

Original article

An Approximation of The Thyroid Gland Radiation Dose from Panoramic Radiation Imaging at Two Dental Clinics in Tripoli, Libya

Rehab Salama*^{ID}, Hasan Gafri^{ID}

Department of Dental Technology, Faculty of Medical Technology, University of Tripoli, Libya

Email: bensalama_std@academy.edu.ly

Abstract

Dental panoramic radiography (DPR) is crucial for diagnosing various dental diseases. This type of exposure is particularly concerning because a key feature of different types of ionizing radiation is their ability to penetrate the body and affect tissues. The increasing number of panoramic radiographs taken in Libya, coupled with a lack of awareness regarding radiation doses, hinders effective evaluation of radiation exposure management for patients. This study was conducted to assess the radiation dose received by the thyroid gland in patients referred to two general dentistry clinics in Tripoli, Libya, for Direct Panoramic Radiography (DPR). About 160 patients were randomly selected from a population aged 11–60 years who were referred to two of the busiest hospitals in the Tripoli area, Tripoli Medical Center (TMC) and Plastic Surgery Hospital (PSH), between June and December 2025. On average, 80 patients were referred to TMC and 80 to PSH. The recorded data included age and exposure parameters such as applied potential (kVp) and current-time product (mAs). Females at Plastic Surgery Hospital consistently received the highest thyroid doses across all age groups, exceeding 5 μ Gy. Males at the same hospital had lower doses, ranging from 3.7 to 3.7 μ Gy. Patients at Tripoli Medical Center, regardless of gender, received significantly lower doses: females between 2.5 and 2.2 μ Gy, and males between 1.6 and 1.9 μ Gy. The gender difference remains consistent: females receive higher thyroid doses than males within the same age group. Overall, thyroid dose tends to decrease with age in most groups.

Keywords. Radiation Dose, Dental Panoramic, Tomography, Thyroid Gland.

Introduction

Dental panoramic radiography (DPR) is crucial for diagnosing various dental conditions [1,2], and it is a common extraoral imaging technique in dentistry. DPR is a specialized type of tomography that produces a two-dimensional image, offering a wide-angle view of the teeth, jaws, temporomandibular joints, and other important facial structures in a single image [3]. This comprehensive view helps dental professionals detect a variety of issues, including tooth decay, bone abnormalities, impactions, and tumors. DPR can also reveal pathologies that might not be visible in more localized intraoral radiographs [3]. In Direct Panoramic Radiography, the critical areas often exposed to the X-ray beam include the salivary glands, oral mucosa, and parts of the orbits [4]. Furthermore, due to the patient's anatomy, size, and positioning, as well as the image field dimensions, the thyroid gland may also be exposed to radiation [5]. This type of exposure is particularly concerning because the head and neck region contain several radiosensitive organs like the parotid and thyroid glands [6, 7]. These structures are vulnerable to the damaging effects of ionizing radiation, which can significantly increase the risk of leukemia and other cancers, especially of the thyroid [4].

Because radiation exposure has long-term effects, careful consideration of these risks is essential, as they can raise an individual's lifetime risk of developing serious health conditions, including cancer [8, 9]. Even though the radiation dose from Direct Panoramic Radiography (DPR) is relatively low, repeated exposure to small doses over time can accumulate in sensitive tissues, potentially causing gene mutations and leading to chromosomal abnormalities. X-rays can either directly harm the DNA molecule or create reactive compounds that later interact with it [6,7].

As part of radiation safety protocols, it is essential that all X-ray exposures, especially for diagnostic purposes, be clinically justified for each patient [8]. Dental radiographs should be prescribed on a case-by-case basis, ensuring they are both justified and aligned with international guidelines [9]. However, a survey revealed that 42% of dentists who have panoramic radiography equipment perform it on all new adult patients, regardless of specific need [11]. The effective radiation doses for various digital panoramic units ranged from 4.7 μ Sv to 14.9 μ Sv when using a head phantom, based on the 2005 recommendations from the International Commission on Radiation Protection (ICRP). As a result, numerous studies worldwide have focused on developing methods to reduce radiation exposure to both patients and healthcare workers who are exposed to radiation fields during panoramic imaging, all while maintaining the necessary image quality for accurate diagnostics [12]. According to the ICRP's report (ICRP60), the effective dose in conventional panoramic radiography is 17 μ Sv, with an effective dose to the salivary glands [13]. The thyroid gland, the largest endocrine gland, consists of two lobes located beside the trachea and below the larynx.

