Patients often read about the dangers of ionizing radiation, out of proportion to the actual dangers that exist. When you recommend the taking of radiographs, patients will probably ask you to how much radiation they are being exposed and the dangers. It is important that we know the facts and how to answer their questions. You must be able to explain the possible disadvantages and the probable advantages of taking radiographs to your patients in an intelligent way that they understand.

Average annual effective dose in the U.S. to the population.

There are many sources of ionizing radiation to which the population is exposed. They can be divided into

A. Natural Sources
   3.00 mSv. (0.3Sv) Or 30Rem

   External
   Internal

B. Artificial Sources
   0.60 mSv or 60 Rem

   Medical
   Occupational
   Fallout
   Miscellaneous

SOURCES OF RADIATION EXPOSURE.

The population is exposed to a great variety of sources of ionizing radiation. By far the greatest source is Radon which accounts more than half of the total.

A. Natural or Background Radiation.

This accounts for more than 80% of the total sources. There is no proved relationship between the level of background radiation and the incidence of leukemias or congenital malformations. Recently some evidence has appeared in Brazil, South America between the incidence of background radiation and skin cancer.

External.

a. Cosmic Radiation.

Cosmic radiation is primarily a function of altitude, almost doubling every 2,000 meters in elevation. People living at sea level are exposed to lower levels than people at high altitudes. Airline travelers
are exposed to greater amounts because of the altitude and as more people are travelling by air
cosmic radiation is becoming a significant contributor. Astronauts are an extreme example.

b. **Terrestrial Radiation.**

The rates vary tremendously in different parts of the country. The average for the country is
0.30mSv; depending on the type and content of the soil. In parts of the country the average is double
this amount. Naturally occurring radionuclide **potassium - 40** and the radioactive decay products of
**uranium - 238** and **thorium 232** produce gamma radiation from the superficial 8 inches of the soil.
Indoor exposures are very similar to outdoor exposures in an area. People living on **granite** receive
more radiation than people living on sandy soil.

c. **Internal Sources.**

These sources of radiation are external sources that get taken up internally, mainly by ingestion and
inhalation. The body does not differentiate normal elements from the radioactive isotopes.

**Radon**

Radon from the earth is transported in water and air that enters our homes and attaches to aerosols
that can be deposited in the respiratory tract. **Radon** is the greatest source and accounts for more
than half of the radiation exposure of the U.S population and accounts for up to 10,000 deaths a year
from lung cancer.

**Other Internal Sources.**

Artificial radionuclides resulting from nuclear explosions reach the body through natural food chains,
especially **Strontium - 90** a beta emitter and **uranium 238**. This source has been dramatically
reduced because of a ban on nuclear testing world wide.

B. **Artificial Radiation.**

Technological advances have added a number of sources of radiation to the environment.

a. **Medical Diagnostic and Therapeutic.**

There are almost half a million X-ray machines in the U.S. contributing about 15% of the total
radiation received by the population. There are about 350,000 dental units in the US. The dose
received from dental exposure is a small, about 2.5% of this total and about 0.3% of the overall total.
Dental exposures however, could and should be much less than it is as many dentists are utilizing
short cones, D-speed film, low kVp etc. In 1993 300 million dental examination were done world
wide. Radiation used in the healing arts is the largest amount of radiation to which the US population
is exposed.

b. **Consumer and Industrial Sources.**

By far the greatest users of X-rays but this source contributes only about 3% of the average annual
dose. A few unsuspecting categories of radiation sources are found in this group; namely dental
porcelains, television receivers, some pocket watches, domestic water supply, smoke alarms, airport
detectors, and also smoking [Pb and Po are alpha emitters]
c. **Other Artificial Sources.**

There are about 113 nuclear power reactors in this country, another 70 are being used for research and at 100 reactors are being used in US Navy ships and accidents such as Three Mile Island can again occur. However the total from this source, we are told, is small. The Chernobyl disaster resulted in much more radiation being pushed into the atmosphere and it is estimated that tens of thousands of people in that area will die during our lifetime, from leukemia and solid tumors. There is radiation in the air from the nuclear weapons testing in the 1950's

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**EXPOSURE AND DOSE RADIATION.**

The ALARA Principle should always be applied for patients and operators. One should always assess one’s radiographic techniques to ensure that the patient will receive the minimum amounts of radiation and that the operator complies with state and federal requirements.

