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RADIATION HAZARDS FROM THE USE OF DENTAL X-RAY UNITS

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Introduction

It is well known that for many years x-rays have been used in the dental profession as a potent diagnostic tool. Deprived of this means of exploration, the dentist and patient alike would be at a great disadvantage. In spite of the necessity of x-rays in the dental field, little has been done, however, to protect the patient and the dentist from unnecessary exposure. X-rays cannot immediately be felt or seen, and therein lies the hazard attending their use. What cannot be sensed is often ignored, and through unconcern and neglect an exposure resulting in biological impairment or damage may result. It was felt therefore, that the potential hazard occurring during oral roentgenography should be investigated and that the results of the investigation would be of interest to the dental profession.

Instruments and Techniques

The primary standard employed to measure x-ray dosages in the voltage range (50 - 75 kv) common in dental practice was the Victoreen Condenser r-meter and thimble chamber. To supplement these measurements, two types of special monitoring film (Dupont No. 552 and No. 558) as well as a portable ionization chamber were used. The density of the test exposure film was compared directly with the density on standard exposure films by means of a Photovolt densitometer.

All dosages or dosage rates are expressed in roentgens (r), one roentgen being that quantity of x or gamma radiation producing in 1 cc of STP air ions carrying 1 e.s.u. of charge of either sign. The r is equivalent in energy absorption to 83 ergs per gram of tissue and results in the production per gram of tissue of 1.615×10^{12} ion pairs. The presently accepted tolerance dose of x or gamma radiation is 0.3 r per week (specifically excepting possible genetic effects).

Surveys Made to Investigate Hazard to Dentists and Technicians

Radiation survey results are shown below for six dentists' offices in the San Francisco Bay Area. Radiation dosage rates refer to the condition ex-

isting when the voltage and current values were those most commonly used.

Survey Results

Office Number 1: The operator in this office was exposed to a field of x-radiation in excess of 1.2 r/hr.

Office Number 2: Our survey showed that the operator in this office was exposed to a field of radiation in excess of .2 r/hr. The receptionist was exposed to a field of radiation in excess of .06 r/hr.

Office Number 3: The operator in this office was exposed to a field of radiation in excess of 1.5 r/hr. (In this case, recommendations were carried out. Upon resurveying this office, we found the operator was exposed to between .001 - .003 r/hr.)

Office Number 4: In this office the operator was exposed to a field of radiation in excess of .2 r/hr. The walls of this office were portable and very thin. Consequently, the field of radiation in the next office was also in excess of .2 r/hr.

Office Number 5: It was found that the operator was exposed to a field of radiation in excess of 1.2 r/hr. This was a very busy and small office and one of the most hazardous we surveyed. Recommendations were made and steps taken to shield the operator.

Office Number 6: In this office the operator was found to be exposed to a field of radiation in excess of 2.0 r/hr. This was a very small office. The receptionist was exposed to a field in excess of .04 r/hr.

Monitoring films worn by dentists and technicians who made only moderate use of their x-ray equipment in general showed less than tolerance blackening. However, occasional overexposure may result no matter how little the x-ray machine is used. In one instance after a dental technician had worn a film for the period of one week the resultant density was so great that the film could not be read on the densitometer. This density would correspond to an exposure to more than five roentgens or more than seventeen times the maximum permissible weekly exposure.

Discussion

It can be seen that these six offices, assumed to be typical, presented hazards in a greater or lesser degree. The fact that the x-ray machine operator is exposed at all demonstrates the advisability of taking all reasonable precautionary measures against radiation damage.

In general, most of the hazards were removed by the use of:

1. proper shielding
2. collimation of the x-ray beam
3. filtration of the x-ray beam
4. safer physical positions for the x-ray tube and the operator

As an example of (1) and (4), one might construct a semi-permanent screen of 1/16 inch lead sheet through which a lead glass viewing port may be cut. An additional few feet of x-ray machine timer cord would be necessary to allow the operator to stand behind the screen. Collimation should absorb that portion of the x-ray beam that cannot be utilized to expose the dental x-ray film, while filtration with 1 - 2 mm of aluminum actually improves the quality of the x-ray pictures by absorbing the easily scattered, fog producing, low voltage x-rays.

It is probable that all dental offices should be routinely monitored to prevent development of any radiation hazard. Certainly, at the time of installation of equipment an adequate survey should be made. In the event that this was overlooked, one should be made by a competent health physicist in the following manner.