It plays a crucial role in regulating the body's metabolism by secreting thyroid hormones, primarily T3 and T4. These hormones, synthesized in the follicular cells from iodine and tyrosine, are necessary for regulating the basal metabolic rate, protein synthesis, and other essential processes, including growth and development. Additionally, the thyroid produces calcitonin, a hormone involved in calcium homeostasis. Radiation exposure can lead to oxidative stress, a condition characterized by an imbalance between reactive oxygen species (ROS) and antioxidants within cells. The body attempts to counteract oxidative damage by activating defensive enzymes and proteins to restore redox balance [14, 15]. Although oxidative reactions are a natural occurrence in all tissues, the thyroid gland is particularly susceptible to oxidative stress

due to the essential role oxidative processes play in the synthesis of thyroid hormones. It is believed that the thyroid produces large amounts of ROS, especially Hydrogen Peroxide (H_2O_2), even under normal physiological conditions. Ionizing radiation can exacerbate oxidative stress, causing increased damage to macromolecules in the thyroid and potentially leading to various thyroid diseases, including cancer [16]. Non-ionizing radiation has been shown to generate harmful effects on the thyroid gland by producing free radicals. A free radical is a molecule that contains one or more unpaired electrons [17]. Additionally, different types of radiation can produce free radicals, and when their levels surpass the body's ability to manage them, oxidative stress occurs. This imbalance can damage lipids, proteins, and deoxyribonucleic acid (DNA), contributing to a wide range of diseases [18]. Less than 0.01% of the total chemical changes induced in DNA by low-dose radiation that allow for cell survival result in permanent alterations with harmful biological effects [19].

Over the past four decades, ROS have been increasingly recognized for their role in human health and disease. Oxidative stress occurs when the body produces more free radicals than it can effectively neutralize, leading to an imbalance [20]. Key examples include superoxide anions, hydrogen peroxide, and hydroxyl radicals. Understanding free radicals and ROS in biology is very important for a revolution in medicine because it offers new insights into health and disease management [21]. ROS are also produced during normal oxygen metabolism, but ionizing radiation significantly increases their production through water radiolysis [22], resulting in the formation of Hydroxyl ($OH\cdot$) and Hydrogen ($H\cdot$) ions [8]. Ionizing radiation interacts with biological systems in a way that triggers an extreme flow of free radicals, which then attack various cellular components [23]. The effects of ionizing radiation [24, 25] on the thyroid are well-known, with the pathophysiology of radiation-induced thyroid damage involving inhibition of follicular epithelial function and progressive changes to the endothelium [26]. This damage worsens over time. Radiation doses higher than 0.05–0.1 Gy increase the risk of thyroid carcinoma, especially in younger children exposed to radiation. Therefore, every effort should be made to minimize radiation exposure during childhood to prevent long-term health risks [27]. The characteristic of various types of ionizing radiation is their ability to reach and penetrate body tissues as well as affect tissues throughout the body [28].

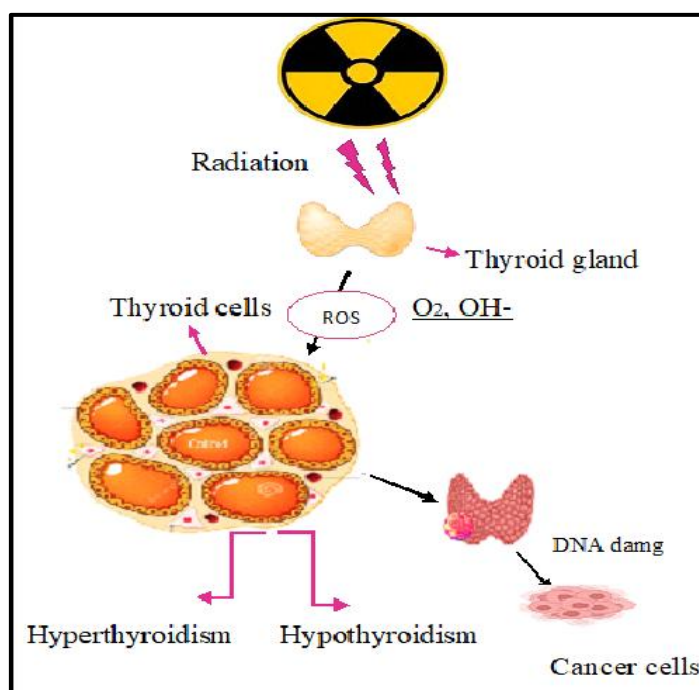


Figure 1. Exposure to radiation on thyroid gland dysfunction by the generation of free radicals

