionizing Radiation Report* of the National Academy of Sciences. (97) A brief summary of the status of this knowledge as it relates to dental radiology follows; data typifying radiation exposures and doses encountered in dentistry will be presented, and the concept of risk from dental x-rays will be explored.

Although several factors combine to yield specific exposure and dose levels unique to each examination, some illustrative values can be reported. A Japanese study reported ranges of doses from the full-mouth x-ray examination to be 12-17 rads to the skin, 260-1800 mrads to the lens of the eye, and 340 to 2500 mrads to the thyroid. (49) A patient exposure study performed at the Baltimore Public Health Service Hospital, however, determined that the maximum exposure at any location during a 14-film full-mouth survey was 827 mR. (90) Exit exposure was found to be one to two percent of entrance exposure.

The Bureau of Radiological Health has calculated mean skin exposure and active bone marrow doses per film for various types of examinations. (92) For anterior teeth projections, the figures are 1110 mR and 2.9 mrads respectively; for posterior teeth they are 1170 mR and 0.8 mrads. These low bone marrow doses mean that despite the high rate of utilization, dental exams contribute only about 3 percent of the total adult per capita mean active bone marrow dose. Moreover, both skin exposure and mean active bone marrow dose in dental exams decreased significantly from 1964 to 1970. Presumably, this decline can be attributed to increased use of faster speed films.

Educational efforts can also be effective in reducing exposures. In a study of 72 private offices, machine output for interproximal films decreased from an average of 542 mR in 1972 to 340 mR in 1973, following visits and consultation with radiological health representatives. (93) Furthermore, others have noted that the mean exposure per film at skin surface is a function of the year of the dentist's graduation from dental school. Mean exposure was 1,230 mR for 1940-1949, 850 mR for 1950-1959, 650 mR for 1960-1964, and 560 mR for 1965-1970 graduates. (91) Overall, a 20 percent decrease in mean exposure per film at skin surface from 1,140 mR to 910 mR, for all types of exams took place between 1964 to 1970. (17)

One of the numerous variables affecting exposure, and ultimately dose, is the particular technique employed. The survey of private offices cited earlier showed that the mean exposure per film was 595 mR for the bisecting-angle technique as opposed to 359 mR for the right-angle technique. (93) This lower dose may occur in part because dentists using the paraalleling technique are likely to be younger, and to use better processing methods and newer equipment. Similar differences were noted when various types of panoramic units were compared. (51) For panoramic machines produced by three separate manufacturers, exposure to the thyroid ranged from 5 to 13 mR, and exposure at the base of the tongue ranged from 50 to 272 mR.

Although radiation exposure of several other organs (thyroid, salivary glands, eye, skin, gonads) also are of concern during dental x-ray procedures, the bone marrow is often regarded as the major critical organ. For this reason the principal risk from dental radiography is believed to be the potential for induction of leukemia. (91) One researcher has shown that panoramic techniques result in a bone marrow dose approximately a fifth or less of that delivered by conventional periapical radiography. (97) Lateral cephalometric projections gave bone marrow doses equivalent to those arising from panoramic exams. In the same study, it was found that the bone marrow dose to the head and neck was greater from a set of full-mouth films than from extraoral radiography.

The estimated average equivalent whole-body per-person exposure to the U.S. population from dental radiography approximates 7 mR per year. (91) It was projected that this exposure could lead, at most, to an additional 8 to 11 leukemia deaths per year in the U.S. population. Gregg concluded that the risk of developing any type of cancer within 25 years of irradiation as a result of a full-mouth exam of 21 films is 3 in 1 million or 0.0003 percent per exam. (98)

ROUTINE X RAYS

The so-called routine use of x rays is attracting increasing attention. In this context, routine means the automatic use of x rays without prior consideration of the patient's history or clinical signs and symptoms. The degree to which practitioners routinely incorporate x rays into management schemes for their patients raises the question of possible overutilization. It is important, therefore, to describe the extent of routine x-ray use and to consider the yields that are expected.

The American Association of Dental Schools' position is quite clear:

> "Patients should not be subjected to mass radiographic screening examinations prior to initial clinical examination to determine the need and desirability of specific radiographs to aid in evaluating their acceptability as clinic patients.
>
> "Students should be taught to assess critically the need for diagnostic radiographic information and to evaluate the risk to the patient before ordering the radiographs needed to diagnose the patient's oral health needs." (99)

Furthermore, the Radiation Protection Subcommittee of the American Academy of Dental Radiology has stated that, "The patient shall not be exposed unnecessarily. There must be a good and valid reason for each exposure." (36) Finally, recommendations entitled "Radiation Protection Guidance to Federal Agencies for Diagnostic X Rays" and given to Federal health care facilities contain a clause that dental radiographs be taken only after a dentist has seen the patient and established the need for x rays; a full-mouth or bitewing series is not justified as part of periodic preventive dental care. (100)

Nevertheless, evidence exists that the principles embodied in this guidance are not universally accepted. In her book *X rays: More Harm Than Good?*, Priscilla Laws relates the experience of dental patients who encountered problems as a result of questioning the need for periodic routine x rays. (101) Testimony given by the ADA at the Congressional hearings acknowledged that, "Some dental settings, schools, clinics, and practitioners still routinely conduct x-ray examinations on all new patients regardless of indicated need." (7) It was also alleged at those hearings that a "high number" of dental school clinics routinely give full-mouth x rays, albeit largely because many of the patients are of low income and have not had recent dental examinations.

A telephone survey conducted in the Boston area elicited some specific information on the routine use of x rays in initial visits. (102) Ninety-five percent of the 40 offices sampled reported that x rays were routinely performed as part of initial exams of new patients. Forty-seven and one-half percent of the offices said that full-mouth series are routinely included in the initial exam. Only one office reported that the decision to employ x rays was determined by the dentist following his clinical exam. On the other hand, the Nashville Study indicated that only ten percent of the offices surveyed reported a policy of doing full-mouth series on all new patients. (78)

Another survey sought to learn what dental schools recommended the intervals between x-ray examinations should be. (94) The researchers found that the predominant time span recommended between full-mouth examinations was 1 year, although one school said that a 5-year interval was recommended. Some, however, answered that they taught no definite routine and determined the need for x-ray examination according to the individual patient's status and progress. The situation was analogous for both bitewing and interproximal radiographs.

Older textbooks tend to perpetuate advice conflicting with the ideals expressed by the ADA. One states simply that, "No examination should be considered complete without a full series of roentgenograms." (96) A second adds that, "Routine intraoral periapical and bitewing roentgenograms should be available when the patient is examined." (103)

The professional literature contains other differences of opinion. On the basis of reviewing a set of patients in seemingly good health in whom clinical exams revealed no abnormal conditions but x rays uncovered problems, one author recently argued that a complete x-ray examination should be done during a patient's initial visit. (104) It is true that "scouting" types of x-ray examinations do yield unanticipated findings, however, more critical review of so-called surprise x-ray discoveries may reveal inattention to the physical or historical aspects of a patient's examination. For example, the x-ray discovery of an impacted third molar should not be a surprise, since physical examination should have demonstrated the tooth's absence and the patient's history should have indicated that the tooth had not been removed.

REFERRAL CRITERIA

A possible way to ensure more informed use of radiographs is the development of criteria that practitioners can use in deciding the appropriateness of certain radiographs. Although rigid guidelines can not and should not substitute for professional judgment, referral criteria can refine that judgment and foster a more efficacious use of radiographs in dentistry.

Inspection of the available literature discloses that such referral criteria have not been broadly developed. The foundation for such criteria may be discerned in studies that focus on either the utility of a technique or the extent to which it is utilized by the dental profession. For example, the Bureau of Radiological Health is currently funding a grant supporting the development of referral criteria for panoramic radiography.

When asked to indicate their preference in the use of common radiographic projections, 66 out of 72 U.S. and Canadian dental schools responded. (105) Ninety-five and one-half percent of the respondents identified the bitewing as one of the more frequently ordered exams, and 80.3 percent said the same of the full-mouth exam. Seventy-seven and one-third percent of these institutions reported using a combination of bitewings and full-mouth periapicals. The full-mouth series was viewed as not essential by 20 percent of these schools.

Several authors have compared the detection of lesions by intraoral and by panoramic radiography. One study observed that panoramic radiographs allowed the detection of lesions not seen in intraoral exams in 5.3 percent of the cases analyzed. (106) Only a very small fraction of these lesions required treatment, however. In this instance, the utility of panoramic radiography appeared quite limited. Others have contended that the panoramic film either is ineffective in early detection of lesions, or should be used only in special cases, as an adjunct to intraoral examinations. (107, 108)

Extraoral radiographic techniques have been deemed an essential tool in general dentistry. (109) Because the periapical film does not always visualize an entire lesion, panoramic or other extraoral projections occasionally are needed. Recommendations have been made relative to the intervals at which radiographs should be taken for the long term management of cleft palate deformities. (110 Radiographic procedures for such patients include cephalometric, panoramic, and fluoroscopic exams. The recommended intervals between exams correlate with stages of dentition.