**Occupational Dosage.**

In the past the principle of the Maximum Permissible Dose was applied and for operators is the maximum dose that an operator or an organ can receive in a stated period and still be considered as working in a safe environment/profession.

The MPD previously was 5 rem (50 mSv or 0.05 Sv) per year and this is the number that is asked in the Boards and is used for calculations in those exams. The amount was reduced several years ago to 2 rem (20 mSv or 0.02 Sv) and this is the dose that I use. The calculation for determining MPD for an operator is

\[
\text{MPD} = 2(N - 18).
\]

IN THE EXAMS THEY STILL USE 5 rem

Where N is the age of the patient. Operators may not be less than 18 years of age.

We now work on the ALARA Principle - **As Low As Reasonably Achievable.**

**PATIENT DOSE.**

In dental radiology, the amount of radiation received by an organ and the skin or the surface area are usually measured but the thyroid, bone marrow and gonads are also measured. The surface area is important and utilizing E-speed plus film, high kVp and rectangular collimation, a full mouth periapical survey has been calculated to be one third the effective amount of a chest X-ray. Using a short cone, D-speed film and low kVp can account for many times this exposure.

Patient dose is calculated as the **effective dose** so that possible adverse effects from irradiation to a limited part of the body can be compared with possible adverse effects from irradiation to the whole body. It is important to understand this as by **direct** comparison a single periapical radiograph exposes the patient to much more radiation than a chest exposure.

**Mean Active Bone Marrow Dose.**
There is very little bone marrow in the structures that we radiate and thus the mean active dose is much less than a chest X-ray. Chronic radiation to bone marrow can result in leukemia.

**Thyroid Dose.**

This is where the utilization of a long, rectangular collimator instead of a short, round collimator makes a *drastic difference* in the amount of radiation received by this organ. When correctly exposed a FMS will expose the patient to one sixth of the radiographic examination of the spine. With *thyroid shields* this may be even less.

**Gonadal Dose**

The gonads should receive no radiation from dental exposures if the correct collimation and lead aprons are utilized. When a patient is in the supine position, the beam is not directed in the direction of the gonads.

**Brain dose.**

When one changes from a short round cone to a long rectangular cone the *volume* of brain tissue radiated is reduced by over 90%.

**METHODS OF DOSE REDUCTION.**

**Patient Selection**

The ADA states that professional judgment should be used to determine the type, frequency and extent of each radiographic examination.

Do not take a radiograph unless it is absolutely necessary and a clinical examination has determined that it is required and *which views should be taken.* Only registered dentists may prescribe radiographs. The ADA is concerned that radiographs are being taken too often and that too many radiographs are taken at each examination.

**CONDUCT OF THE EXAMINATION.**

Once it has been determined that radiographs are required, one must consider

1. **Choice of Equipment.**

   **Receptor selection.** One should use the film with the fastest speed consistent with high image quality. i.e. E-speed plus. Most dentist still use D-speed film. Some people have suggested halving the exposure time and superimposing the two dental radiographs on each other to provide sufficient density. This is where digital radiology may be of value.

   **Focal spot to film distance.** Doubling the distance reduces the intensity of radiation dramatically, particularly to the thyroid with the rectangular cone. The short round cone should only be utilized when taking occlusal radiographs as a large area is being examined, with patients who will not co-operate, or for endodontics where the rubber dam obscures the area. However, special aligning
instruments are now on the market to solve this problem in endo.  NOTE in the Board examinations they often use an antiquated term for the cone; the PID - position indicating device.

Collimation. The diameter of beam should be collimated so as not to be larger than 7cm (2.75 inches) at the patients skin surface. It is important to remember that the larger the beam the larger the amount of scatter and thus the smaller beam reduces primary and scatter radiation to the patient. This in turn reduces fog on the film resulting in better detail of the image. Collimation is achieved by the diaphragm aperture, the collimator tube, lead lined cones. In addition, one can use film holders to collimate the beam.