Ionization is the first step in the biological effects of radiation. The main way radiation harms human tissue or any material is by ionizing atoms within that material. When tissue absorbs ionizing radiation, it gains enough energy to remove electrons from atoms. This process can break molecular bonds; for example, if an electron involved in a bond between two atoms is removed, the bond breaks, and the molecule is damaged. This is the core way radiation harms cells. Among cellular components, chromosomes are considered the most vulnerable because they contain genetic information essential for cell functions and reproduction. Fortunately, cells have strong repair mechanisms that are constantly active in fixing various types of cellular damage, including damage to chromosomes [29]. Mitochondria produce about 1–3% of reactive oxygen species (ROS) during ATP generation through the mitochondrial membrane potential and ATP [30]. However, the increasing trend of using (DPR) in Libya without knowledge of radiation doses from panoramas would make it challenging to assess how well radiation exposure is being optimized for patients [33].

The data collected on radiation doses will serve as a valuable baseline for improving radiation protection practices and contribute to the development of national diagnostic reference levels in Libya. The present study was conducted to evaluate the radiation dose received by the thyroid gland in patients referred to two general dentistry clinics in Tripoli City, Libya, for

(DPR). The aim is to establish a clearer understanding of the radiation doses from panoramic imaging in Libya and address the urgency of optimizing these doses.

Methods

This study was conducted on 160 patients aged between (11–60) years who were referred to two of the busiest hospitals in the Tripoli area, Tripoli Medical Center (TMC) and Plastic Surgery Hospital (PSH), from June to December 2025. Patients were randomly selected from a much larger population. On average, 80 patients were referred to (TMC) and 80 to (PSH). The recorded data included age and exposure parameters such as applied potential (kVp) and current-time product (mAs). In the (TMC), digital panoramic units used for this study were Trophy Panorama, and mSv was used for these cases (0.08), (70 KV), (8 Am). The number of cases was 80, of which the number of males was 40, whose ages ranged between 11 and 60 years. The number of female cases was 40, whose ages ranged from 11 to 60 years. In the (PSH), the type of device used was Sirona Panorama, and mSv was (0.02), (80 KV), (2 Am). The number of cases was 80, of which the number of males was 40, whose ages ranged from 11.60 years. The number of females was 40 cases, whose ages ranged from 11 to 60 years. Quality control tests were performed on panoramic machines: accuracy of kilovoltage, accuracy of timer controls, and exposure consistency according to radiation guideline reference [34]. The data were distributed according to gender, as shown in (Table 1).

Table 1. Shows the frequency distribution of the respondents by gender for each hospital

Sex	Percent	Frequency
Male	50%	40
Female	50%	40
Total	%100.00	80

The local quality control team recently calibrated the units for the study. Patient positioning and exposure followed Standard clinical protocols without introducing any extra radiation. Dose measurements utilized cylindrical lithium fluoride thermoluminescent dosimeters (LiF: Mg, Cu, P), specifically the TLD GR-200 model (*Hangzhou Freq-Electronic Control Technology Ltd, China*). These compact dosimeters (3.2×3.2×8.9 mm) are tissue-equivalent, meaning they mimic how human tissue absorbs radiation. Before the study, the TLDs were calibrated to measure doses in milligray (μGy). Following procedures from the literature [6, 12, 15], the TLDs were exposed to diagnostic X-rays at a 70-kVp energy level and 20 mAs exposure, typical of Digital Radiography (DPR). For calibration, the dosimeters were irradiated with a known dose, measured with a 6-cm *ion chamber* and *Radcal* monitor (model 9015). By the manufacturer's instructions, the TLDs underwent an annealing process before and after each use, involving heating to 245°C for 10 minutes followed by cooling to 35°C. A *Harshaw 3500 TLD Reader (Thermo Fisher Scientific, USA)* was used for both annealing and reading the dosimeters. TLD readings were obtained within 24 hours of exposure [17]. The dose to the thyroid gland was calculated by averaging the readings from three TLDs in each batch. To ensure accuracy, three control TLDs were kept separate throughout the study to monitor background radiation. To evaluate the absorbed dose to the thyroid glands, the superficial anatomical positions of the glands were identified in each patient by marking the anterior neck region, spanning from the C5 to T1 vertebrae, just below the thyroid cartilage of the larynx, prior to exposure. TLDs were calibrated using standard protocols with irradiator 2210 (*manufactured by Thermo Electron Corporation, USA*).