Radiographs unquestionably contribute information beyond the clinical exam alone, but disagreement persists as to how much additional benefit accrues. A study of 10-/and 11-year old children concluded that 66 percent of interproximal caries would have been missed had radiographic bitewings been omitted from their exams. (111) On the other hand, when radiologic and clinical findings in assessing caries prevalence in children were compared in another study, reasonable agreement was noted. (112) Moreover, even with standardized exposure techniques, different tilting of the teeth in the maxilla and mandible and rotations could produce error in the radiographic detection of caries. Such inconsistencies demonstrate the need for research that can resolve differences in expectation of yield and consequent use of radiographs. In periodontics, radiographs have been deemed of little value in assessing early destructive changes. (113) Radiographic and clinical measurements were found equally effective in evaluating the long term effects of periodontal therapy. Finally, the suggestion has been made that radiographic artifacts may cancel some diagnostic advantages. (114)

POST-TREATMENT RADIOGRAPHS

In the past, some third-party insurance carriers have required dentists to submit post-treatment radiographs so the carrier can monitor or verify reimbursement claims for treatment. This practice exposes the patient to clinically unnecessary radiation.

The Bureau of Radiological Health became involved with this issue when third-party carriers developed policies requiring post-treatment radiographs as a prerequisite for claim reimbursement. The ADA and many State dental societies have opposed the taking of x rays for this purpose. In addition, in June of 1980, the Bureau published a recommendation in the *Federal Register* discouraging the practice. (115) Although past treatment radiographs may not be a serious problem at this time, their potential requirement on a broader scale must be recognized.

The number of Americans with dental insurance went from 7 million in 1974 to 48 million in 1979, and is expected to reach 70 million by 1982. (19) In addition, over 200 insurance or service carriers are now actively marketing dental plans. (116) Thus, pressure will grow to control costs. Moreover, some form of dental coverage is provided under Medicaid auspices, although the exact extent of this coverage varies among Medicaid jurisdictions. On the other hand, as insurance for dental services becomes more widely available, the use of pre-treatment radiographs is likely to undergo corresponding growth. This issue may merit eventual investigation.

Although reliable data are not available on the extent to which post-treatment radiographs are used nationally, the practice does not seem to be common. The ADA, through its Council on Dental Material and Devices and its Council on Dental Care Programs, as well as State dental societies, have strongly discouraged such use of radiographs. (34, 74, 117, 118, 119)

RECOMMENDATIONS

One recommendation of the ADA's Council on Dental Materials and Devices to dentists is: "Use professional judgment to determine the frequency and extent of each radiographic examination. Determine the number of film exposures that will produce the desired diagnostic information". (74) Programs that could be adopted to support that recommendation include:

- Convening a national conference to consider, among other matters, referral criteria for dental radiographs. This conference would both generate interest in and focus attention on needs in this area;
- Surveying current practices with respect to routine exams and referral criteria, in order to provide a necessary data base;
- Conducting efficacy studies on various dental x-ray exams;
- Establishing, in the absence of efficacy studies, consensus panels to develop widely acceptable policies regarding such issues as the number of films per exam and the utilization of various exams. The recommendations of these panels could be implemented through professional organizations and educational programs.

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DENTAL RADIOLOGY EDUCATION CURRICULA

INTRODUCTION

The competency of the individual who orders or performs a dental x-ray examination is an obvious determinant of the general quality of radiographic services. Training and curriculum requirements, as they apply to the use of ionizing radiation, vary according to category of personnel. Applicable standards for both dentists and auxiliaries must therefore be reviewed.

DENTISTS

The lack of uniformity in the radiological curricula in American dental schools hinders any analysis of the educational methods currently used in teaching dental radiology. The problem of standardizing this aspect of the curriculum has been recognized for over twenty years. In "An Analysis and Evaluation of the Methods Used by Schools of Dentistry for Teaching Oral Roentgenology," Budowsky, et at. concluded that each dental school should evaluate its program in order to determine if radiology was being taught in the most appropriate manner. (120) They suggested the following measures:

1. establish specific sections within departments of oral medicine or stomatology;
2. evaluate lecture material for proper emphasis of the subject;
3. broaden the scope of subject matter to be included in radiology;
4. establish minimum clinical requirements to ensure sufficient practical student experience;
5. establish postgraduate courses in theory, technique, and interpretation.

Nine years later (1967), Lincoln Manson-Hing, DMD, MS, again called attention to the problem in his "Study of the Teaching of Oral Roentgenology".[94] The variability which Dr. Manson-Hing described still exists. Items such as required courses, credentials of the faculty teaching radiology, and the amount of practical experience offered to students vary widely among schools. Surveys of dental radiology education suggest that other than requiring many new patients to undergo x-ray examination, dental schools lack policies concerning the use of x-rays.

Recognizing both the importance of ionizing radiation to dental practice and the need for competent handling of radiation in the dental environment, the American Association of Dental Schools (AADS) recently issued a position paper on the teaching of dental radiology. It urged dental schools to review their curricula to assure that "proper emphasis is given to biological aspects of radiation". (99)

Although no mechanism exists for enforcing this recommendation, the paper is an important step in elucidating the problem of uniform dental education in ionizing radiation.

Following is a description of those areas of the dental radiological curriculum in which a brief review of dental college bulletins and conversations with dentists indicate that variability exists. A major obstacle to analysis is that radiological techniques, as tools to assess conditions in the mouth, are refined throughout the educational experience although they may not be mentioned in course descriptions. The biggest unknown is the basis individuals used to decide when radiographs were needed. This often reflected a school's preference, or that which an individual professor himself learned in dental school, and presumably continued throughout his or her career. Such subjective learning experiences cannot be readily analyzed.

The American Dental Association and the American Association of Dental Schools do not require that dental radiology be taught by a radiologist, although both recommend that radiological techniques be taught by staff "knowledgable in radiographic procedures". (121) The AADS goes on to say that a dental radiologist is preferable.

Manson-Hing found 17 dental schools offering radiology in a separate department. Four schools taught it as an independent section within a department. In eighteen schools (nearly half of those reporting), radiology was taught as part of oral diagnosis. (94) College catalogues also list radiological courses under oral pathology, stomatology, and forensic dentistry.

Programs: In addition to undergraduate courses in dental radiology, several schools offer Master's degree programs in oral radiography. Manson-Hing cited five schools offering advanced degrees in this field, and four with one-year postgraduate programs. (94) The continuing education course listing of the Council on Dental Education for July-December 1979 lists 9 courses in dental radiology (interestingly, the same listing contains 30 such courses for dental auxiliaries). (122) Not all states require continuing education for licensure renewal. Those that do accept any of the accredited courses as fulfilling the licensure requirement. Thus, a dentist need not take any further training in radiology after graduation from dental school.

Teaching time: A survey of the bulletins of twenty-five dental schools showed that lecture time devoted to dental radiology varies from 2 to 30 credit hours (see bibliography). The fraction of this time allotted to various topics such as radiation physics, radiographic technique, interpretation, exposing, developing and mounting radiographs, and radiation hygiene also varies. In general, most of the instruction is devoted to technique and interpretation.

Demonstration time per student for technique ranged from 2 to 18 hours and averaged approximately 15 hours. The total time reported as teaching radiology ranges from 4 to 75 hours, with some of the variation occurring because the topic is often taught under several departments.

Another influential training factor is the number of complete full-mouth series required to be taken by the student. Manson-Hing reported that the requirement ranged from 10 to 70 complete surveys. In addition, the number of other types of radiographic examinations required varied depending on such factors as types of patients seen in the teaching clinics, number of students, facilities, and faculty.

Recently, the Bureau of Radiological Health received a letter from a student who expressed concern that the dental school he attended required that both pre-/and post-treatment radiographs accompany the treatment records in order for him to receive credit. The student calculated that this requirement resulted in 70 to 100 excess radiographs per year per student. He concluded that "between 8,000 and 10,000 needless x-rays will be given to the population [of his state] merely to comply with these instructions." In the student's opinion, the school was encouraging the taking of needless radiographs, a habit that would be carried into students' private practices.

DENTAL AUXILIARIES

The training of other employees or auxiliaries working directly in the dental radiographic process is also important if dental x rays are to be used more efficiently.

Radiographic equipment is used by three general categories of dental auxiliaries: dental assistants, certified dental assistants, and dental hygienists. Each category requires different training and, in some cases, licensure. The responsibilities of each group also differ from State to State. Although the educational requirements for dental hygienists vary somewhat, most variation occurs within the category of dental assistants.

Dental Assistants

An estimated 135,000 dental assistants were practicing in the U.S. in 1976, an increase of approximately 61,000 since 1960. (1)

In most States, many dental assistants have had only on-the-job training. For example, an estimated 90 percent of the dental radiographs in the State of Connecticut were taken by dental assistants with no "formal radiological training". (88) Three States and the District of Columbia currently prohibit the dental assistant from taking x rays. Twelve States require that assistants receive training in x rays, three require a combination of training and a State Board Examination, and three require only a State Board Examination. The amount and type of training specified by the various States vary considerably. It is usually up to the dentist to decide whether or not the taking of radiographs will be included in the assistant's duties, and the dentist can, in effect, train someone with a high school education to take dental x rays. For instance, although California requires that the auxiliaries be certified before taking radiographs, the Bureau of Radiological Health has learned of a case in that state in which a 16 year old volunteer dental assistant was taking dental films after receiving only on-the-job training.

