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Radiation Protection: A Review

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Abstract: *radiographic investigations provide useful diagnostic information which is beneficial to the patient, however, the radiographic examination carries the potential for harm from ionizing radiation which includes cancer. Although the radiation doses used by dentists might be low for individual examinations, patients are exposed to repeated examinations over time, and many people are exposed during the course of dental care. The unregulated habit of taking of dental radiographs based on a single frequency for all patients could lead to unnecessary patient exposure.The aim of this article is to improve awareness of the dental practitioners regarding the importance of safety standards in dental radiology*

Keywords: *Radiation protection, dentists, safety standards, safety protocols*

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I. Introduction

Radiology is the branch or specialty of medicine that deals with the study and application of imaging technology like x-ray and radiation to diagnosing and treating disease. Sir Isaac Newton in 1600sproved his theories on gravity. Marie and Pierre Curie had begun their studies in chemistry and physics and Dimitri Mendeleev had introduced the periodic system of elements. Just before the turn of the century, Wilhem Conrad Roentgen discovered the basic properties of X-Rays, the properties of ionizing radiation and the possibility of using radiation in medicine. Finally, in 1896, Henri Becquerel announced the discovery of radioactivity to the Academy of Sciences in Paris. By the early 1900s the study of radiation was a widely accepted scientific endeavor. Dental radiography based on silver halide emulsion has been in use since 1896, just 2 weeks following the discovery of the X-ray by Professor Wilhelm Conrad Roentgen in Wurzburg, Germany. The first dental bitewing radiograph, performed on himself by Otto Walkhoe in 1896, took 25 min to expose due to the unreliable output of the generator combined with the relatively low sensitivity of the receptor, a glass plate coated by hand with photographic silver emulsion.[1]

But, these discoveries did not come without a price. Scientists learned that radiation was not only a source of energy and medicine, it could also be a potential threat to human health if not handled properly. As new uses for radioactive elements were discovered, potentially fatal incidents of overexposure increased. The hazard of radiation, when applied externally, was quickly recognised. The erythema produced by X-rays was noted within a few days after the discovery of this radiation and, shortly after the discovery of radium, similar damage to the skin was found. Thirty years were to elapse before the severe lesions caused by the internal deposition of radium in the body were recognised and described. In September 1924, at a meeting of the American Roentgen Ray Society, Arthur Mutscheller was the first person to recommend a “tolerance” dose rate for radiation workers, a dose rate that in his judgement could be tolerated indefinitely. He based his recommendation on observations of physicians and technicians who worked in shielded work areas. In 1934, the U.S. Advisory Committee on X-ray and Radium Protection proposed the first formal standard for protecting people from radiation sources. By then the quantitative measurement of ionizing radiation had become standardized in units of roentgens, and therefore, the recommended limit on dose rate was expressed as 0.1 roentgen per day. The International Commission of Radiation Protection (ICRP) was formed in 1928 on the recommendation of the first International Congress of Radiology in 1925. The commission consists of 12 members and a chairman and a secretary who is chosen from across the world based on their expertise. The first International Congress also initiated the birth of the ICRU or the International Commission on Radiation Units and measurements.

The Indian regulatory board is the AERB, Atomic Energy Regulatory Board. The Atomic Energy Regulatory Board was constituted on November 15, 1983 by the President of India by exercising the powers conferred by Section 27 of the Atomic Energy Act, 1962 to carry out certain regulatory and safety functions under the Act. The regulatory authority of AERB is derived from the rules and notifications promulgated under the Atomic Energy Act, 1962 and the Environmental (Protection) Act, 1986. The mission of the Board is to ensure that the use of ionizing radiation and nuclear energy in India does not cause undue risk to health and environment .

