University of Diyala
Collage of Medicine
Sixth stage
2021

DENTAL X-RAY AND RISK OF THYROID CANCER

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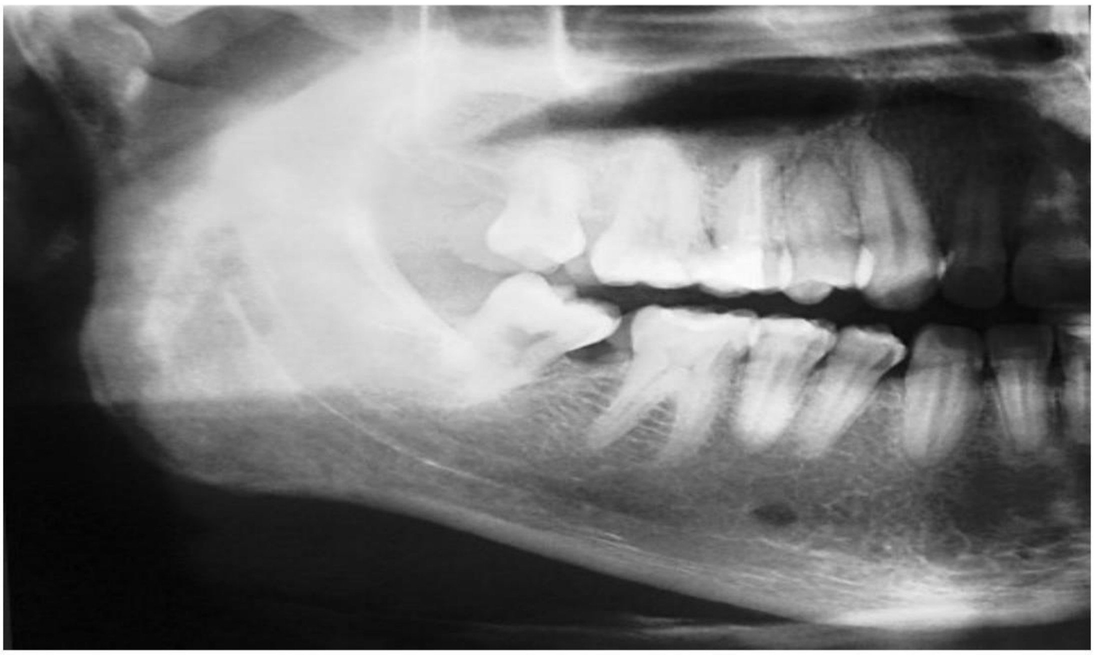

On this lecture we going to discuss the following:

- **Thyroid cancer background and epidemiology.**
- **Types of thyroid cancer .**
- **Risk factors of thyroid cancer.**
- **Exposure to dental X-rays and risk of developing thyroid cancer.**
  - **Dental radiology .**
  - **Radiation dose and risk.**
  - **Epidemiology Studies of dental X-ray and risk of thyroid cancer .**
- **Radiation shielding in dentistry.**

Abstract

The thyroid, a small butterfly-shaped gland that impacts almost all of the body's metabolic processes ,is among the most susceptible sites to radiation induced carcinogenesis. The risk of thyroid cancer arising from radiation exposure is strongly dependent on age at exposure. This risk is greatest in children, increasing dramatically as the child's age at exposure decreases.Risk of thyroid cancer for adults exposed to radiation is low, but not absent. It is only recently that a risk for exposure after the age of 15 has been observed .Among children and adults alike, the risk of thyroid cancer resulting from radiation exposure is reduced proportionately with the dose of radiation received. Thyroid cancer incidence is increasing throughout the world. In the US in particular, it is increasing faster than any other cancer, with more than 56,000 people diagnosed with thyroid cancer in 2012 alone .Although it is unlikely that radiation exposure is the predominant contributor to this trend, an increase in the use of diagnostic x-rays, is widespread and necessitates the protection of the thyroid gland where possible to diminish thyroid cancer risk .