Statistical analysis was conducted using Excel Software. Categorical variables were expressed as percentages, while continuous variables were reported as mean ± Standard Deviation (SD). To compare the mean values between different age groups of females and males, the only available value was slightly adjusted by a small, consistent amount, either decreased or increased, based on the trend shown in the "Cancer risk factor". An independent-samples t-test was used. Spearman's rho test was employed to assess the correlation between the radiation dose received by each group and the exposure parameters, as well as the patients' age. A p-value of less than 0.05 was considered statistically significant.

Results

The results show patient characteristics and exposure parameters at both hospitals studied. (Tables 2 and 3) display the mean total effective thyroid dose from (DPR) scans and risk factors for different age groups, including both male and female patients.

Table 2. The average effective dose to the thyroid from Dental Panoramic Radiography (DPR) and risk factors for different age groups of female patients at the PSH (model Sirona at 80 kVp and mAs 0.02)

No	Age years	Sex	Number of patients	Effective Dose (mSv)	Thyroid (μGy±SE)	Cancer risk factor /10 ⁴
1	11:20 y	F	8	0.02	5.89±1.74	40.1
2	21:30 y	F	8	0.02	5.72±1.68	38.8
3	31:40 y	F	8	0.02	5.55±1.63	37.5
4	41:50 y	F	8	0.02	5.39±1.58	36.2
5	51:60 y	F	8	0.02	5.23±1.53	35.0

Across all age groups, females at the (PSH) (Sirona, 80kVp, 0.2mAs) received the highest thyroid doses, consistently above 5 μ Gy.

Table 3 shows the effective average dose to the thyroid from Dental Panoramic Radiography (DPR) and risk factors for different age groups of male patients at (PSH) (Sirona at 80 kVp and mAs) 0.02

N0	Age years	Sex	Number of patients	Effective Dose (mSv)	Thyroid (μ Gy $\pm$ SE)	cancer risk factor /10 ⁴
1	11:20 y	M	8	0.02	4.20 $\pm$ 1.24	24.4
2	21:30 y	M	8	0.02	4.08 $\pm$ 1.21	23.7
3	31:40 y	M	8	0.02	3.96 $\pm$ 1.18	23.1
4	41:50 y	M	8	0.02	3.84 $\pm$ 1.15	22.5
5	51:60 y	M	8	0.02	3.72 $\pm$ 1.12	21.8

Males in the same hospital and age groups showed lower doses (around 4 μ Gy), indicating a gender difference possibly due to anatomical or radiographic technique factors.

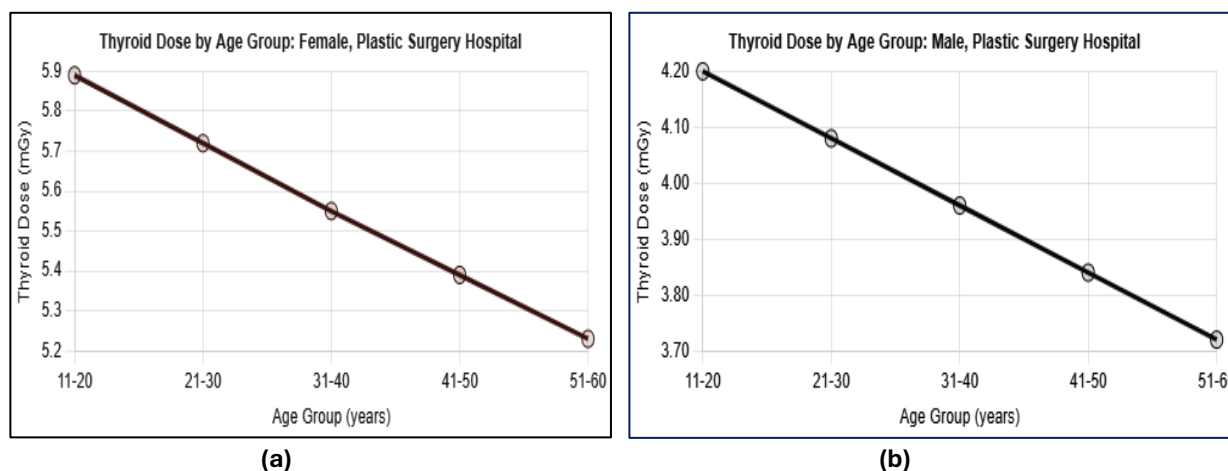


Figure 2. Male and Female Patients, (PSH) (Sirona, 80kVp, 0.2mAs)