1. A survey with an air ionization chamber, film and Victoreen r-meter.
2. Report and recommendations for shielding and any other necessary steps.
3. Resurvey and complete report of corrected conditions.

A few remarks are in order with respect to the dangers involved when a dentist or technician holds a film in position while making an exposure. This practice is not only extremely dangerous but entirely unnecessary, and repeated performances will very surely result in the loss of at least one and quite often several members of the hand used. However, it should be pointed out thqt this type of injury is on the decline, which can be attributed in part to the following conditions that now prevail in the dental profession.

First, and most important, is the fact that with few exceptions the present day dentist has been properly indoctrinated with respect to this hazard. Second, modern equipment, methods, and techniques have also contributed in a large measure toward eliminating this type of injury. Although the incidence of this kind of injury is lower today than in the past, the potential hazard is always present. With this in mind the dentist must be ever vigilant if injuiries of this nature are to be completely eliminated.

Investigation Made of the Hazard to the Patient

Upon visiting a dentist for preliminary examination, the patient in most instances is subjected to a full mouth x-ray examination. This may entail the taking of 20 to 35 radiographs, depending on the technique used.

The amount of radiation delivered to the patient depends on several factors, which are as follows:

1. The energy of the x-rays used.
2. The focal distance (distance between tube target and skin).
3. The amount of filtration used.
4. The amount of current used.
5. The total time the patient is exposed.

The energy of the x-rays is important, as it is the major factor in determining the rate at which the radiation is being delivered and also in determining the depth of penetration. In most cases, the higher the energy, the greater the rate of delivery and, of course, the greater the energy, the greater the depth of penetration.

In general there are two focal distances used. One technique employs an 8-inch focal distance, the other technique uses a 16-inch focal distance. In using the 8-inch distance, the exposure time is shorter as compared to the 16-inch distance, but the total amount of radiation delivered to the patient can be as high as three to four times that which is delivered when the longer focal distance is used. One might think that the dosage delivered to the patient would be the same in both cases and that the exposure time using the 8-inch distance should be one-fourth that used in the 16-inch technique. However, this is not the case. In most cases the total exposure time using the 8-inch technique is only about 35 percent shorter than the time used with the 16-inch technique.

The amount of filtration used with dental machines is very important. In many instances no filtration is used. The failure to filter out all soft radiation increases the dosage tremendously.

Most machines examined in this study were using a current of 10 M.A.

The total time of exposure for a full mouth examination varies, depending on the technique employed. It can be as short as 50 sec. and may be as long as 1 min. 35 sec. This is no doubt the most important factor in determining the total dose delivered to the patient.

Films were used to determine the dose delivered to various anterior and lateral surfaces of the face, neck and chest. This was accomplished in

the following manner. Films were placed in contact with the patient's neck, completely surrounding that portion of the body. In addition, films were also placed at twelve locations on the anterior surface of the body between the neck and the waist. This technique was used with three patients. These location films were read on a Photovolt Densitometer against a previously run set of film standards. The measurement pertaining to the rate at which the dose is delivered was repeated several times in all cases.

Dental Units Examined and Results Obtained

Thirty-two dental units were examined in the San Francisco Bay Area. The following data was collected from three of these units. These machines were assumed to be typical, and as one can see, the results vary depending on the machine and the technique used.

Machine A. This machine was operated at 65 K.V., 10 M.A., no filtrations, and at a 16-inch focal distance. The number of exposures for a full mouth examination averaged about 30. The total time of exposure was about 90 sec. The rate of delivery was 75 r/min. or a total of 113 r delivered to the area during a full mouth examination.

Machine B. This machine was operated at 45 K.V., 10 M.A., no filtration and at an 8-inch focal distance. The number of exposures for a full mouth examination in this office was about 25. Total exposure time was about 70 sec. The rate of delivery was 270 r/min. or a total of about 315 r to the area during a full mouth examination.

Machine C. This machine was operated at 65 K.V., 10 M.A., no filtration and at an 8-inch focal distance. The number of exposures for a full mouth examination in this office was about 28. Total exposure time was about 75 sec. The rate of delivery was 190 r/min. or a total of about 238 r delivered to the area during a full mouth examination.

An examination of Machine B was made after a 2 mm Al filter had been installed, all other operating conditions remaining the same. The rate of delivery is now 40 r/min. as compared to 270 r/min. without filtration. The radiographs were of much finer quality owing to the fact that much of the softer radiation that tends to fog the film was now eliminated.