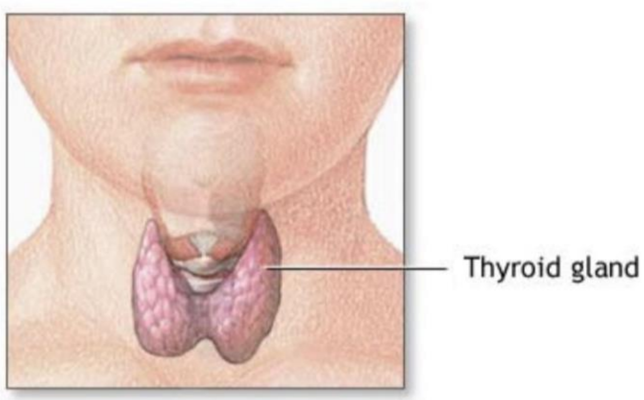

Fig 1: Thyroid gland.

Introduction

The thyroid gland is a small butterfly-shaped gland highly susceptible to radiation carcinogenesis and exposure to high-dose ionising radiation is the only established cause of thyroid cancer. Evidence for an association between exposure to high-dose ionising radiation and thyroid cancer has come from studies of children who had received x-ray treatment for benign conditions such as enlarged tonsils, hae-mangioma, ringworm of the scalp , skin disorders, and painful arthritis and spondylosis of the cervical spine [3]. Similar evidence has also come from radiation treatment of children with a range of malignancies where the treatment field included the thyroid. Additional evidence has come from the study of Japanese survivors of the American atomic bombs of 1945 and the Chernobyl nuclear power plant accident in 1986 [4].Medical diagnostic x-rays of the head and neck, particularly dental x-rays are an important source of ionising radiation to the thyroid gland. The anatomic position and the relatively high radiosensitivity of the thyroid gland make it an organ of concern in dental radiography. There is limited epidemiological data on thyroid cancer risk associated with low-dose radiation exposures from common diagnostic x-rays. Low-dose radiation has been associated with thyroid dysfunction such as thyroid autoimmunity among young females, thyroid cysts in females of all ages and papillary thyroid cancer in younger women. An increased risk of thyroid cancer has also been reported in dentists,dental assistants , diagnostic x-ray workers and radiologic technologists suggesting that multiple low-dose exposures in adults may also be important.

Thyroid cancer background and epidemiology

Thyroid cancer is the most common type of endocrine malignancy,thyroid cancers represent approximately (1%) of new cancer diagnoses each year. About 23,500 cases of thyroid cancer are diagnosed annually in the United States. The incidence of the disease is three times higher in women than in men and the incidence of thyroid cancer peaks in the third and fourth decades of life.A study by Davies et al using data from the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) Program and the National Vital Statistics System found that between 1975 and 2009, the rate of thyroid cancer among adults in the United States rose from 4.9 per 100,000 individuals to 14.3 per 100,000 persons.Thyroid cancers are divided into papillary carcinomas represents (80%)of all thyroid neoplasms. Follicular carcinoma is the second most common thyroid cancer, accounting for approximately(10%) of cases. medullary thyroid carcinomas (MTCs) represent(5-10%) of neoplasms. Anaplastic carcinomas account for (1-2%). Primary lymphomas and sarcomas are rare[5].Patients with thyroid cancers generally have a favorable prognosis compared with that of patients with many other solid tumors, an estimated 1200 patients died of thyroid cancer in the United States in 1998. Contemporary treatment of patients with thyroid malignancy requires a multidisciplinary approach involving an endocrinologist, a thyroid surgeon, a radiologist, and, on occasion, medical and radiation oncologists.

Types of Thyroid Cancer

Papillary carcinoma

Papillary carcinoma is the most common thyroid malignancy representing approximately(80%). Papillary carcinoma and follicular carcinoma make up the well-differentiated thyroid carcinomas. Women develop papillary cancer 3 times more frequently than men do and the mean age at presentation is 34-40 years.[5]

Follicular carcinoma

Follicular carcinoma is the second most common thyroid malignancy and represents about (10%) of thyroid cancers. Follicular carcinoma represents an increased portion of thyroid cancers in regions where dietary intake of iodine is low. Similar to papillary carcinoma, follicular carcinoma occurs 3 times more frequently in women than in men. Patients with follicular carcinoma are typically older than those with papillary carcinoma at presents. The mean age range at diagnosis is late in the fourth to sixth decades.[5]