In dental practice , the people who are the risk of radiation poisoning are

- Dentist
- Patient
- Assistant

The governing bodies have set guidelines for protection of the above.
In general, the amount and duration of radiation exposure affects the severity or type of health effect. There are two broad categories of health effects:

- Stochastic
- Deterministic

Stochastic effects are associated with long-term, low-level (chronic) exposure to radiation. Cancer is considered by most people the primary health effect from radiation exposure. Radiation can cause changes in DNA, the "blueprints" that ensure cell repair and replacement produces a perfect copy of the original cell. Changes in DNA are called mutations.Deterministic effects appear in cases of exposure to high levels of radiation, and become more severe as the exposure increases. Short-term, high-level exposure is referred to as 'acute' exposure. If the dose is fatal, death usually occurs within two months. The symptoms of radiation sickness include: nausea, weakness, hair loss, skin burns or diminished organ function. For these reasons, compliance to as low as reasonably achievable (ALARA) principles becomes important in their practice in order to reduce patient exposure to ionizing radiation[2].Although widely accepted selection criteria are lacking, there is general agreement about the methods to reduce radiation dose. Despite this numerous surveys have concluded that patients are subjected to unnecessary radiation exposure during dental radiography.[3]

Principles of radiation protection
The current radiation protection standards are based on three general principles :-
a) Justification of a practice i.e. no practice involving exposures to radiation should be adopted unless it provides sufficient benefit to offset the detrimental effects of radiation.
b) Protection should be optimized in relation to the magnitude of doses, number of people exposed and also to optimize it for all social and economic strata of patients.
c) Dose limitation, on the other hand, deals with the idea of establishing annual dose limits for occupational exposures, public exposures, and exposures to the embryo and fetus[4]

Guidelines for practicing dental radiography Critical examination of the machine
The plans for the installation of a dental X-ray set should be critically reviewed by a qualified expert to ensure that all aspects of radiation safety for both practice staff and the public. In particular, the following aspects need evaluation: Installation of the X-ray machine: On installation, dental X-ray equipment should be subject to the following inspections/ tests:
1. Critical examination of plans for installation from the point of view of radiation safety of staff and members of the public.
2. Acceptance test – performed prior to the equipment's use in clinical practice. 3. Routine tests – these should be performed at regular intervals[5].

Radiation protection actions
The triad of radiation protection actions comprise of "time-distance-shielding". Reduction of exposure time, increasing distance from source, and shielding of patients and occupational workers have proven to be of great importance in protecting patients, personnel, and members of the public from the potential risks of radiation[6] .

Time
The exposure time is related to radiation exposure and exposure rate (exposure per unit time) as follows :

$$\text{Exposure time} = \frac{\text{Exposure}}{\text{Exposure rate}}$$

Or
Exposure = Exposure rate x Time

The algebraic expressions simply imply that if the exposure time is kept short, then the resulting dose to the individual is small[6].

Distance

The second radiation protection action relates to the distance between the source of radiation and the exposed individual. The exposure to the individual decrease inversely as the square of the distance. This is known as the inverse square law,

The Inverse Square Law

$$\frac{I_1}{(I_2)} = \frac{(d_2)^2}{(d_1)^2}$$

I_1 is the initial intensity of radiation, d_1 is the initial distance, and d_2 is the final distance, and I_2 is the final intensity.

In mobile radiography, where there is no fixed protective control booth, the technologist should remain at least 2 m from the patient, the x-ray tube, and the primary beam during the exposure. In this respect, the ICRP (1982), as well as the NCRP (1989a), recommended that the length of the exposure cord on mobile radiographic units be at least 2 m long[6].

Another important consideration with respect to distance relates to the source-to-image receptor distance (SID). The appropriate SIDs for various examinations must always be maintained because an incorrect SID could mean a second exposure to the patient. Long SID results in less divergent beam and thus decreases the concentration of photons in the patients. Short SID results in the reverse action and increases the patient dose. Hence the longest possible SID should be employed in examinations. However, if a greater than standard SID is used then greater intensity of radiation would be required to produce the same film density. Therefore it is recommended that only standard SIDs should be used[6] .

Shielding

The third radiation protection action relates to shielding. Shielding implies that certain materials (concrete, lead) will attenuate radiation (reduce its intensity) when they are placed between the source of radiation and the exposed individual.

We shall discuss four aspects of shielding in diagnostic radiology :

1. X-ray tube shielding
2. Room shielding
(a) X-ray equipment room shielding
(b) Patient waiting room shielding.
3. Personnel shielding
4. Patient shielding (of organs not under investigation)

X-ray tube shielding (Source Shielding)

The x-ray tube housing is lined with thin sheets of lead because x-rays produced in the tube are scattered in all directions. This shielding is intended to protect both patients and personnel from leakage radiation[6] . Leakage radiation is that created at the X-ray tube anode but not emitted through the x-ray tube portal. Rather, leakage radiation is transmitted through tube housing. Manufacturers of x-ray devices are required to shield the tube housing so as to limit the leakage radiation exposure rate to 0.1 R hr-1 at 1 meter from the tube anode[7] . AERB recommends a maximum allowable leakage radiation from tube housing not greater than 1mGy per hour per 100 cm2[8] .