To become certified by the ADA, assistants must have one or two years of academic training (depending on the institution) from one of the 280 (as of 1973) accredited dental assistant programs in the United States. (1) The total number of graduates from formal training programs in dental assisting increased from 695 to 5,297 between 1963 and 1973. (123)

The curriculum in a dental assisting program includes courses in radiation physics, radiation biology, radiation techniques, and, in a few cases, radiation safety. The number of hours that an assistant spends in dental radiology varies from two to as many as 64, depending upon the school. The student assistant also is given clinical experience, which in some cases involves the use of x rays. Both phantoms and people are used to train the students in using x rays, with the students sometimes practicing on each other.

Assistants who attend a school in dental assisting are eligible, but not required, upon graduation to take the National Certification Examination given by the Certifying Board of the American Dental Assisting Association. Most States do not require that assistants be certified.

Dental Hygienists

An estimated 27,000 dental hygienists were practicing in the U.S. in 1976; the total had increased by approximately 5,000 from 1973. (1)

Dental hygienists are required to have two years of formal training from one of the 182 schools in dental hygiene accredited by the ADA. (1) Courses that a dental hygienist takes are more in-depth than those taken by the assistant enrolled in a one-/or two-year training program except in radiology, where the course descriptions are in many cases identical. Both the hygienist and the assistant spend approximately the same number of class hours in radiology courses.

Upon completing their training, dental hygienists in most states are required to take the Dental Hygiene National Board Examination. The hygienist must also pass the State Board Examination for the State in which he or she wishes to practice.

In summary, the dental hygienist must have formal training and is required to take the Dental Hygiene National Board Examination (written and clinical) before practicing dental hygiene. In most cases, the dental assistant's training is on-the-job rather than formal. In most States the assistant is not required to take any certifying examination before taking dental x rays. However, some States prohibit assistants from taking x rays.

There appears to be a need for regulating on-the-job training of dental auxiliaries.

CONTINUING EDUCATION

Continuing education courses in radiology are available for both dentists and dental auxiliaries. These courses range in length from one day to two weeks, depending on the sponsoring school. Of 596 continuing education courses listed in 1979 by the JADA, 39 pertained specifically to radiology. Approximately 80 percent of these 39 were described as primarily applicable to auxiliaries and 20 percent to dentists.

Two consortia in continuing education, the New England Foundation for Continuing Dental Education and the Consortium on Continuing Dental Education Programming, are involved in preventing the duplication of efforts among dental schools, hospitals, and other institutions. They are also attempting to increase the number of practicing dentists, hygienists, and assistants in continuing education programs. The consortia do not plan any of the courses,but list possible speakers and publish a newsletter indicating what courses are being offered where.

A total of 77,715 students were enrolled in all continuing education courses in 1974-1975 with an estimate of 30 per class. There were 2,676 instructors considered "regular faculty" involved in continuing education, with 64 percent of the schools using nondental instructors. Twenty-three of the 59 dental schools said that they had separate facilities for continuing education classes ,and 20 percent of the schools used operatories or x-ray laboratory facilities in a separate clinic or hospital. (124)

The most popular format in all courses was the lecture followed by a question/answer session. Almost all of the schools used some patient demonstration as well. Ninety-eight percent of the schools used topics suggested by the faculty and 79 percent of the schools used surveys of former students to choose courses. Seventy percent of the schools took suggestions from dental societies.

Forty percent of the schools said that there was room for more participants and 62 percent said that there was "an unfilled need for more continuing education programs in their locality". (124) Although the above statistics are for all continuing education courses in dentistry, they may provide some insight as to the condition of continuing education in dental radiology.

PROFESSIONAL ORGANIZATIONS' GUIDELINES FOR TRAINING AND USE

INTRODUCTION

This chapter, on guidelines for dental radiology training, traces the development of curricula in undergraduate and graduate programs, discusses several surveys that have provided information on past and present dental radiology curricula, and provides recommendations for diagnostic radiology training as advocated by the American Association of Dental Schools. Several factors external and internal to the profession changed dental radiology training over a period of years. The changes have resulted primarily, however, from the efforts of dental educators placing a high priority on the development of the educated professional.

CURRICULA DEVELOPMENT

Several milestones can be noted in the development of curricula for dental radiology training in dental undergraduate and graduate programs as advocated by professional organizations. In 1966, the executive council of the American Academy of Oral Roentgenology approved recommendations for minimal curricula standards for teaching dental radiology in American dental schools. (125) These recommendations were:

(1) Eliminate the use of dental students as x-ray technicians. It was felt that competency could be obtained without subjecting students to repetitive chairside and darkroom service procedures.

(2) Fix 130 hours as a minimum necessary to develop competency. The training included 32 lecture hours, approximately one week of intraoral procedure training, and approximately two weeks of clinic time for supervised small group film interpretation seminars. The designation of dental radiology as an autonomous discipline rather than as a segment of some other teaching activity would best accomplish these objectives.

(3) Lecture course content generally to include:

History of radiology
Fundamental concepts of radiation
Radiation production
Radiation protection and measurement
Radiation biology
Projection geometry
Film types and characteristics
Intraoral, extraoral, and special techniques
Film-processing theory
Film-viewing procedures
Normal intraoral and extraoral radiographic anatomy
Radiographic appearance of common oral disease entities
Radiographic signs of less common disease conditions
Radiographic signs of systematic malfunction
Research potential and recent advances in dental radiology and future trends

(4) In order to provide proper sequence of teaching, lectures on technique and associated clinical experience could be provided in the second or third year. Lectures and then seminars on interpretation should follow completion of the course in oral pathology.

In 1973, the Oral Radiology Section of the AADS took the position that appropriate training and certification of radiation users was mandatory. (126) It was recognized that radiology had previously been relegated to service rather than teaching status in most dental schools. In order to upgrade the teaching of radiology, an outline for a suggested undergraduate dental radiology curriculum was developed. The Oral Radiology Section position paper noted that policies, philosophy, and economics differ among dental schools and that substitute conditions might be necessary, but nevertheless urged that fulfillment of the requirements be judged as objectively as possible.

The didactic portion of the course was divided into seven main categories and was to be supported by laboratory exercises or seminars. After receiving didactic and demonstrative instruction, the student should produce complete mouth intraoral radiographic surveys and also demonstrate competency in the more common extraoral radiographic procedures, including panoramic methods.

Revised guidelines for an advanced educational program in dental radiology were prepared by the American Academy of Dental Radiology in 1974. (127) That document was intended to serve as a guide for institutions in establishing new, advanced educational programs in dental radiology, and to assist directors of existing training programs in improving and upgrading their programs. Consultants to the Council on Dental Education of the American Dental Association could also use the guidelines as a standard to evaluate new and existing advanced training programs in dental radiology.

The primary objectives of the 1976 ADA/AADS comprehensive study of dental curricula of American dental schools include: (128)

(1) Collection of baseline information to facilitate future comparative studies;

(2) Documentation of current practices in predoctoral dental education;

(3) Interpretation of the data collected to identify reasons for curriculum change, and determination of ways to improve dental curriculums.

The study identified radiology as one of 23 major teaching areas and subdivided it into:

a. Radiation Physics
b. Interaction of X-Radiation and Matter
c. Factors Affecting Radiographic Image Production
d. Biological Effects of X-Radiation
e. Radiation Safety and Protection
f. Intraoral Radiographic Techniques
g. Extraoral Radiographic Techniques
h. Interpretation of Radiographs

Fifty-nine schools reported a range of from 19 to 278 hours of required instruction in radiology (median = 70). State-related schools and schools with less than 4,400 total hours of instruction tended to have the fewest required hours in radiology. One school had no didactic instruction in radiology and depended exlusively on self-instructional programs. Although almost half of the schools reported that emphasis in all areas of radiology instruction had increased over previous years, fewer than a third reported an increase in clock hours; improved instructional methods apparently permitted more content to be presented in the same amount of time. Radiation safety and protection and the interpretation of radiographs received the greatest increase in attention. The report states that there is no "right number" of clock hours for any subject area, and clock hours do not necessarily reveal the depth or quality of instruction. Yet numbers of clock hours do suggest the scope of instruction and indicate where instruction has been omitted or minimized.

Finally, it should be noted that the Oral Radiology Section of the American Association of Dental Schools (AADS) and the American Academy of Dental Radiology are currently working on revised guidelines for teaching dental radiology to dental students.

In order to determine the extent to which schools were attempting to keep abreast of "new" technologies, faculty from various departments were asked to indicate the number of clock hours of instruction provided in the "new" topics. Panoramic radiographs were listed as one of the most frequently taught "new" topics in the clinical science, with 58 schools reporting some instruction in this subject.