Medullary thyroid carcinomas

MTCs represent approximately(5%)of all thyroid malignancies. A slight female preponderance is observed. Tumors arise from the parafollicular C cells of the thyroid gland. C cells are neural-crest derivatives and produce calcitonin. About (75%) of MTCs occur sporadically, and(25%)occur familially. Familial cases are commonly multifocal throughout the thyroid gland, whereas sporadic cases are usually not multifocal.[5]

- **Anaplastic Thyroid Carcinoma**

Anaplastic thyroid carcinoma is one of the least common thyroid carcinomas, accounting for(1.6%) of all thyroid cancers. However, it has the most aggressive biologic behavior of all thyroid malignancies and one of the worst survival rates of all malignancies in general. Like papillary and follicular carcinomas, anaplastic thyroid carcinomas affect more women than men, with a female-to-male ratio of about 2-3:1. Patients with anaplastic thyroid carcinomas present later than those with other thyroid malignancies,the former most typically present in the sixth or seventh decade of life.[5]

Risk factors of thyroid cancer

Risk factors for thyroid cancer include the following:

- **Gender** : Women are diagnosed with 3 of every 4 thyroid cancers.
- **Age**:Thyroid cancer can occur at any age, but about two-thirds of all cases are found in people between the ages of 20 and 55. Anaplastic thyroid cancer is usually diagnosed after age 60.
- **Genetics**:genetic conditions such as familial medullary thyroid cancer (FMTC), multiple endocrine neoplasia type 2A syndrome (MEN2A), or multiple endocrine neoplasia type 2B syndrome (MEN2B).
- **Family history** of thyroid disease or thyroid cancer.
- **Race**:White people and Asian people are more likely to develop thyroid cancer, but this disease can affect a person of any race or ethnicity.
- **Low dietary intake of iodine** does not increase the incidence of thyroid cancers overall. However, populations with low dietary iodine intake have a high proportion of follicular and anaplastic carcinomas.[5]
- **Breast cancer:** recent study showed that breast cancer survivors may have a higher risk of thyroid cancer, particularly in the first 5 years after diagnosis and for those diagnosed with breast cancer at a younger age.

- **Radiation:** Radiation exposure significantly increases the risk for thyroid malignancies, particularly papillary thyroid carcinoma. This finding was observed in children exposed to radiation after the nuclear bombings in Hiroshima and Nagasaki during World War II. Additional evidence was gathered after atomic bombs were tested in the Marshall Islands, after the accident at the Chernobyl nuclear power plant, and in patients who received low-dose radiation therapy for benign disorders (eg, acne, adenotonsillar hypertrophy). Low-dose radiation exposure from imaging studies has not been found to have a tumorigenic effect. Radiation targeting the thyroid gland (eg, iodine-131 ablation of the thyroid) or high-dose external-beam radiation therapy does not appear to increase the risk of papillary thyroid carcinoma. This is presumably because cell killing increases with these doses.[5]

Exposure to dental X-rays and risk of developing thyroid cancer

❖ Dental radiology

Radiographs are essential to dentists for diagnosis, treatment planning and monitoring treatment or lesion development. However, an integral part of radiography is exposure of patients and potentially clinical staff to X-rays. No exposure to X-rays can be considered completely free of risk, so the use of radiation by dentists is accompanied by a responsibility to ensure appropriate protection.[2]

- **Three factors make dental x-rays a concern as a potential risk for thyroid cancer.**
  - First, in contrast to mammograms they are used routinely in children and also in the treatment of prevalent dental conditions in children.
  - Second, the thyroid gland in children is especially sensitive to the effects of radiation.
  - Third, a child's thyroid gland is closer to the target of the dental x-ray.