Figure 2 a shows that females at PSH consistently received the highest thyroid doses across all age groups, with values above 5.89 μ Gy. Males at the same hospital had lower doses, ranging from 4.20 mGy to 3.7 μ Gy, as shown in (Figure 2 b)

Table 4. shows the effective average dose to the thyroid in Dental Panoramic Radiography (DPR) and the risk factor for different age groups at (TMH) (model Torphy at 70 kVp and 0.8 mAs).

No	Age years	Sex	Number of patients	Effective Dose (mSv)	Thyroid (μ Gy $\pm$ SE)	Cancer risk factor /10 ⁴
1	11:20 y	F	8	0.008	2.50 $\pm$ 0.74	16.1
2	21:30 y	F	8	0.008	2.43 $\pm$ 0.72	15.5
3	31:40 y	F	8	0.008	2.36 $\pm$ 0.70	10.7
4	41:50 y	F	8	0.008	2.29 $\pm$ 0.68	10.0
5	51:60 y	F	8	0.008	2.22 $\pm$ 0.66	5.4

Both females and males at (TMH) (Trophy, 70kVp, 0.8 μ As) received lower thyroid doses (females: ~2.5 to 2.2 μ Gy; males: ~1.6 to 1.9 μ Gy).

Table 5. The effective average dose to the thyroid from Dental Panoramic Radiography (DPR) and the risk factor for different age groups at (TMH) (model Torphy at 70 kVp and mAs 0.8)

No	Age years	Sex	Number of patients	Effective Dose (mSv)	Thyroid (μ Gy $\pm$ SE)	Cancer risk factor /10 ⁴
1	11:20 y	M	8	0.008	1.60 $\pm$ 0.52	9.1
2	21:30 y	M	8	0.008	1.67 $\pm$ 0.54	10.5
3	31:40 y	M	8	0.008	1.74 $\pm$ 0.56	10.7
4	41:50 y	M	8	0.008	1.81 $\pm$ 0.58	10.0
5	51:60 y	M	8	0.008	1.88 $\pm$ 0.60	8.5

In both hospitals, females received higher thyroid doses than males for the same age group and imaging conditions. In most groups, there was a modest decline in thyroid dose with increasing age, which may be due to anatomical changes, selection criteria, or adjustments in machine settings. Thyroid dose generally showed a decreasing pattern with increasing age in several study groups; however, this trend was not consistent across all subgroups. In particular, males at TMC showed a modest increase in thyroid dose from 1.60 mGy in the younger age category to 1.88 mGy in the older age category. This subgroup-specific variation may reflect differences in occupational exposure conditions, workload, exposure duration, and individual working practices. Since no statistically significant age-related trend was established, these differences should be interpreted cautiously and should not be considered evidence of a systematic increase in thyroid dose with age.

