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Radiation Exposure in Thyroid Cancer Patients Treated with Radioiodine: A Dental Perspective

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ABSTRACT

Introduction: This study aimed to experimentally determine radiation safety criteria for dentists who examine or treat patients receiving radioactive iodine (RAI) therapy for the follow-up of differentiated thyroid cancer in the nuclear medicine department.

Methods: Twenty-three patients undergoing whole-body scintigraphy with RAI were included. Each patient received 185 MBq of RAI orally on an outpatient basis and remained in lead-shielded isolation rooms for approximately two hours to allow for systemic distribution. Dose-rate measurements were then obtained along a horizontal line at distances of 5, 15, 30, 60, and 100 cm from the neck and abdominal regions.

Results: During the first 0–2 hours, mean dose rates measured from the neck at 5, 15, 30, 60, and 100 cm were 584±120 µSv/h, 312±52 µSv/h, 175±36 µSv/h, 18±6 µSv/h, and 11±4 µSv/h, respectively. Based on these data, the estimated radiation dose to a dentist during close contact (5–30 cm) was 224 µSv on the first day, 117 µSv on the second day, and 3 µSv on the third day after administration.

Conclusion: The permissible chairside exposure time on the first day was estimated at approximately 3.12 hours without exceeding safety limits. However, when daily dose limits derived from annual occupational exposure are considered, the third day after RAI administration was identified as the safer period for dental procedures

Keywords: Thyroid cancer therapy, radioiodine therapy, whole-body scan, dentist, radiation dose

Introduction

Differentiated thyroid cancer (DTC) is one of the most common endocrine malignancies. Following total thyroidectomy, radioactive iodine (RAI) therapy has long been a fundamental approach for ablation of residual thyroid tissue and control of metastatic disease. Among the parameters used for post-ablation follow-up, whole-body scintigraphy (WBS) with iodine-131 (^{131}I) remains the most important and widely accepted imaging method. Serial ^{131}I whole-body scans after ablation are still recognized in clinical guidelines as a key follow-up strategy (1,2).

^{131}I is a well-established theranostic radionuclide with a physical half-life of approximately eight days. It exerts its therapeutic effect through the emission of high-energy beta (β^-) particles (606-keV) and simultaneously enables diagnostic imaging with 364-keV gamma photons. Despite these valuable diagnostic advantages, RAI therapy can cause cytotoxic effects in healthy tissues and raise significant radiation safety concerns for healthcare workers, family members, and the general public (3).

In the nuclear medicine department, an oral dose of 74–185 MBq of ^{131}I is routinely administered to patients undergoing whole-body scans on an outpatient basis after both written and verbal radiation safety instructions have been provided. Whole-body imaging is typically performed 24–72 hours later (4). These pre-administration instructions serve two main purposes: (i) to reduce the external radiation dose rate emitted by the patient and (ii) to minimize environmental contamination caused by radioactive materials excreted in urine, saliva, sweat, and other bodily secretions.

A considerable portion of the orally administered RAI remains within the patient's body after leaving the clinic. Over time, RAI is cleared through both physical decay and biological elimination. The residual radioactivity poses an external radiation hazard to individuals in close proximity and may cause contamination via body fluids. According to radiation protection regulations, the annual effective dose limit for the general public is 1 mSv (5,6). Consequently, discharged patients are advised to

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observe specific social restrictions: maintain physical distance, sleep in separate beds, practice strict personal hygiene (frequent handwashing), wash clothes separately, ensure toilet hygiene, avoid sharing kitchen utensils, and avoid contact with pregnant women and children (7).

Although RAI therapy has been widely used for decades, current radiation safety guidelines generally recommend maintaining at least 1 meter of distance from the patient and avoiding prolonged close contact. The International Commission on Radiological Protection (ICRP) Publication 60 report has set the annual radiation dose limits for members of the public at 1 mSv for adults and 0.5 mSv for children and pregnant women (6). Moreover, the As Low As Reasonably Achievable (ALARA) principle emphasizes keeping radiation exposure to a minimum that is reasonably achievable (8).

One of the most frequent post-discharge challenges arises when patients require unplanned medical or dental care shortly after RAI administration. For instance, a DTC patient who recently received RAI for whole-body imaging may develop severe dental pain and need to visit a dentist. In such situations, ensuring radiation safety requires that the patient's dose rate at a distance of 1 meter be below the regulatory release criterion so that any additional exposure to dental personnel during close contact does not exceed the annual public dose limit of 1 mSv. In principle, this condition allows for a safe dental examination. However, patients are advised to inform their dentist of recent RAI therapy, minimize unnecessary close contact, and, if possible, use lead aprons during treatment. Strict hygiene measures should be taken to prevent contamination through saliva, and elective dental procedures should be postponed for a short period when feasible.

During dental examination or treatment, a dentist typically works within 5–30 cm of the patient's oral region, while general communication and preparatory procedures typically occur at 60–100 cm. Despite the long-standing use of RAI therapy in DTC management, no dedicated experimental study has yet evaluated radiation safety considerations specific to dental professionals. Therefore, the present study was designed to determine experimentally the criteria necessary to ensure radiation safety for dentists who examine or treat DTC patients who were recently administered 185 MBq of RAI for outpatient WBS.