There is little doubt that, when used appropriately, dental x-rays are of benefit.[22]

❖ Radiation dose and risk

X-rays

X-rays are a type of electromagnetic radiation. electromagnetic radiation also includes visible light, radio waves, microwaves, cosmic radiation, and several other varieties of rays. All can be considered as packets of energy, called photons, which have wave properties most importantly a wavelength and frequency. X-rays are short wavelength, high frequency electromagnetic radiation. The importance of this is that high frequency means high energy. When X-rays hit atoms this energy can be transferred, producing ionisation of atoms.[2]

Radiation damage

When patients undergo X-ray examinations millions of photons pass through their bodies. These can damage any molecule by ionisation ,but damage to the DNA in the chromosomes is of particular importance. Most DNA damage is repaired immediately, but rarely a portion of a chromosome may be permanently altered (a mutation). This may lead ultimately to the formation of a tumour.

The latent period between exposure to X-rays and the clinical diagnosis of a tumour may be many years. The risk of a tumour being produced by a particular X-ray dose can be estimated, so knowledge of the doses received by radiological techniques is important. While doses and risks for dental radiology are small, a number of epidemiological studies have provided evidence of an increased risk of thyroid[6,7]tumours for dental radiography.

Radiation Exposure and Dose

Radiation dose is expressed as an effective dose measured in units of energy absorption per unit mass (Joules / kg) called the Sievert (more usually the microSievert, μSv, representing one millionth of a Sievert). In practice, effective dose is calculated for any X-ray technique by measuring the energy absorption in a number of key organs in the body, so that the final figure is a representation of whole body detriment. While effective dose is an impossible quantity to measure in vivo, it is possible to determine it from laboratory studies or computer modelling. This can then be used to estimate radiation risk.Many studies have measured doses of radiation for dental radiography, but only a few have estimated effective doses. There are still a number of radiographic techniques for which no published data are available and some for which very different results have been reported.[2]

- **The amount of exposure varies depending on the following:**

- **Film speed**: Radiation exposure can be limited by using the fastest film available. The use of F-speed film instead of D-speed reduces the absorbed dose by (60%). Using F-speed film instead of E-speed reduces the absorbed dose by an additional (20%).[8]
- **Collimation**: Radiation exposure can be limited by using rectangular collimation. The use of rectangular collima- tion instead of round collimation reduces the absorbed dose by(60%) to(70%).[8]
- **Technique**: Radiation exposure can be limited by increasing the source-to-film distance. The use of the long-cone paralleling technique and increased source to film distance reduces the skin dose.[8]
- **Exposure factors**: Radiation exposure can be limited by using a higher kilovoltage peak. The use of higher kilovolt- age peak reduces the skin dose.

Surface exposure or the measure of the intensity of radia-tion at the patient's skin surface in coulombs per kilogram or roentgens, is typically used when referring to patient exposure. A single intraoral radiograph (D-speed film, 70 kVp, long PID) results in a mean surface exposure of 250 milli- roentgens (mR). With F-speed film, a single intraoral radio- graph results in a mean surface exposure of 100 mR.[8]The concept of absorbed dose may also be used when referring to patient exposure and dose. The absorbed dose from a 20-film series of dental radiographs (round collima- tion, F-speed film, long PID) is estimated to be 41 mrads (0.00041 Gy). If rectangular collimation is used, the absorbed dose decreases to approximately 13 mrads (0.00013 Gy).[8]

Film	Absorbed Dose (mrads)
Bite-Wing Examination	
F-speed, 4 films, 16-inch PID, round	15.6
F-speed, 4 films, 16-inch PID, rectangular	2.5
Full-Mouth Survey	
F-speed, 20 films, 16-inch PID, round	41.1
F-speed, 20 films, 16-inch PID, rectangular	12.9

Table 1: Absorbed dose from intraoral radiographs.[8]

The risks

Radiation damage can be considered as the total harm experienced by an irradiated individual. In terms of stochastic effects, this includes the lifetime risk of fatal cancer, non-fatal cancer and hereditary effects. The probability of radiation-induced stochastic effects for the whole population is 7.3 x 10-2Sv-1.

Detriment (10^{-2} Sv^{-1})	
Fatal cancer	5.0
Non-fatal cancer*	1.0
Severe hereditary effects	1.3
Total	7.3

Table 2 :Nominal lifetime probability coefficients for stochastic effects.[23]

Risk is age-dependent ,being highest for the young and least for the elderly.In fact, risk for females is always relatively higher than for males.