Surveys of instructional programs in dental radiology have been conducted in dental schools. A 1969 survey conducted by Greer and Wuehrmann with support of the Bureau of Radiological Health presented data on the qualifications and training of those teaching dental radiology at that time. (129) Forty-five of the 49 dental schools queried responded to their questionnaire. Their findings follow below:

Educational experience of those teaching radiology:

Entirely self taught	33%
Limited, intermittent formal courses	25%
	58%
Postgraduate work for 6 months or more	14%
Formal course work for M.S. or Ph.D.*	28%
	42%

The authors thought that adequate instruction required at least 1.5 full-time equivalent (FTE) dental radiology teachers per 50 students (i.e. an FTE per student ratio of 0.03). Only four schools in this survey had that ratio. Ten schools had ratios between 0.02 and 0.03, while most had ratios less than 0.02.

In 1975, Boozer and Rasmussen conducted a curriculum survey of American and Canadian Dental Schools. (130) In comparision with the results of surveys in the previous two decades, they observed: (1) a slight increase in the number of curriculum hours devoted to teaching radiology methods, (2) that the paralleling technique is the preferred procedure over bisecting angle method; and (3) owing to technological advances, equipment used in radiology clinics also changed considerably.

Boozer and Rasmussen also provided recommendations for strengthening existing radiology curricula: (1) guidelines for national or regional requirements should be established; (2) diagnostic radiology courses should be taught prior to or concurrently with oral pathology courses; and (3) graduate programs in radiology should be expanded to meet the need for qualified faculty. Also, graduate students in other specialties should be given the opportunity to study advanced radiological techniques.

*Only 10% of these had advanced degrees in radiology.

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FINDINGS AND RECOMMENDATIONS OF PROFESSIONAL ORGANIZATIONS

A summary of the most recent information on dental education was reported by the Council on Dental Education, American Dental Association, in cooperation with the American Association of Dental Schools. (131) Highlights are:

- The United States currently has 59 fully operational dental schools.
- Between 1975 and 1979 the number of applicants to dental schools declined by 35 percent. (As a result, several schools that had automatically rejected applicants with low grade point averages and Dental Admission Test scores have ceased to do so.)
- Fifty to 60 percent of recent graduating dentists enter private practice immediately after graduation. Only about 20 percent enter advanced dental education programs after graduation.
- The proportion of dental school graduates enrolled in first-year specialty programs declined from 28.3 percent in 1974 to 22.8 percent in 1978.
- Dental school tuition costs are increasing substantially and Federal support is decreasing. State and local governments have compensated for most of the decrease in Federal monies, however.
- The number of qualified teachers of dental radiology is extremely small.

Dr. Allan Reiskin, School of Dental Medicine, University of Connecticut, Farmington, testifying before the Subcommittee on Health and the Environment of the Committee on Interstate and Foreign Commerce, on July 11, 1978, stated that "although x-ray diagnosis is considered to be an essential component of dental practice, radiology has never been given the recognition accorded to other dental specialties and it rarely has a position of prominence in dental curricula". (88) Dr. Reiskin went on to say, "In the long term, improvement of practice standards will require substantial upgrading of our educational system. It is important to recognize, however, that a decision to expand the radiology curriculum in dental schools could not be readily implemented because of the extremely small number of qualified teachers. Therefore, in the short term, it may also be necessary to regulate the use of diagnostic x-ray equipment."

In response to the data that Dr. Reiskin presented and to public concerns about the use and abuse of ionizing radiation, the American Association of Dental Schools adopted an official position on "Ionizing Radiation" at their 1979 annual meeting. The position paper urges dental educators to review their schools' procedures to control the use of ionizing radiation and to modify any practices that do not conform to acceptable standards. (99) The position paper includes the following recommendations:

1. Physical facilities:

   a. All existing radiographic equipment and facilities should be upgraded to meet all regulations specified and/or recommended by *The Radiation Control For Health and Safety Act* of 1968, NCRP Handbook 35 on Dental X-Ray Protection, and the ADA recommendations on acceptable radiographic practices.

   b. Radiographic facilities should be designed or modified to maximize student/operator/patient protection from unnecessary exposure to ionizing radiation.

   c. Film processing, including time-temperature relationships, should be monitored regularly (preferably daily) to assure film quality.

2. Instructional/teaching support for clinical activities:

   a. Faculty and supporting technical staff should be knowledgeable and skillful in all radiographic procedures and preferably licensed in the field of dental radiology.

   b. Students should be clearly supervised by faculty or staff during all clinical radiographic procedures conducted on patients.

   c. Techniques to minimize patient exposure, e.g., long open-shielded beam indicating devices (BID's), rectangular collimating devices to collimate beams to the size of the film packet, lead aprons, film-holding devices, and high-speed film should be emphasized.

3. Institutional obligations to the patient:

   a. Patients should not be subjected to a large number of retakes to satisfy technical perfection rather than clinical acceptability. (A minimally acceptable complete mouth radiographic survey should demonstrate, at least one time, each root apex and each interproximal space, without overlapping and with clarity and accuracy.)

   b. Students should not serve as live technique mannequins unless some benefit is to be received by taking and interpreting the radiographs.

   c. Patients should not be subjected to mass radiographic screening examinations prior to initial clinical examination to determine the need and desirability of specific radiographs to aid in evaluating their acceptability as clinic patients.

   d. Radiographs should be made available to private practitioners or other appropriate professionals when so requested by patients who indicate they no longer desire treatment or care at the institution.

   e. Radiographs should be limited to the minimum number needed for a complete diagnostic workup of the patient's dental needs.

4. Institutional obligations to the student:

   a. Students should be taught to assess critically the need for diagnostic radiographic information and to evaluate the risk to the patient before ordering the radiographs needed to determine the patient's oral health needs.

   b. Students should be well-prepared to assume the challenges of clinical dental radiography and should receive appropriate guidance from faculty and staff.

   c. Technical perfection in radiographic procedures should be achieved on mannequins; students should be taught to recognize clinical situations in which it may be necessary to compromise technical perfection.

   d. Students should be allowed to take no more than three retakes on a complete mouth radiographic survey without the direct supervision of faculty or staff. More than three retakes indicate a lack of minimally acceptable skills and close supervision is justified.

   e. Students should be prepared to establish private practices in which adequate concern is given to selecting equipment and following procedures that will minimize radiation to the patient and assure high-quality films for diagnostic interpretation.

In March, 1978, the Council on Dental Materials and Devices, American Dental Association, published 11 recommendations on the use of diagnostic radiology. (74) Recommendation No. 1, on the frequency of dental radiographic examinations, urges that professional judgment be used to determine the frequency and extent of each radiographic examination and the minimum number of exposures needed to produce the desired diagnostic information. Other recommendations provide advice for protection of the patient, office personnel, and dentist, and on modernization of x-ray equipment, use of fast-speed film, and proper darkroom procedures.

NCRP Report No.35 also provides recommendations on proper operating procedures. (37) Here too,it is stated that deliberate exposure of an individual to the useful beam for training or demonstration purposes shall not be permitted unless necessary for diagnosis and the exposure is prescribed by a dentist or physician.

In addition, both the American Academy of Dental Radiology and the American Association of Dental Schools have noted that State and National Board Examinations do not thoroughly test the competency of dentists in radiology. (126, 132) This deficiency may result in part from the lack of an independent specialty of dental radiology.

STATE ACTIVITIES

The information in this chapter is based mainly on a report published in 1978 to provide information on State and local radiological health programs to reduce or control population exposure to ionizing and nonionizing radiation. (133) Selected data on dental x-ray programs are provided. This chapter also includes a brief description of a Bureau of Radiological Health program to identify dental x-ray facilities in which exposure reduction and improvement in quality assurance can be achieved. This program is known as the Dental Exposure Normalization Technique (DENT) and is more fully discussed in the section on quality assurance. Information on States' requirements for licensing dental auxiliary personnel is provided in the section on demographics. Many States conduct compliance inspections under contract to FDA, although the number of these inspections for conventional dental x-ray equipment is decreasing.

State agencies, several local agencies, and regional offices of the Food and Drug Administration provide combined reviews of their radiological health programs in a series of reports. These reports are submitted by these agencies as directed in the FDA contract with the Conference of Radiation Control Program Directors, Inc. (CRCPD), formed approximately 10 years ago as a means of exchanging information between State and Federal agencies, as well as among States themselves, in areas of mutual concern or interest. The Conference is supported primarily by the Food and Drug Administration, the Environmental Protection Agency, and the Nuclear Regulatory Commission.

In Fiscal Year 1977, (133) 38 States reported regulatory programs for dental/medical x-ray activities, 5 States reported voluntary activities, and 8 States reported combined regulatory/voluntary programs. Seven of the 8 States reporting combined activities changed from regulatory in 1976 to combined in 1977 in order to highlight the voluntary user activities being carried out in the State programs. (For the purpose of the report, Puerto Rico and the District of Columbia were counted as States. Nevada did not report.)

Compliance information is provided on a facility basis, because most State programs record data in this manner. X-ray facilities are inspected for compliance in areas other than equipment performance, such as film development requirements, registration, and shielding and use, depending on State regulations. Therefore, equipment need not be considered noncompliant when facilities are shown to be not in compliance with regulations.