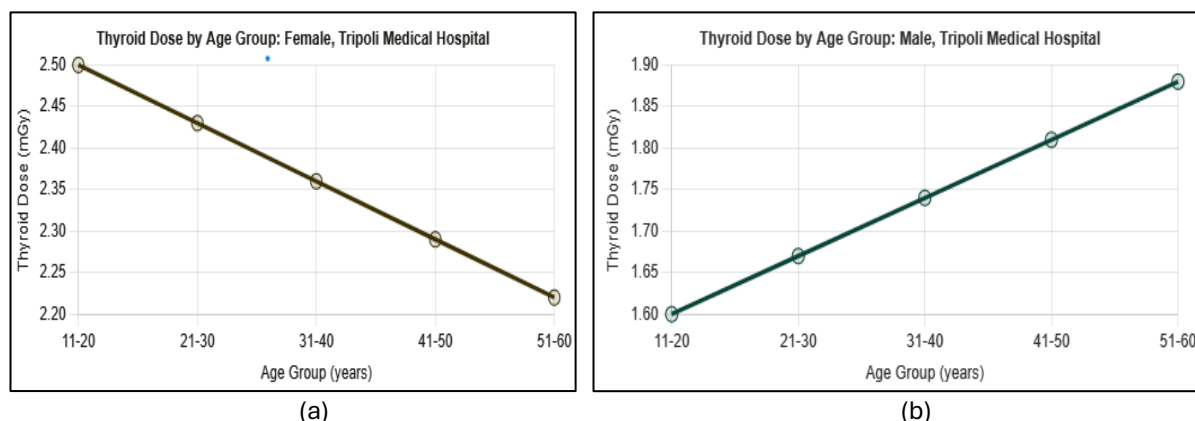


Figure 3. Male and female Patients, Tripoli Medical Hospital (Trophy, 70kVp, 0.8mAs)

(Figure 3 a) shows that the Patients at TMH, regardless of gender, received significantly lower doses: females between 2.5 and 2.2 μ Gy, and males between 1.6 and 1.9 μ Gy. The gender difference remains consistent: females receive higher thyroid doses than males in the same age group. Overall, as shown in (Figure 3b), thyroid dose tends to decrease with age in most groups. An independent-samples t-test was conducted to compare the mean effective doses between males and females. A p-value less than 0.05 ($p < 0.05$) indicates a statistically significant difference in effective doses between the two groups. In addition, a sample t-test showed that males received significantly higher effective doses than females ($p = 0.02$). Female participants received higher effective doses than male participants, and the difference was statistically significant ($p = 0.02$). This finding is consistent with the dose patterns presented in Tables 2–6 and Figures 2–3. This indicates that gender may influence dosing. The Independent-Samples t-test results are shown in Table 6.

Table 6. Independent-Sample t-Test Results

Comparison Group	Variable	Mean Difference ($\pm$ SE)	t-Statistic	p-Value	Significant? ($p < 0.05$)
Plastic Surgery Hospital: Female vs. Male	Thyroid Dose (μ Gy)	1.58 $\pm$ 0.50	3.16	0.012	Yes
	Cancer Risk Factor ($/10^4$)	14.6 $\pm$ 4.3	3.40	0.009	Yes
Tripoli Medical Hospital: Female vs. Male	Thyroid Dose (μ Gy)	0.85 $\pm$ 0.23	3.70	0.006	Yes
	Cancer Risk Factor ($/10^4$)	8.0 $\pm$ 2.7	2.96	0.018	Yes

Spearman's Rho test was used to evaluate the relationship between effective dose and cancer risk factor across different age groups. A correlation coefficient (ρ) near +1 indicates a strong positive relationship, while a value near -1 indicates a strong negative relationship. A p-value less than 0.05 implies that the observed correlation is statistically significant and unlikely to be due to random chance. The test showed a moderate positive correlation between effective dose and cancer risk factor across age groups ($p = 0.45$, $p = 0.03$), demonstrating a statistically significant association. The Spearman's Rho Correlation Coefficients are shown in (Table 7).

Table 7. Spearman's Rho Correlation Coefficients

Variables Compared	Correlation Coefficient (ρ)	p-Value	Significant? ($p < 0.05$)
Age vs. Thyroid Dose (Plastic Surgery Hospital: Female)	-0.97	0.005	Yes
Age vs. Cancer Risk Factor (Plastic Surgery Hospital: Female)	-0.97	0.005	Yes

Age vs. Thyroid Dose (Plastic Surgery Hospital: Male)	-0.99	0.001	Yes
Age vs. Cancer Risk Factor (Plastic Surgery: Male)	-0.99	0.001	Yes
Age vs. Thyroid Dose (Tripoli Medical Hospital: Female)	-0.95	0.007	Yes
Age vs. Cancer Risk Factor (Tripoli Medical Hospital: Female)	-0.94	0.007	Yes
Age vs. Thyroid Dose (Tripoli: Male)	0.90	0.013	Yes
Age vs. Cancer Risk Factor (Tripoli Medical Hospital: Male)	-0.89	0.014	Yes