Age Group (years)	Multiplication factor for risk
<10	x 3
10-20	x 2
20-30	x 1.5
30-50	x 0.5
50-80	x 0.3
80+	Negligible risk

Table 3: Risk in relation to age. [23]

Beyond 80 years of age, the risk becomes negligible because the latent period between X-ray exposure and the clinical presentation of a tumour will probably exceed the life span of a patient. In contrast, the tissues of younger people are more radiosensitive and their prospective life span is likely to exceed the latent period.

X-ray technique	Effective dose (μSv)	Risk of fatal cancer (per million)
Intraoral radiograph (bitewing/periapical)	1 - 8.3	0.02 - 0.6
Anterior maxillary occlusal	8	0.4
Panoramic	3.85 - 30	0.21 - 1.9
Lateral cephalometric radiograph	2-3	0.34#
Cross-sectional tomography (single slice)	1 - 189	1 - 14
CT scan (mandible)	364 -1202	18.2 - 88
CT scan (maxilla)	100 - 3324	8 - 242

Table 4 :Effective doses and risks of stochastic effects. [24]

Dental radiography is associated with low doses and risks for the individual patient. However, while dental radiography is generally low dose, it is a high volume procedure, with many millions of radiographs taken annually in the European Union .

EU Country	Annual number of radiographs x 10^3 (One radiograph means one exposure)	Annual number of radiographs per 1,000 population*
Denmark	2,400	449
Germany	22,520	274
Spain	5,515	138
Luxembourg	191	433
Netherlands	2,700	169
Portugal	986	96
Finland	1,484	286
Sweden	15,000 **	1,660**
United Kingdom	12,500	209

Table 5: Estimated annual numbers of dental radiographs in EU countries for which data are available .[9]

❖ Epidemiology Studies

Studies from Los Angeles County suggest that epidemiologic methods could be used to identify the risk of cancer from dental x-rays. For example, a case-control study of (408)patients with benign (269) and malignant (139) parotid gland tumors and (408) neighborhood controls found an association between cancer and both cumulative radiation exposure and exposure before age 20 from full-mouth and panoramic dental x-ray examinations. Recognizing the possibility of selective recall in a study of this kind, the authors verified the dental records of a subset of the cases and controls. Thyroid cancer was not part of this study and it is likely that the doses for the examinations included in this study have decreased with technological advances [10,11].In Kuwait 313 thyroid cancer cases were matched to an equal number of controls.

Personal interviews were conducted and the consistency of the interviews was confirmed by follow-up phone interviews in a subset of the participants.
Any dental x-ray versus no dental x-rays were associated with significantly increased risk of thyroid cancer (OR 2.1, 95% CI 1.4-3.1). Also, the number of dental x-rays reported was significantly associated with thyroid cancer [12].This study should be considered inconclusive. First, it depended completely on self-reporting of diagnostic x-rays which is subject to recall bias. Second, the number of dental x-ray procedures used as a surrogate for dose cumulative doses to the thyroid in this study are not known. Third, other sources of radiation exposure were also obtained by self-reporting and were adjusted for however, the procedure used to perform this adjustment was not described.The potential for recall bias in case-control studies of diagnostic x-ray exposure has been carefully documented in two studies, one in Sweden and one in the U.S and Sweden [13,14]Studies in both countries found substantial lack of agreement between interview and medical records and potential evidence of bias, although largely non-differential.

Radiation shielding in dentistry

❖ External shielding

Shielding is the application of an external material to attenuate the primary X-ray beam and any external scatter of the X- rays. Shielding should be the final consideration in dose reduction after optimizing all other variables such as ,collimation ,film speed and exposure. Shielding should be applied to radiosensitive structures (e.g. the thyroid) when they are within 5 cm of the primary beam, and the shielding does not impair the necessary diagnostic information. Doses to tissues outside the X- ray beam occurring from internal scatter radiation cannot be shielded.[1],so it is important to use external shielding when indicated and to position it precisely to maximize dose reduction.