Table 12 provides comparative information on the reported estimated numbers of dental x-ray machines and inspections for Fiscal Years 1975, 1976, and 1977. (133) Whereas the number of machines increased between 1975 and 1977, the number of inspections decreased slightly.

Table 12. Number of Reported Dental X-Ray Machines and Number of Inspections for Fiscal Years 1975, 1976, and 1977

[illegible]

Of the estimated 145,000 dental x-ray machines in the United States in Fiscal Year 1977, 92.6 percent were registered with State agencies. The 24,833 inspections conducted represent 17.2 percent of the total estimated number of machines reported. Of the estimated 82,123 facilities, 5.0 percent (4,165) were not in compliance with State regulations. As noted above, compliance figures reflect not only machine performance, but also other variables. For a complete breakdown by State on Dental X-Ray Program Activities, see reference 133.

Suggested State Regulations for Control of Radiation (SSRCR) have been published and revised since 1962. Approximately 40 States had adopted the 1970 or 1974 revisions, or were intending to adopt the 1978 revisions of Part F, "X Rays in the Healing Arts," according to a recent survey conducted by the Executive Director of Regional Operations, FDA. Dental x-ray systems are subject to Sections F.3, General Requirements; F.4, General Requirements for all Diagnostic X-Ray Systems; F.6, Extraoral Dental Radiographic System Requirements; and the Requirements of F.7, which apply to X-Ray Equipment and Associated Facilities Used for Dental Radiography. (134)

The Bureau of Radiological Health has worked with the States to develop a program called Dental Exposure Normalization Technique (DENT), which provides a means of identifying dental x-ray facilities where patient exposure exceeds the normal range, and for correcting this situation through consultation and education. (82) A panel of dentists established a range of exposures that would produce acceptable radiographs at various kVp settings. Pilot studies conducted in cooperation with State radiation control agencies in Rhode Island (1973) and New Hampshire (1972) showed that of all the known dental x-ray machines in these two States, 46 percent exceeded the upper limits of these exposure ranges. State personnel visited these dental offices to normalize the x-ray system, i.e., demonstrate exposure and processing conditions that would enable the dentist to operate within the acceptable exposure range. The average exposure after these site visits was one-fifth the former value, with diagnostic quality of films maintained or improved.

The DENT program can be adopted by radiation control agencies that actively and routinely conduct compliance surveys, or the demonstration aspects of DENT can be added to compliance surveys. A radiation control agency with a minimal or nonexistent dental radiological health program could use the DENT program to identify and correct excessive exposure conditions. A suggested methodology for organizing and coordinating a DENT program is provided in reference 134. Additional information and/or assistance is available from the Bureau of Radiological Health. Figure 4 shows DENT program participants as of January 1, 1979.

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DENT Program Participants

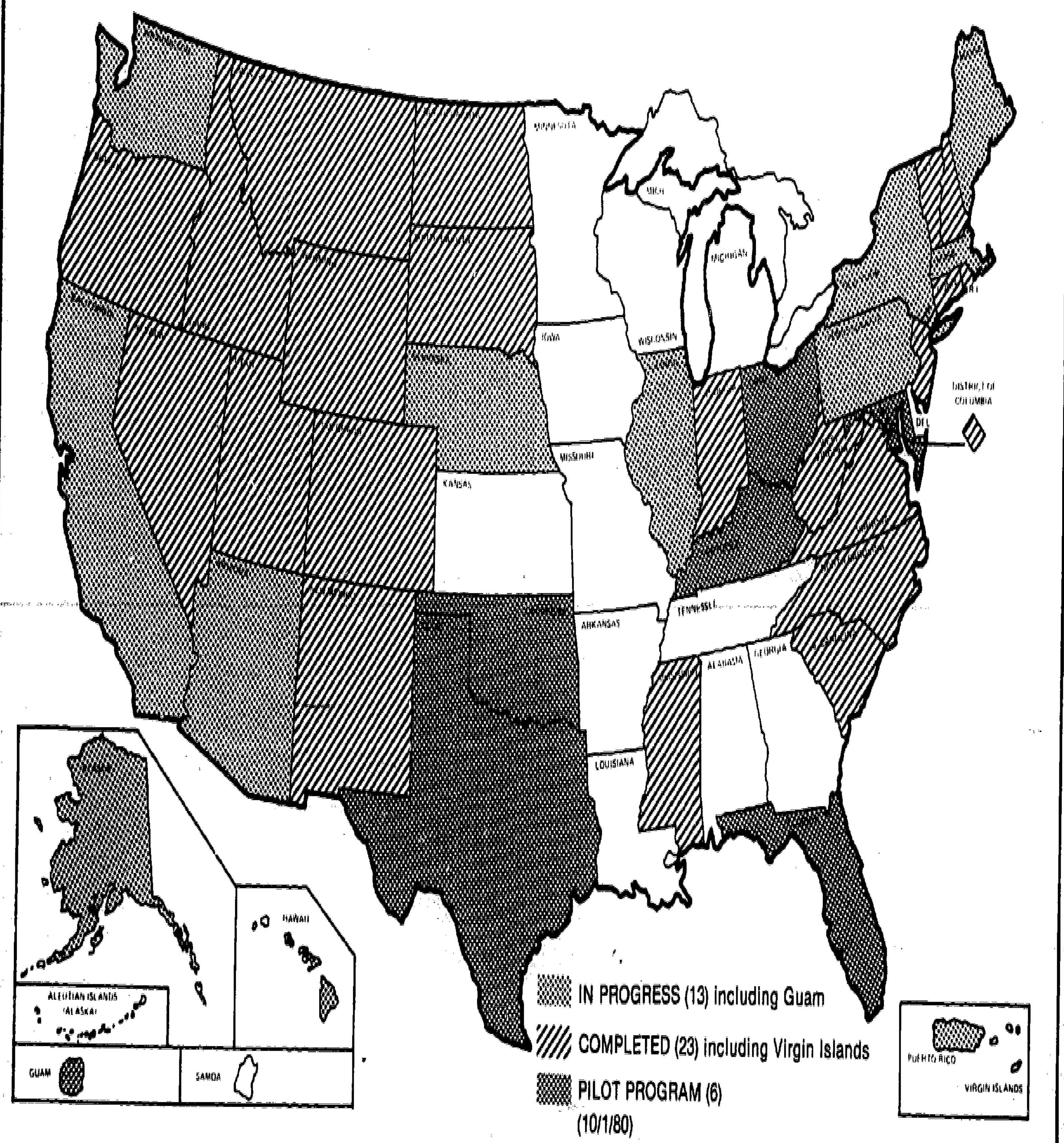

Figure 4. *DENT Program Participants*

SUMMARY AND CONCLUSIONS

X-rays play an indispensable role in dental diagnoses. Impressive technological gains have been made in equipment, and proven new modalities, such as tomography, greatly enhance diagnostic capabilities. Xeroradiography, a newer experimental technique in dentistry, also promises to become a useful imaging tool.

Most States now have active regulatory programs for registration and inspection of equipment. In conjunction with Federal performance standards, these programs have been instrumental in correcting equipment-related radiation exposure problems. In the past, significant exposure reductions were achieved through attention to such factors as beam filtration, collimation, and timer accuracy. One matter that bears consideration, however, is the assessment of new technology. A mechanism is needed to investigate and assess advances such as intraoral sources and xeroradiography.

Unnecessary exposure to x rays can probably be further decreased through conscientious implementation of well-defined quality assurance programs, which also would optimize information yield and cost. Twenty percent of the radiographs submitted to Pennsylvania Blue Shield during a 1976 study were judged unsatisfactory because of poor density or improper processing. Data from the NEXT and DENT programs indicate that exposures often are outside of established acceptable ranges for various dental radiographic procedures. This problem likely stems from lack of sufficient training in the radiographic process. The existing DENT program and the Nashville study are two examples of quality assurance efforts based on an educational approach. Both have successfully elicited voluntary, positive responses from practitioners. Uniform methods of systematically applying quality assurance principles in dental radiology need to be developed and promoted.

Although improvements in equipment have decreased radiation exposures per examination, unnecessary examinations have been alleged. Excessive utilization is at least partially attributable to lack of agreement regarding how and when x-rays should be used in particular cases. For instance, opinions vary on such matters as the frequency with which full mouth x-ray examinations should be performed and the number of projections required for various exams. The efficacy of some procedures (e.g., routine and pre- and post-treatment radiographs for third-party carriers) has been questioned. Explicit guidance, in the form of referral criteria, could help to solve these difficulties. Although the radiation risks associated with dental x-rays are relatively minor, in combination with cost concerns they generate a strong incentive to foster more efficacious use. This is particularly true in light of expanding dental services and broader insurance coverages.

One basic reason for differences in x-ray utilization patterns is the educational process. Curricula and training standards for dentists and auxiliaries vary widely. A discrepancy exists between the number of lecture hours recommended by the American Academy of Dental Radiology and the amount of time actually devoted to the teaching of this subject in most dental schools. The number of qualified dental radiology instructors in dental schools is small. Recognition of oral radiology as a separate and autonomous specialty by the ADA has been identified as a possible solution to this problem. Lastly, State and National Board Examinations have been termed deficient in the area of radiology and thus do not serve well in promoting competency.