Filtration. The ADA recommends that there should be selective filtration of excessively high-energy and excessively low-energy ionizing radiation. Aluminum filtration increases the average intensity of the beam by removing most of the photons with long wave length. At present no dental machines eliminate the high energy range of photons. In time to come the aluminum filters in the dental machines will be replaced by nobium, yttrium and erbium as these eliminate excessive energy at both extremes. For energy levels at or above 70kEv the filter must be 2.5mm aluminum equivalent and under 70 kEv 1.5mm aluminum equivalent.

Intensifying screens. The standard phosphor is calcium tungstate and rare earth phosphors are gadolinium or lanthanum. This is another way to reduce radiation to the patient. Rare earth screens are about twice as fast as standard screen thus reducing the radiation to the patient by about half.

Lead aprons and thyroid shield. The amount of radiation received to the gonads with rectangular collimation is zero yet one applies the ALARA principle. The effect to the thyroid gland has been discussed above. The thickness of the aprons should be 0.25 mm lead equivalent. Thyroid shields are not used with panoramic

The recommendations of the ADA is that pregnant patients can be radiographed, as they assume that all dentists take all the above precautions. Because research has shown that this is very far from factual, I teach that optional radiographs should NOT be taken on pregnant patients.

Technique. It is important that one obtains high quality radiographs consistently and the only way that this can be achieved is by utilizing aligning instruments. Exceptions to this rule were previously discussed.

Operating Equipment.

1. Kilovoltage

Ideally the kVp used should be in the range of 70 to 90kVp. - the exposure factor that controls the energy of the beam.

Diagnostically, an image of high contrast is better suited to for visualizing large differences in density within an object, such as caries or soft tissue calcifications. As the kilovoltage is decreased, the effective energy of the X-ray beam is decreased and the radiographic image contrast increases.

As the kilovoltage is increased, the effective energy of the X-ray beam is increased and the radiographic image contrast decreases. This type of image is more useful for soft tissue visualization and minute changes in bone must be detected.
High kilovoltage utilization produce images of low contrast, also reduce the effective dose delivered, per exposure.

2. **Milliamperes per second** mAs.

Image density is controlled by the **quantity** of photons produced which is controlled by the combination of milliamperage and exposure time. Exposure time has been shown to be the most critical factor in influencing diagnostic quality. In attempt to save time many dentists purposely overexpose the patient to save time processing the film. All too often the film is of very inferior quality.

3. **Processing**

The textbooks claim that ideally the time - temperature technique gives the best results. With a **fully automatic** processor the same results are obtainable. Most errors occur because insufficient attention is paid to correct processing. By retaking radiographs because of poor processing the dose to the patient is increased.

4. **Interpretation**

It is basic that one knows normal anatomy and pathology in order to be able to interpret radiographic anatomy and pathology.

It is essential that radiographs be interpreted on a **viewing box** with the **correct** illumination - 200 candle power. The background illumination should be **subdued**. A **magnifying glass** (to detect small changes in density) and a **ruler** must be at hand when interpreting radiographs.

**PERSONNEL PROTECTION.**

The operator should always stand outside the operatory. Where this is not possible, the operator must stand at least 6 feet away from the X-ray machine and at ninety to 135 degrees to the central beam.

Many states mandate written radiation safety procedures. When mandating barrier thickness for wall, the **number** of radiographs per week (the **workload**), the **distance** to the next room, the **occupancy** of the adjacent room, and the **direction** of the beam are considered.

Radiographs should NEVER be held in position by the patient or the operator. Film holding devices must be used.

The head of the X-ray machine may not drift. This will require the patient to hold the cone and this is NOT permitted.

Film badges should be warn to monitor stray radiation. They contain LiF (Lithium Fluoride) and this technique is known as **thermoluminescent** dosimetry. The LiF is heated, and the amount of light is measured, thus indicating the amount of radiation that the patient received in that wearing period. The only problem is that often one can not remember where or when the exposure occurred.

**Quality Assurance**
Quality assurance programs insure high quality radiographs and thus prevent the necessity for retakes which thus reduce the patient exposures. A simple step wedge can be made from plastic and lead foil. A radiograph is taken utilizing a molar tooth exposure and the radiograph is processed. The one section should be black; if not, the developer solution is exhausted other section should be clear; if not the fixer solution is exhausted and should be changed.