❖ Intraoral dental imaging

Thyroid collar

The thyroid gland is one of the more radiosensitive organs in the head and neck region. It is frequently exposed to scattered radiation and occasionally to primary beam during dental radiography. Because people under age 30 are at greater risk of radiation induced thyroid cancer than older individuals, some have argued that thyroid collars should be used when intraoral radiographic examinations are made on this population[15].However, it is probable that rectangular collimation for intraoral radiography offers a similar level of thyroid protection to lead shielding.Thyroid shielding is inappropriate for panoramic radiography as it may interfere with the primary beam. In cephalometric radiography lead thyroid protection is necessary if the beam collimation does not exclude the thyroid gland. Thyroid shielding was found to reduce radiation doses of 45% during CT of the head and is strongly recommended, especially in younger age groups [16].

Leaded aprons

Lead aprons do not protect against scattered internal radiation, and their use does not provide a significant difference in the extremely low gonadal doses, so they are not indicated for dental imaging.[17]

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), the UK Guidance/National Radiation Protection Board, the American Academy of Oral and Maxillofacial Radiology and the European Commission on Radiation Protection all agree that there is no justification for the routine use of lead aprons.

Pregnant women

Many studies conclude that there is no need for a protective lead apron during pregnancy and deem routine use unnecessary unless they are used to allay perceived patient anxiety.[18]Therefore, providing there is sound clinical justification, pregnant women should not have their treatment deferred due to potential foetal risk from ionizing radiation from intraoral dental radiography.[18]

Panoramic radiography

ARPANSA and the European Academy of DentomaxilloFacial Radiology guidelines emphasize that there is no evidence supporting the routine use of lead apron or thyroid shielding in panoramic imaging if the thyroid is outside the primary beam.[19]Thyroid shielding may interfere with the primary beam and cause artefacts. It may also obscure anatomical structures or pathosis which may lead to the need for a repeat exposure.[18]

Cephalometric imaging

In the case of cephalometric radiographs, shielding of the thyroid is only warranted when it cannot be excluded from the primary beam via collimation or positioning.[18]

Collimation

Collimation of the primary beam should be matched to the receptor size, and hence rectangular collimation should be used. This has been shown to reduce patient exposure by at least 50% compared to a standard 7 cm circular collimator.[20]the use of rectangular collimators in dental practice is very rare.

Film speed

Changing film speed has a significant impact on the exposure required to produce an image. Simply switching from D- speed to F- speed film can reduce patient exposure by (60%). Utilizing digital sensors can further reduce the exposure by approximately (25%), but this is subject to variances, e.g. the type and manufacturer of the sensor, and the brand of X- ray machine being used [21]with some digital sensors and X- ray machines using the same exposure as F- speed film. Although digital radiography has a claimed dose reduction benefit of(50–80%), the increased number of radiographs taken utilizing digital systems reduces this figure to approximately(25%).[21]This is likely to be a result of the procedure for retaking digital images being so convenient that the clinician may be more inclined to repeat exposures compared to those using film.A reduction in dose by a factor of 10 for bitewings can be achieved by adopting rectangular collimation and F- speed film as opposed to circular collimation and D- speed film.[20]

Other people

A lead apron, or equivalent is required for any individual in the room during radiographic exposure if additional to the individual who is being irradiated (e.g. a parent when a child is having radiographs taken). Alternatives to a lead apron are the use of an external shield, or by ensuring that there is at least two metres distance from the X- ray tube and the person is not positioned in the direct pathway of the primary beam.[19]

Conclusions

Exposure to ionizing radiation at a young age is an established risk factor for thyroid cancer. However, the data to support this are based largely on studies of atomic bomb survivors and therapeutic doses of radiation, which involves exposure to much higher levels of radiation than dental imaging. Although it is thought that the low doses of dental radiography present little risk to patients until there is clear evidence for a threshold dose below which patients are not at risk, it must be assumed that dental radiography involves a small, but real risk. Therefore, reducing techniques such as the use of thyroid shielding should be employed where possible, and when it will not interfere with image quality.

References

1.Khong P- L, Ringertz H, Donoghue V, et al. ICRP publication 121:radiological protection in paediatric diagnostic and interventional radiology. Ann ICRP 2013;42:1–63.