With the advent of new technologies and continuing concern over radiation risk and health care costs, it is imperative that unproductive radiation exposure be minimized. Referral criteria for dental x-ray examinations, quality assurance programs, and upgraded educational standards all would appear to contribute to this goal.

REFERENCES

1. U.S. Department of Labor, Bureau of Labor Statistics. Occupational Outlook Handbook 1978-79 edition. U.S. Government Printing Office, Washington, D.C. (1978).

2. U.S. Department of Health, Education, and Welfare, Public Health Service, Health Resources Administration, National Center for Health Statistics. Health Resources Statistics, Health Manpower and Health Facilities, 1975. HEW Publication No. (HRA) 76-1509. Rockville, Maryland (1976).

3. Personal communication with Health Resources Administration (1979).

4. U.S. Department of Health, Education, and Welfare, Public Health Service, National Center for Health Statistics. Excerpts of Health Resources and Utilization Statistics, 1976. HEW Publication No. (PHS) 79-1245. Hyattsville, Maryland (1978).

5. U.S. Department of Health, Education, and Welfare, Public Health Service, Health Resources Administration, Bureau of Health Manpower Analysis Branch. A Report to the President and Congress on the Status of Health Professions and Personnel in the United States. HEW Publication No. (HRA) 79-93 (Formerly HEW No. (HRA) 78-93) (1979).

6. U.S. Department of Health, Education, and Welfare, Public Health Service, Health Resources Administration, Bureau of Health Manpower. Executive Summary-Report to the President and Congress on the Status of Health Professions Personnel in the United States. HEW Publication No. (HRA) 79-93 (1978).

7. U.S. Department of Health, Education, and Welfare, Public Health Service, National Center for Health Statistics. Current Estimates from the Health Interview Survey: United States - 1977. HEW Publication No. (PHS) 78-1554. Hyattsville, Maryland (1978).

8. U.S. Department of Health, Education and Welfare, Public Health Service, National Center for Health Statistics. Current Estimates from the Health Interview Survey: United States - 1976. HEW Publication No. (PHS) 78-1547. Hyattsville, Maryland (1978).

9. U.S. Department of Health, Education and Welfare, Public Health Service, Health Resources Administration, National Center for Health Statistics. Current Estimates from the Health Interview Survey: United States - 1974. HEW Publication No. (HRA) 76-1527. Hyattsville, Maryland (1976.)

10. U.S. Department of Health, Education and Welfare, Public Health Service, Health Resources Administration, National Center for Health Statistics. Current Estimates from the Health Interview Survey: United States - 1973. HEW Publication No. (HRA) 75-1522. Rockville, Maryland (1975).

11. U.S. Department of Health, Education and Welfare, Public Health Service, Health Resources Administration, National Center for Health Statistics. Current Estimates from the Health Interview Survey: United States - 1972. HEW Publication No. (HRA) 74-1512. Rockville, Maryland (1974).

12. U.S. Department of Health, Education and Welfare, Public Health Service, Health Services and Mental Health Administration, National Center for Health Statistics. Current Estimates from the Health Interview Survey: United States - 1971. HEW Publication No. (HSM) 73-1505. Rockville, Maryland (1973).

13. U.S. Department of Health, Education and Welfare, Public Health Service, Health Services and Mental Health Administration, National Center for Health Statistics. Current Estimates from the Health Interview Survey: United States - 1970. HEW Publication No. (HSM) 72-1054. Rockville, Maryland (1972).

14. U.S. Department of Health, Education and Welfare, Public Health Service, Health Services and Mental Health Administration, National Center for Health Statistics. Current Estimates from the Health Interview Survey: United States - 1969. Rockville, Maryland (1971).

15. Personal communication with John Dugan, Eastman Kodak, Rochester, New York (August 1979).

16. Goepp, R. Statement of the American Dental Association Before the Subcommittee on Health and the Environment-Committee on Interstate and Foreign Commerce. United States House of Representatives (July 13, 1978).

17. Bureau of Radiological Health and Health Services and Mental Health Administration. Population Exposure to X Rays: U.S. 1970. HEW Publication (FDA) 73-8047 (November 1973).

18. Public Health Reports, Vol. 94, No. 2, March-April, 1979.

19. Bailit, H.L., M. Raskin, S. Reisine, and D. Chiriboga. Controlling the Cost of Dental Care. Am J Pub Health 69:699-703 (1979).

20. Reports of Councils and Bureaus of the American Dental Association. Dental fees charged by general practitioners and selected specialists in the United States, 1975. J Am Dent Assoc 94(2):340-352 (1977).

21. U.S. Department of Health, Education and Welfare, Public Health Service, Office of Health Research, Statistics and Technology, National Center for Health Statistics. Family Out-of-Pocket Health Expenses United States, 1975. HEW Publication No. (PHS) 79-1555. Hyattsville, Maryland (1979).

22. U.S. Department of Health, Education and Welfare, Public Health Service, Office of the Assistant Secretary for Health, National Center for Health Statistics. Personal Out-of-Pocket Health Expenses United States, 1975. HEW Publication No. (PHS) 79-1550. Hyattsville, Maryland (1979).

23. Source Book of Health Insurance Data 1975-76, REF-GEN W 275AA1 S724.

24. Murray, J.B. and E.M. Bishop. The Growth and Growing Pains of Dental Prepayment. J Am Dent Assoc 89:828-832 (1974).

25. U.S. Department of Health, Education and Welfare, Public Health Service, Health Services and Mental Health Administration, National Center for Health Statistics. Age Patterns in Medical Care, Illness, and Disability – United States 1968-1969. HEW Publication No. (HSM) 72-1026. Rockville, Maryland (1972), and National Health Interview Survey. Unpublished data.

26. U.S. Department of Health, Education and Welfare, Public Health Service, Health Services and Mental Health Administration, National Center for Health Statistics. Children and Youth – Selected Health Characteristics – United States 1958 and 1968. Rockville, Maryland (1971).

27. National Health Interview Survey. Unpublished data.

28. Alcox, R.W. Physical Survey Manual Dental X Ray. HEW Publication (National Center for Radiological Health (April 1967).

29. Dental machine assembler reports. Bureau of Radiological Health, HEW. Unpublished data.

30. Miller, J.W. Progress in dental radiological health. Radiological Health Data, pp. 499-504 (October 1964).

31. Fess, L.R., R.B. McDowell, W.R. Jameson, and R.W. Alcox. Results of 33,911 x-ray protection surveys of facilities with medical or dental diagnostic x-ray equipment, fiscal years 1961-1968. Radiological Health Data and Reports, pp. 581-611 (November 1970).

32. Spaulding, C.K. and R.F. Cowing. A survey of radiation received by dentists and dental assistants. Am Industr Hyg Assoc Quar 20:424-427 (1959).

33. Yale, S.H. Survey and analysis of roentgen exposure of dentists: preliminary report. J Am Dent Assoc 58:49-54 (1959).

34. Miller, J.W., S. Kinsman, and R.L. Stockman. Occupational radiation exposure to dental personnel. Wash State Den J 28:6-8 (1959).

35. National Committee on Radiation Protection: Medical X Ray Protection Up to Three Million Volts. National Bureau of Standards Handbook 76, U.S. Government Printing Office, Washington, D.C. 20402 (February 1961).

36. Richards, A.G., J.H. Barr, and R.E. Silham. The effective use of x-ray radiation in dentistry. Oral Surg, Oral Med, Oral Pathol 16:294-304 (1963).

37. National Council on Radiation Protection and Measurements. Dental X-Ray Protection, NCRP Report No. 35, Bethesda, MD 20014 (reprinted 1972).

38. Performance Standards for Ionizing Radiation Emitting Products. Title 21, CFR, Chapter 1, Subchapter J, Part 1020.

39. Council on Dental Materials and Devices, American Dental Association. New ADA Specification No. 26 for dental x-ray equipment. Reports of Councils and Bureaus. J Am Dent Assoc 39:386-392 (1974).

40. Jacobson, A.F. and J.P. Ferguson. Evaluation of the S.S. White Panorex X-Ray Machine. HEW Publication (FDA) 72-8020 (December 1971).

41. Phillips, J.E. Principles and function of the Orthopantomograph. Oral Surg, Oral Med, Oral Pathol 24:41-49 (1967).

42. Woodcock, R.C. and W.S. Properzio. Evaluation of a Westinghouse Panoramix x-ray machine. Oral Surg, Oral Med, Oral Pathol 31:650-663 (1971).

43. Gibbs, S.J. Preventive dental radiology. J Am Soc Prev Dent 8-14 (January/February 1976).

44. Lund, T.M. and L.R. Manson-Hing. Relations between tooth positions and focal troughs of panoramic machines. Oral Surg, Oral Med, Oral Pathol 40:285-293 (1975).

45. Council on Dental Materials and Devices, American Dental Association. Advantages and Disadvantages of the Use of Dental Tomographic Radiography. Reports of Councils and Bureaus, J Am Dent Assoc 94:147 (1977).