In all three cases where film was used to measure the dosage to various lateral and anterior surfaces of the body the dose delivered to any area below the shoulder line did not exceed 2 r. In the region of the face

and neck the dose delivered was much greater, and exceeded 75 r to both lateral surfaces and somewhat less to the anterior surface.

In the region of the neck there is a concentration of lymphatic tissue. This tissue is exceedingly sensitive to radiation[1] and with such high dose rates changes in the blood picture of patients undergoing such examinations might be expected.

At the present writing ten patients have been observed in the following manner. A W. B. C. and differential counts were done every hour beginning at 8:00 A. M. and running in some cases until 10:00 P. M. two to three days before exposure to a full mouth x-ray examination. This allowed observation of the normal diurnal variation of the particular patient. On the day of examination the same procedure was followed. The patient was observed daily after the first day for several days and will be observed weekly for several weeks.

The ten patients who received full mouth x-ray examinations were exposed to the following amounts: 35 r, 115 r, 135 r, 65 r, 315 r, 315 r, 285 r, 282 r, 285 r, 280 r. The last six amounts represent dosages delivered to patients exposed to Machine B. In all cases a significant change in the blood picture was observed to a greater or lesser degree depending on the dose delivered. With the exception of the patient who received only 35 r, all others showed an apparent depression in lymphocytes[2]. This depression was noted as early as the 7th hour after the x-ray examination, and in some cases did not occur until about 12 hours after the x-ray examination. The lymphocyte count remained depressed for a period varying from two hours to 30 hours. In one case when the patient received 315 r, the depression seemed to be close to 45 percent. Other hematological changes were observed and are being further investigated.

Discussion of Results

It can be seen from the above data that a considerable amount of radiation is absorbed by the patient. The exposure is not confined entirely to the area being radiographed but extends over a much larger area. It can also be seen that very good radiographs can be obtained without exposing the patient to an unnecessary dose of radiation. It should be pointed out that the total amount of radiation delivered to the patient is delivered to an

area embracing the entire jaw and neck area. To any 1 c.c. of skin surface the dose will in most cases not exceed 100 r. However, it should also be pointed out that there are many intersecting lines of radiation within the neck and oral cavity due to the angle at which the radiographs are taken. These points of intersection are definitely points of higher ionization.

The results of the hematological studies will be discussed in a future report. For the present it can be said that significant blood changes have been observed in patients exposed to full mouth x-ray examinations to a greater or lesser degree, depending on the total exposure.

Other points that should be mentioned are the following: A patient could conceivably be exposed several times to a full mouth x-ray examination within a short period of time. In many cases, the entire upper portion of the body is bathed in radiation to a greater or lesser degree.

Summary and Recommendations

In the future the use of x-rays as a diagnostic tool will certainly increase rather than decrease, both in the medical as well as the dental profession. In view of this trend it would seem logical that the dentist give careful consideration to all factors involved before ordering full mouth radiography. The patient should be questioned with respect to prior x-ray examinations of any nature. It might be well to bear in mind that present thinking is that ionizing radiation of all types has a cumulative biological effect.

It is entirely possible that a patient could be undergoing a radiographic examination of some other portion of the body during the same period that oral roentgenography is being performed. In many cases this would be very objectionable.

Personnel who presumably will be engaged for many years in a profession necessitating their working with various types of radiation and radioactive materials should avoid full mouth radiography as a routine procedure.

A record of exposure should be kept of all persons undergoing x-ray examination of any type.

All personnel whose profession requires them to use x-ray equipment of any kind should be completely familiar with the equipment they use with respect to the K.V. used, the currents used, what filtration is

employed, if any, and of course the output of the unit.

Several recommendations are in order at this point with respect to the dental unit itself.

1. All dental units should be equipped with proper filtration.
2. The x-ray beam should be collimated so as to cover precisely the area to be radiographed.
3. A long focal distance should be used at all times.
4. The shell housing the tube should be x-ray proof. (Many in use at the present time are not.)
5. It might be profitable to investigate some new film techniques, such as impregnating the emulsion with a material that would fluoresce upon being irradiated. One might use a piece of calcium tungstate to be included as an integral part of the film packet.
6. It might also be worthwhile to consider a shield of some sort to protect the patient's neck from secondary and scattered radiation.

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References

1. M. Ingram, and W. B. Mason: The Effects of Acute Exposure to Roentgen Radiation on the Peripheral Blood of Experimental Animals, A. E. C. Report UR 122 (July 17, 1950).
2. L. O. Jacobson, and E. K. Marks: The Hematological Effects of Ionizing Radiation in the Tolerance Range, Radiology 49, 286-298 (September, 1947).