2.van der Stelt, P. F. 1995. Radiation protection and quality assurance in dental radiography. The safe use of radiographs in dental practice. Office for Official Publications of the European Communities, Luxembourg.

3.Ron E, Lubin JH, Shore RE, Mabuchi K, Modan B, Pottern LM, et al. Thyroid cancer after exposure to external radia- tion: A pooled analysis of seven studies. Radiat Res 1995; 141:259–77.

4.Williams D. Cancer after nuclear fallout: Lessons from the Chernobyl accident. Nat Rev Cancer 2002;7:543–9.

5.https://emedicine.medscape.com/article/851968-overview.

6.Hallquist, A., L. Hardell, A. Degerman, G. Wingren, and L. Boquist. 1994. Medical diagnostic and therapeutic ionizing radiation and the risk for thyroid cancer: a case-control study. Eur J Cancer Prevention 3:259-67.

7.Wingren, G., A. Hallquist, and L. Hardell. 1997. Diagnostic X-ray exposure and female papillary thyroid cancer: a pooled analysis of two Swedish studies. Eur J Cancer Prevention 6:550-6.

8.J. M. Iannucci, L. J. Howerton.Dental radiography principle and techniques .Saunders; 4th edition (March 29, 2011).

9.2001. United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR Report to the General Assembly with Scientific Annex.

10.Preston-Martin S, Henderson BE, Bernstein L. 1985. Medical and Dental X-Rays as Risk Factors for Recently Diagnosed Tumors of the Head. Natl Cancer Inst Monogr 69:175- 179.

11.Preston-Martin S, Thomas DC, White SC, Cohen D. 1988. Prior Exposure to Medical and Dental X-Rays Related to Tumors of the Parotid Gland. J Natl Cancer Inst 80:943-949.

12.Memon A, Godward S, Williams D, Siddique I, Al Saleh K. 2010. Dental X-Rays and the Risk of Thyroid Cancer: A Case-Control Study. Acta Oncol 49:447-453.
13.. Berrington DG, Ekbom A, Glass AG, Galanti MR, Grimelius L, Allison MJ, Inskip PD. 2003. Comparison of Documented and Recalled Histories of Exposure to Diagnostic X- Rays in Case-Control Studies of Thyroid Cancer. Am J Epidemiol 157:652-663.
14.Hallquist A, Jansson P. 2005. Self-Reported Diagnostic X-Ray Investigation and Data from Medical Records in Case-Control Studies on Thyroid Cancer: Evidence of Recall Bias? Eur J Cancer Prev 14:271-276.
15.White, S. C., E. W. Heslop, L. G. Hollender, K. M. Mosier, A. Ruprecht, M. K. Shrout, and American Academy of Oral Maxillofacial Radiology ad hoc Committee on Parameters of Care. 2001. Parameters of radiologic care. An official report of the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 91:498-511.
16.Beaconsfield, T., R. Nicholson, A. Thornton, and A. Al-Kutoubi. 1998. Would thyroid and breast shielding be beneficial in CT of the head? Eur Radiol 8:664-7.
17.Horner K. Review article: radiation protection in dental radiology. Br J Radiol 1994;67:1041–1049.
18.European Commission. European Guidelines on Radiation Protection in Dental Radiology. The Safe Use of Radiographs in Dental Practice. 2004.
19.Australian Radiation Protection and Nuclear Safety Agency. Radiation Protection in Dentistry. Code of Practice and Safety Guide. December 2005.
20.Ludlow JB, Davies- Ludlow LE, White SC. Patient risk related to common dental radiographic examinations. J Am Dent Assoc 2008;139:1237–1243.
21.Berkhout WER, Sanderink GCH, Van Der Stelt PF. Does digital radiography increase the number of intraoral radiographs? A questionnaire study of Dutch dental practices. Dentomaxillofac Radiol 2003;32:124.

22.https://www.thyroid.org/wpcontent/uploads/statements/ABS1223_policy_statement.pdf .

23.1990. ICRP Publication 60. Recommendations of the International Commission on Radiological Protection. Annal of the ICRP 21.

24.White, S. C. 1992. Assessment of radiation risk from dental radiography. Dentomaxillofac Radiol 21:118- 26.