46. Personal Communication: Stuart C. White, D.D.S., Ph.D., School of Dentistry, University of California, Los Angeles, (June 1979).

47. White, S.C. and T.C. Rose. Absorbed bone marrow dose in certain dental radiographic techniques. J Am Dent Assoc 98:553-558 (1979).

48. Alcox, R.W. and W.R. Jameson. Patient exposure from intraoral radiographic examinations. J Am Dent Assoc 88:568-579 (1974).

49. Antoku, S., T. Kihara, W.J. Russell, and D.R. Beach. Doses to critical organs from dental radiography. Oral Surg, Oral Med, Oral Pathol, 41:251-260 (1976).

50. Block, A.J., R.A. Goepp, and E.W. Mason. Thyroid radiation dose during panoramic and cephalometric dental x-ray examinations. The Angle Orthodontist 47:17-24 (January 1977).

51. Manson-Hing, L.R., and D. Greer. Radiation exposure and distribution measurements for three panoramic x-ray machines. Oral Surg, Oral Med, Oral Pathol 44:313-321 (1977).

52. McMahon, J.J. A Study of Head and Neck Exposures from Panoramix Roentgenography. HEW Publication (BRH/DEP) No. 70-5 (March 1970).

53. National Institutes of Health. Rod Anode X-Ray Sources in Dentistry, Workshop Proceedings, HEW Publication (NIH) 79-248 (June 14-16, 1976).

54. Lieberman, J.E. and R.L. Webber. Clinical evaluation of a prototype intraoral source x-ray system. Oral Surg, Oral Med, Oral Pathol 46:318-327 (1978).

55. Wolfe, J.N. Breast Xeroradiography. Cancer 24:1222-1225 (1969).

56. Wolfe, J.N. Xeroradiography of the bones, joints, and soft tissues. Radiol 93:583-587 (1969).

57. McMaster, R.C. New Developments in Xeroradiography. Nondestructive Testing 10:8-25 (1951).

58. Rawls, H.R. and W.D. Owen. The Dental Prognosis for Xeroradiography. Oral Surg, Oral Med, Oral Pathol 33:476-480 (1972).

59. Lopez, J. Xeroradiography in Dentistry. J Am Dent Assoc 92:106-110 (1976).

60. Hyman, J. and V. Bakker. Xeroradiographic Detection of Tooth and Bone Pathology. Oral Surg, Oral Med, Oral Pathol 47:482-484 (1979).

61. Gratt, B.M., E.A. Sickles, and C.P. Parks. Xeroradiography of Dental Structures. I. Preliminary Investigations. Oral Surg, Oral Med, Oral Pathol 44:138-152 (1977). II. Image Analysis. Oral Surg, Oral Med, Oral Pathol 46:156-165 (1978).

62. Jeromin, L.S., G.F. Geddes, S.C. White, and B.M. Gratt. Xeroradiography for Intraoral Dental Radiology: A Process Description. Oral Surg, Oral Med, Oral Pathol (in press).

63. Gratt, B.M., E.A. Sickles, and C.R. Parks. Use of Intraoral Cassettes for Dental Xeroradiography. Oral Surg, Oral Med, Oral Pathol 46:717-720 (1978).

64. Gratt, B.M., S.C. White, E.A. Sickles, and L.S. Jeromin. Imaging Properties of Intraoral Dental Xeroradiography. J Am Dent Assoc 99:805-809 (1978).

65. White, S.C. and B.M. Gratt. Clinical Trials of Intraoral Dental Xeroradiography. J Am Dent Assoc 19:810-816 (1979).

66. Manson-Hing, L.R. A Study of the Fexitron 845 in Dental Roentgenography. Alabama J Med Sciences 3:46-53 (1966).

67. Yin, L.I., J.I. Trombka, S.M. Seltzer, R.L. Webber, M.R. Farr, and J. Rennie. The Low Intensity X-Ray Imaging Scope (LIXISCOPE). SPIE Vol 143, Applications of Electronic Imaging Systems (1978).

68. Goddard Space Flight Center. LIXISCOPE; Preliminary Applications and Evaluation Results. Draft Report (February 1979).

69. Webber, R.L. and M. Seidband. Seminar Presented at the National Institute of Dental Research, NIH (July 25, 1979) and R.L. Webber, private communication.

70. Isaac Masel Company, Inc., Philadelphia, PA 19154.

71. Rinn Corporation, 1212 Abbott Drive, Elgin, IL 60120.

72. Reiskin, A. D. Phil, E. Hummel, S. Kirchhof, and M.L. Freedman. Rare Earth Imaging In Dental Radiology. J Prev Dent 4:7-13 (1977).

73. Quality Assurance Programs for Diagnostic Facilities; Final Recommendation. Federal Register (44 FR 71728) (December 11, 1979).

74. Council on Dental Materials and Devices, American Dental Association. Recommendations in radiographic practices. J Amer Dent Assoc 96:485-486 (1978).

75. X Ray Exposure Study, U.S. 1970. Unpublished data.

76. U.S. Department of Health, Education and Welfare, Public Health Service. Population Exposure to X Rays, U.S. 1964. Public Health Service Publication No. 1519 (1966).

77. Division of Training and Medical Applications, Bureau of Radiological Health. Nationwide Evaluation of X-Ray Trends Tabulations, Representative Sample Data January 1, 1978 to December 31, 1978.

78. Crabtree, C.L., O. Johnson, and S.J. Gibbs. Nashville Dental Project: An Educational Approach for Voluntary Improvement of Radiographic Practice. HEW Publication (FDA) 76-8011 (July 1975).

79. Beideman, R.W., O. Johnson, and R.W. Alcox. A study to develop a rating system and evaluate dental radiographs submitted to a third party carrier. Journal of the American Dental Association 89:1010-1013 (1976).

80. Fortier, A.P. Preventive care and maintenance of the automatic dental film processor. Journal of Preventive Dentistry 4:20-21 (1977).

81. Thunthy, K.H. Automatic film processing. Journal of Preventive Dentistry 4:18-19 (1977).

82. Crabtree, C.L. and W. Jameson. Dental Exposure Normalization Technique Instruction Manual. HEW Publication (FDA) 76-8042 (May 1976).

83. Unpublished Data from the DENT Program, Division of Training and Medical Applications, Bureau of Radiological Health.

84. NIH Guide for Grants and Contracts, Vol. 8, No. 4 (March 16, 1979).

85. Manson-Hing, L.R. Fundamentals of dental radiography. Lea and Febiger, Philadelphia, PA (1979).

86. The following papers were presented at the 120th Annual Session of the American Dental Association, Dallas, Texas (October 21-25, 1979).
Beideman, R.W. Radiographic Quality Assurance
Crabtree, C.L. Safe Effective X Rays

87. Burkhart, R.L. Diagnostic Radiology Quality Assurance Catalog. HEW Publication (FDA) 77-8028 (July 1977).

88. Reiskin, A.B. Testimony before the Subcommittee on Health and the Environment-Committee on Interstate and Foreign Commerce. United States House of Representatives (July 13, 1978).

89. Environmental Assessment Report for Performance Standard for Diagnostic X-Ray Systems and Their Major Components. HEW, Bureau of Radiological Health (1974).

90. Crabtree, C.L. Prevention of Overirradiation to Teeth and Supporting Tissues. Presented at ADA Annual Meeting (1966).

91. White, S.C. and N.W. Frey. An estimation of somatic hazards to the United States population from dental radiographs. Oral Surg 43(1):152-159 (1977).

92. Shleien, B., T.T. Tucker, and D.W. Johnson. The Mean Active Bone Marrow Dose to the Adult Population of the United States from Diagnostic Radiology. HEW Publication (FDA) 77-8013 (January 1977).

93. Gibbs, S.J., C.L. Crabtree, and O.N. Johnson. An educational approach to voluntary improvement of dental radiological practices. J Am Dental Assoc 95:562-569 (1977).

94. Manson-Hing, L.R. Study of the Teaching of Oral Roentgenology. J Dent Educ 32(2):153-157 (1968).

95. Stafne, E.C. and J.A. Gibilisco. Oral Roentgenographic Diagnosis, 4th Ed W.B. Saunders Co., New York, N.Y. (1975).

96. McGehee, W., H. True, and E. Inskipp. Operative Dentistry. McGraw-Hill Book Co., Inc., New York, N.Y. (1956).

97. National Academy of Sciences, National Research Council. The Effects on Populations of Exposure to Low Levels of Ionizing Radiation. Washington, D.C. (1972).

98. Gregg, E.C. Radiation Risks with Diagnostic X-Rays. Radiology 123:447-453 (1977).

99. American Association of Dental Schools. Resolution 9-79-H – Position Paper on Ionizing Radiation. J Dent Ed 43(8):422-424 (1979).

100. Radiation Protection Guidance to Federal Agencies for Diagnostic X Rays. Federal Register (43 FR 4377) (February, 1978).