Room shielding (Structural Shielding)

The lead lined walls of Radiology department are referred to as protective barriers because they are designed to protect individuals located outside the X-ray rooms from unwanted radiation There are two types of protective barriers.

(a) Primary Barrier: is one which is directly struck by the primary or the useful beam.

(b) Secondary Barrier: is one which is exposed to secondary radiation either by leakage from X-ray tube or by scattered radiation from the patient.

The shielding of X-ray room is influenced by the nature of occupancy of the adjoining area. In this respect two types of areas have been identified.

(a) Control Area: Is defined as the area routinely occupied by radiation workers who are exposed to an occupational dose. For control area, the shielding should be such that it reduces exposure in that area to <26 mC/kg/week.

(b) Uncontrolled areas: Are those areas which are not occupied by occupational workers. For these areas, the shielding should reduce the exposure rate to <2.6mC/kg/week[6].

AERB has laid down guidelines for shielding of X-ray examination room and patient's waiting room which are as follows.

(a) X-ray examination room shielding

Rooms housing diagnostic X-ray units and related equipment are located as far away as feasible from areas of high occupancy and general traffic, such as maternity and paediatric wards and other departments of the hospital that are not directly related to radiation and its use. The room housing an X-ray unit is not less than 18 m2 for general purpose radiography and conventional fluoroscopy equipment. In case the installation is located in a residential complex, it is ensured that (i) wall of the X-ray rooms on which primary X-ray beam falls is not less than 35 cm thick brick or equivalent, (ii) walls of the X-ray room on which scattered X-rays fall is not less than 23 cm thick brick or equivalent, (iii) there is a shielding equivalent to at least 23 cm thick brick or 1.7 mm lead in front of the doors and windows of the X-ray room to protect the adjacent areas, either used by general public or not under possession of the owner of the X-ray room . Unshielded openings in an X-ray room for ventilation or natural light, are located above a height of 2 m from the finished level outside the X-ray room.

Patient waiting area

Patient waiting areas are provided outside the X-ray room. A suitable warning signal such as red light and a warning placard is provided at a conspicuous place outside the X-ray room and kept 'ON' when the unit is in use to warn persons not connected with the particular examination from entering the room[8].

Shielding of the Xray control room :

The control room of an X-ray equipment is a secondary protective barrier which has two important aspects:
(a) The walls and viewing window of the control booth, which should have lead equivalents of 1.5mm.
(b) The location of control booth, which should not be located where the primary beam falls directly, and the radiation should be scattered twice before entering the booth[6].

The AERB recommends the following shielding for the X-ray control room: The control panel of diagnostic X-ray equipment operating at 125 kVp or above is installed in a separate room located outside but contiguous to the X-ray room and provided with appropriate shielding, direct viewing and oral communication facilities between the operator and the patient. In case of X-ray equipment operating up to 125 kVp, the control panel can be located in the X-ray room. AERB recommends that the distance between control panel and X-ray unit/chest stand should not be less than 3 m for general purpose fixed x-ray equipment[8].

Personnel shielding

Shielding of occupational workers can be achieved by following methods:

(a) Personnel should remain in the radiation environment only when necessary (step behind the control booth, or leave the room when practical)

(b) The distance between the personnel and the patient should be maximized when practical as the intensity of radiation decreases as the square of distance (inverse square law).

(c) Shielding apparel should be used as and when necessary which comprise of lead aprons, eye glasses with side shields, hand gloves and thyroid shields.

Lead aprons are shielding apparel recommended for use by radiation workers. These are classified as a secondary barrier to the effects of ionizing radiation. These aprons protect an individual only from secondary (scattered) radiation, not the primary beam[9]. The thickness of lead in the protective apparel determines the protection it provides. It is known that 0.25 mm lead thickness attenuates 66% of the beam at 75kVp and 1mm attenuates 99% of the beam at same kVp. It is recommended that for general purpose radiography the minimum thickness of lead equivalent in the protective apparel should be 0.5mm[9] . It is recommended that women radiation workers should wear a customized lead apron that reaches below midthigh level and wraps completely around the pelvis. This would eliminate an accidental exposure to a conceptus[10].