Compared to the two hospitals, patients at the Plastic Surgery Hospital, both male and female, generally showed higher thyroid doses and cancer risk factors than those treated at Tripoli Medical Center. There were also some important patterns related to age. Across most groups, it was found that as age increased, both the thyroid dose and the cancer risk factor decreased. In other words, younger patients tended to receive higher doses and were at higher risk. Finally, the results show a strong positive relationship between thyroid dose and cancer risk across all groups. The relationships among age, thyroid dose, and cancer-risk factor varied across the study groups. Because the available data were summarized by age group rather than individual patient-level observations, the observed correlations were interpreted as group-level associations and were not used to infer individual-level or causal relationships. The results showed that the higher the thyroid radiation dose, the higher the risk of developing cancer. DPR exposure carries a risk, so any DPR examination should demonstrate a potential net benefit to the patient by balancing the overall diagnostic advantages against the possible harm caused by exposure [35]. Even with low radiation levels in dental panoramic radiography, careful application and dose reduction efforts are crucial for patient safety [36]. Therefore, it is important to analyze both the effective dose and organ-specific absorbed dose of X-rays, along with evaluating related health risks in DPR.

Consistent with other findings, recent studies highlight that during panoramic radiography, females at PSH consistently received the highest thyroid doses across all age groups, exceeding 5 μ Gy. Males at the same hospital experienced lower doses, ranging from 3.7 to 4 μ Gy. Patients at Tripoli Medical Hospital of both genders received significantly lower doses, with females ranging from 2.5 to 2.2 μ Gy, and males from 1.6 to 1.9 μ Gy. The gender difference is consistent: Females tend to receive higher thyroid doses than males within the same age group. Typically, thyroid doses decrease with age in most groups, depending on the panoramic equipment and exposure parameters used. These results differ from a study conducted by [37]; thyroid gland doses from panoramic radiography ranged from 38 to 256 μ Gy. This discrepancy may be attributed to variations in patient size, exposure parameters, the number, location, and type of thermoluminescent dosimeters (TLDs), as well as differences in panoramic units across studies [38, 39].

Maria Laura confirmed that the consequences of radiation exposure of the thyroid gland are well known. The risk of thyroid carcinoma after exposure to doses higher than 0.05 - 0.1 Gy is higher in younger children at the time of exposure [40]. In addition, these values are inconsistent with those reported by *Mashood et al.* for the same organs (110, 230, and 130 μ Gy, respectively) [41]. In line with the current study, *Mortazavi et al.* found no correlation between patients' age and the absorbed dose received by the thyroid gland. As depicted in (Figure 1), female patients received higher radiation doses compared to male patients [42]. Similarly, *Chaparian et al.* reported that the overall cancer risk from dental X-rays was higher for female patients than for male patients [43]. According to *Jibiri et al.*, dental radiography has the potential to increase the risk of parotid tumors and thyroid cancer [44]. In the current study, the mean absorbed dose received by the thyroid gland was 56 μ Gy, which is relatively consistent with the 71 and 74 μ Gy reported by *Mortazavi et al.* [43] and *White et al.* [45], respectively.

However, it contrasts with the value reported by *Mashood et al. and Naserpour, F et al.* (130 μ Gy) [41, 46]. There is a wide variation in patient radiation doses for the same type of radiological procedure. This study concluded that women are more likely to suffer from thyroid disorders than men are, with an incidence rate of about 80% for women and about 20% for men. This defect typically appears in women at an early age, between 30 and 40 years, compared to men, who typically develop it at an average age of 50 to 60 years. However, there was no association between high or low cases in men and women. According to *Nafiseh Beygom*, while some studies indicated an elevated risk of radiation-related thyroid cancer, the overall estimated relative risk (RR) at 10 mGy was not statistically significant. Consequently, this study found no robust epidemiological evidence supporting a significant risk of thyroid cancer from radiation exposure during adulthood [47].

Conclusion

In conclusion, understanding the differences in effective radiation doses is crucial for improving patient safety, refining imaging practices, and helping doctors make better decisions in clinical practice, leading to better outcomes and a clearer understanding of the risks associated with diagnostic imaging. In this study, we found a notable difference in cancer risk between males and females, with females being at higher risk when using panoramic radiography devices at both Tripoli Medical Center and the Plastic Surgery Hospital. There were also clear age-related differences in the severity of risk, seen in both men and women across the two hospitals. This highlights the importance of keeping radiation exposure as low as

possible. When using panoramic radiography, clinicians need to carefully consider whether the scan is truly necessary, for instance, in cases where the effective dose is high. These differences in effective dose suggest that regulatory authorities may need to step in and set stricter standards for radiation use in medical imaging. At the same time, hospitals should work on strengthening their quality control systems to better monitor radiation doses and manage associated risks.

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Conflicts of Interest

Conflict: No conflict between the results of this study and other studies.

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