101. Laws, P. X-Rays: More Harm Than Good? Rodale Press, Emmaus, Pa. (1977).

102. Stolurow, K.A. and D. W. Moeller. Dental X-ray Use in Boston. Am J Pub Health 69:709-710 (1979).

103. Burket, L.W. Oral Medicine, Diagnosis and Treatment, 3rd Edition, J.B. Lippincott Co., Philadelphia, Pa. (1957).

104. Redtenbacher, K. On the importance of roentgenographic examination of clinically lesion-free jaws. I.C.D.,Sc Ed Jrnl 10(1):11-14 (1977).

105. Henry, J.L. and D.A. Garcia. Use of radiographic projections in dental schools in the United States and Canada. J Am Dental Assoc 97:947-948 (1978).

106. White, S.C. and D.D. Weissman. Relative Discernment of Lesions by Intraoral and Panoramic Radiography. J Am Dental Assoc. 95:1117-1121 (1977).

107. Hurlburt, C.E. and A.H. Wuehrmann. Comparison of interproximal carious lesion detection in panoramic and standard intraoral radiography. J Am Dental Assoc. 93:1155-1158 (1976).

108. Stephens, R.G., S.L. Kogon, J.A. Reid, and A. Ruprecht. A comparison of panorex and intraoral surveys for routine radiography. J Canad Dent Assoc 6:281-286 (1977).

109. Manson-Hing, L.R. Utilization of Extraoral Roentgenographic Techniques in General Dental Practice. The Dental Clinics of North America, W.B. Saunders Co. (1961).

110. Hochschild, T.J. Radiographic Technique in the Management of Cleft Palate Deformities. Radiography 45(533):100-102 (1979).

111. Hotz, P. Milchzahnkariesdiagnostik, Bedeutung des Rontgenbildes. Schweiz Monatsschr Zalmheikd 87:416-421 (1977).

112. Holst, D. A Comparative Radiographic Investigation of Caries Prevalence in Danish Schoolchildren. Community Dent Oral Epidemiol 4:254-258 (1976).

113. Lang, N.P. and R.W. Hill. Radiographs in Periodontics. J. Clinical Periodontology 4:16-28 (1977).

114. Williams, J.E., C.J. Donnelly, and J.T. Fulton. An Appraisal of the Necessity for Radiographs in Clinical Trials of Caries-Inhibitory Agents. J Pub Health Dentistry 27(2):54-62 (1967).

115. Administrative Dental X-Ray Examinations; Final Recommendation. Federal Register (45 FR 40976) (June 17, 1980).

116. A Technical Overview for the Recommendation on Use of Dental Post-Treatment Radiographs by Third Party Carriers. HEW, Bureau of Radiological Health (1978).

117. Council on Dental Care Programs. Dental Prepayment. J Am Dental Assoc. 88:1234-1235 (1974).

118. Green, D. Double Expose Your Insurance X-rays? Dental Management (July, 1975).

119. Sabin, N.M. Dental Insurance Negotiations. J Wisc Dent Assoc 52(1):34-35 (1976).

120. Budowsky, J., E.V. Zegarelli, A.H. Kutscher, and J. Mercadante. An Analysis and Evaluation of the Methods Used by Schools of Dentistry for Teaching Oral Roentgenology. J Dent Ed 25:338-342 (1961).

121. American Dental Association. Statement Before the Subcommittee on Health and the Environment – Committee on Interstate and Foreign Commerce. United States House of Representatives (July 13, 1978).

122. Council on Dental Education. Continuing Education Course Listing for July-December 1974. J Am Dent Assoc 98:965-995 (1974).

123. U.S. Department of Health, Education and Welfare, Public Health Service, Health Resources Administration, Bureau of Health Manpower. State Regulation of Health Manpower. HEW Publication No. (HRA) 77-49 (1977).

124. Graham, J. and D.R. DeMarais. Continuing Education in U.S. Dental Schools. J Am Dent Assoc 92:1225-1226 (1976).

125. American Academy of Oral Roentgenology. Undergraduate dental school curriculum: Dental radiology. Oral Surg, Oral Med, Oral Pathol 24(2):191-195 (1967).

126. American Association of Dental Schools, Section on Oral Radiology. Guidelines for Dental Radiology Teaching 1973 (Unpublished).

127. American Academy of Dental Radiology, Educational Guidelines Committee. Guidelines for an Advanced Educational Program in Dental Radiology (Revised March 1974, Unpublished).

128. American Dental Association, Council on Dental Education of the American Dental Association in Cooperation With the American Association of Dental Schools. Dental Education in the United States 1976 (1977).

129. Greer, D.F. and A.H. Wuehrmann. A survey of the qualifications and training of dental radiology faculty members and of their radiologic facilities. Oral Surg 31(1):114-121 (1971).

130. Boozer, C.H. and Rasmussen, R.H. Survey of Curriculum and Instruction: Radiology. J Dent Educ 41(4):202-205

131. Association Reports.–Council on Dental Education. Summary of 1978-1979 annual report on dental education. J Am Dent Assoc 98:957-962 (1979).

132. American Association of Dental Radiology Newsletter (December 1977).

133. U.S. Department of Health, Education, and Welfare, Public Health Service, Food and Drug Administration, Report of State and Local Radiological Health Programs Fiscal Year 1977. HEW Publication (FDA) 78-8034 (1978).

134. Suggested State Regulations for Control of Radiation. Prepared by Conference of Radiation Control Program Directors, Inc., U.S. Nuclear Regulatory Commission, U.S. Environmental Protection Agency, and U.S. Department of Health, Education, and Welfare (October 1978).

BIBLIOGRAPHY

Loyola University. Chicago College of Dental Surgery Catalogue, 1976-1978, Vol. 42, No. 15. Chicago, Illinois (1976).

McDonnell, R.E. The Minnesota Experience: Implementing Mandatory Continuing Education. J Am Dent Assoc 92:1218-1224 (1976).

Marquette University. School of Dentistry, 1978-79. Milwaukee, Wisconsin (1978).

New Jersey College of Medicine and Dentistry. (Catalog) Newark, New Jersey (1978).

Ohio State University. Bulletin: College of Dentistry, 1978-79, Vol. 83, No. 7. Columbus, Ohio (1978).

Tufts University. Bulletin of Tufts University School of Dental Medicine, Vol. 3, No. 1. Boston, Massachusetts (1979).

Tufts University. Tufts University School of Medicine. Continuing Education, September-December 1979. Boston, Massachusetts (1979).

U.S. Department of Health, Education, and Welfare, Public Health Service, Health Resources Administration Division of Dentistry. Legal Provisions on Expanded Functions for Dental Hygienists and Assistants Summarized by State (1973). Second edition (1974).

University of Colorado, School of Dentistry Continuing Education Courses, Winter 1979. Denver, Colorado (1979).

University of Connecticut. University of Connecticut School of Dental Medicine. Farmington, Connecticut (1979).

University of Florida. College of Dentistry 1978-80 Bulletin. Gainesville, Florida (1978).

University of Illinois. College of Dentistry Catalog, 1978-80. Chicago, Illinois (1978).

University of Maryland. Dental School Bulletin 1978-80. Baltimore College of Dental Surgery. Baltimore, Maryland (1978).

University of Michigan. Bulletin: Graduate Dentistry 1978-79, Vol. 8, No. 10. Ann Arbor, Michigan (1979).

University of Nebraska-Lincoln. College of Dentistry and Dental Hygiene Program Bulletin, 1978-80, Series 80, No. 18. Lincoln, Nebraska (1978).

University of Oklahoma. The College of Dentistry: A Bulletin of The University 1976-77. Oklahoma City, Oklahoma (1976).

University of Oregon Health Sciences Center. Profile: School of Dentistry, 1978-79. Portland, Oregon (1978).

Washington University. Bulletin of Washington University School of Dental Medicine, 1979-80, Series 2, Vol. 77, No. 2. St. Louis, Missouri (1979).

Boston University. Continuing Dental Education, Fall 1979. Boston, Massachusetts (1979).

Case Western Reserve University. Bulletin for the School of Dentistry. Vol. 1, No. 5. Cleveland, Ohio (1977).

Clark, H. Armour: The Teaching of Students in Dental Radiology. Brit Dent J 115:181-182 (1963).

Columbia University. Columbia University Bulletin: School of Dental and Oral Surgery, Vol. 13, No. 4. New York, NY (1979).

Creighton University. Boyne School of Dental Science, Vol. 61, No. 7. Omaha, Nebraska (1978).

Dreier, David L. Coordinating Continuing Education Programs Through Consortia. J Am Dent Assoc 92:1230-1232 (1976).

Emory University. Emory University School of Dentistry, 1978-79, Vol. 64, No. 5. Atlanta, Georgia (1978).

Fairleigh Dickinson University School of Dentistry Bulletin, 1978-79, Vol. 36, No. 1. Rutherford, New Jersey (1978).

Indiana University. Bulletin: School of Dentistry, Vol. 77, No. 7. Bloomington, Indiana (1978).

Loma Linda University. Bulletin: School of Dentistry, 1979-80, Vol. 70, No. 2. Loma Linda, California (1979).

Louisiana State University. (Catalog/Bulletin 1979-80). New Orleans, Louisiana (1979).