Care of the lead apparel: It is imperative that lead aprons are not abused, such as by dropping them on the floor, piling them in a heap or improperly draping them over the back of a chair. Because all of these actions can cause internal fracturing of the lead, they may compromise the apron's protective ability. When not in use, all protective apparel should be hung on properly designed racks. Protective apparel also should be radiographed for defects such as internal cracks and tears at least once a year[9].

Other protective apparel include eye glasses with side shields, thyroid shields and hand gloves. The minimum protective lead equivalents in hand gloves and thyroid shields should be 0.5mm[6].

Patient and personnel exposure

In routine dental practice, effective dose should never exceed 1 mSv per year, which is the annual dose limit for the public. Likewise, dose to the skin of the hands should be well below the dose limit. However, in the past, incidences of deterministic damage to fingers have been reported in dentists due to the custom of holding the film in the patient’s mouth, a practice that should avoided. If patient assistance is required, the assisting adult should be provided with a lead apron and positioned so that all parts of their body are out of the main beam. The dental film or detector should only be held by the patient when it cannot otherwise be kept in position. It should never be hand held by a member of the dental practice staff.For a point source of radiation, the dose rate falls off as the inverse of the square of the distance from the source (as light intensity falls off at distance from a light bulb). Standing at a distance of 2 m from the patient’s head will lead to a dose of roughly a quarter of that received standing only 1 m away. For scattered radiation, the use of distance alone is often adequate protection in the dental situation[11].

Darkroom and desktop processing units

Routine checks should be made to ensure that darkrooms remain light tight and that safelights do not produce fogging of films. Desktop units should be similarly checked for light-tightness. This can be done using a simple ‘coin’ test. Routine checks should be carried out every 12 months or if any alterations to darkroom or equipment have been performed[12]

Room layout

Consideration needs to be given to the layout of the room so that radiation safety is optimized. The room should be of adequate size to allow all staff that needs to remain within the room to position themselves outside the controlled area during exposure. It is essential that the operator of the equipment can position themselves so that they have a view of: patient, controlled area and ‘X-rays on’ indicator light. If the room size is limited, it might be necessary for staff to position themselves outside the room, in which case a mirror might be required to ensure that a clear view of the room is maintained. The equipment should be positioned so that the controlled area does not extend to any entrances and so that the primary beam will not be directed towards any doorways or ground floor windows. The exposure switch should be located so that that the operator cans either remain outside of the controlledarea or be behind a protective screen. In addition, attention should be given to the location of the mains on switch[13.]

Protection for adjacent areas

It is essential to consider the likely consequences in terms of radiation dose to staff and members of the public in adjacent areas. Protection is often quoted in terms of the thickness of lead (usually some 0.1-1mm) required and this will be dependent on such factors as distance of the barrier from the X-ray tube, the use of adjacent area, workload etc. Alternatively lead lined plywood or plasterboard can be used to obtain the desired protection. For the average dental facility, structural protection can readily be achieved using traditional building material[14].

Pregnant staff

It is well documented that the fetus is sensitive to ionising radiation. Consequently, special attention is paid to workers using ionising radiation who are pregnant and includes a separate dose limit of 1 mSv to the fetus during the declared term of pregnancy. In dental practice, it would be considered unusual for any members of staff to be exposed to radiation to an extent that would lead to this level of fetal dose. However, female staff should be encouraged to inform their employer of pregnancy. The lead practitioner should ensure that the pregnant employee work load is assessed and if there is a likelihood of the fetal dose exceeding this level then a qualified expert should be consulted for specific advice to ensure that the fetal dose will be limited[15].

II. Conclusion

Many of us, as dentists, even though have an idea of biological hazards of radiation we do not follow the precautions and safety factors especially in our private practice. We consider that a radiation exposure in a private clinic set up is negligible, which is not true as we ourselves take radiograph for the patients where we get directly exposed to X-rays and definitely in a long term will have deterministic effects affecting us. Hence we should follow strictly the radiation protection rules in our clinical practice so that both patients and we are protected from the hazards of radiation due to the diagnostic radiology[16]

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