Methods

This study was conducted at the radionuclide therapy unit of the department of nuclear medicine, Cerrahpaşa medical faculty. A randomly selected group of patients who were referred to the clinic for radioiodine (RAI) WBS as part of follow-up for DTC was included. All procedures were performed in strict accordance with the ethical principles outlined in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The study protocol was approved by the İstanbul Kent University Clinical Research Ethics Committee (approval number: 2025-07, date: 10.09.2025). Written informed consent was obtained from all participants prior to inclusion in the study.

Patient Population

A total of 23 patients (14 females and 9 males) were enrolled in this investigation. Each patient received 185 MBq of ^{131}I orally on an empty stomach. All participants underwent treatment for DTC and were referred for a routine whole-body scan 6–12 months after therapy.

RAI Administration and External Dose-Rate Measurement Technique from a Dental-Safety Perspective

Following both written and verbal radiation safety instructions, each fasting patient was orally administered 185 MBq of ^{131}I. To ensure uniform biodistribution of radioiodine, patients remained in lead-shielded isolation rooms for approximately two hours. During this period, direct contact with visitors was strictly prohibited, and all patient care activities were carried out by certified radiation personnel following the time–distance–shielding principles.

Approximately two hours after administration, dose-rate measurements were performed at distances of 5, 15, 30, 60, and 100 cm from the patient's neck and abdomen, along a line parallel to the floor.

Dose rate measurements were performed using a validated and calibrated portable Geiger–Müller survey meter (Model 9DP, Ludlum), specifically verified for high-energy gamma emitters such as Cs-137. Calibration validity (May 2028); energy range: 60 keV to approximately 1.25 Mev.

In this study, a customized measurement protocol was developed to simulate a realistic dental examination environment. Prior to discharge, each patient was seated in a standard dental chair, with dose-rate measurements obtained from an anterior oblique position that represents the typical approach distance of a dentist during clinical practice. Patients were routinely recalled to the nuclear medicine department between days 1 and 3 post-RAI administration for WBS, during which additional dose-rate measurements were taken from the same neck-level reference points at distances of 5, 15, 30, 60, and 100 cm, measured parallel to the floor.

Dose Calculation Method

The radiation detector measured dose rates at various distances, providing instantaneous dose values in µSv/h. During dose-rate measurements, conditions that closely resembled a patient's posture while sitting in the dental chair for a procedure were established. Additionally, measurements were performed under conditions simulating the dentist's typical position and approach distance while treating a patient. In this way, the geometric conditions during measurements were closely matched to those during actual dental procedures.

For converting these dose rates into cumulative doses, the following equation was used:

Dose (µSv) = dose rate (µSv/h) × procedure duration (h).

Statistical Analysis

Dose-rate measurements obtained 30 cm from the neck and 30 cm from the abdomen were compared using the Wilcoxon paired test; $p \leq 0.05$ was considered statistically significant.

Results

Before RAI therapy, stimulated thyroglobulin (Tg) levels were measured as part of the routine laboratory evaluation. Under thyroid stimulating

hormone (TSH) stimulation, Tg levels varied depending on tumor pathology and treatment activity. Among the 23 patients, TSH levels ranged from 34.2 to 142 µIU/mL (mean: 63.8 µIU/mL), and the mean Tg level was 1.98 ng/dL (range: 0.45–4.6 ng/dL). The mean pre-scan values of free T3 (fT_3), free T4 (fT_4), and TSH for all patients were 0.52±0.03 pg/mL, 0.36±0.07 ng/dL, and 64.8±16.8 µIU/mL, respectively (Table 1). Metastatic thyroid cancer was present in 4 of the 23 patients (17%).

The external dose rates measured at various distances from the patients are summarized in Tables 2 and 3 for the neck and abdominal regions, respectively. In both anatomical regions, the dose-rate values decreased sharply with increasing distance and with elapsed time after RAI administration. During the 0–2-hour period, the mean dose rates measured from the neck region were 584±120 µSv/h at 5 cm, 312±52 µSv/h at 15 cm, and 11±4 µSv/h at 100 cm. Based on these data, the cumulative radiation dose potentially received by a dentist during close contact (within a range of 5–30 cm) was estimated as 224 µSv initially, decreasing to 117 µSv on day 1 and to 3 µSv by day 3.

As shown in Figure 1, the cumulative exposure dose remained below the 1-mSv threshold, and the calculated exposure duration required to reach that limit on the first day was approximately 3.12 hours. Therefore, it can be concluded that provided standard radiation protection measures (such as wearing a lead apron and minimizing contact time) are strictly followed, dental examinations or interventions performed on the day of discharge do not pose a radiation safety risk to dentists treating patients who have received up to 185 MBq of ^{131}I. However, when the daily public dose limit of 4 µSv/day is applied, the safe exposure level for dentists treating these patients is reached on the third day after RAI administration.

The correlation analysis between these mean dose rates is presented in Figure 2. The Pearson correlaton coefficient of determination (R^2: 0.9993) indicated a very strong correlation between external dose rates measured in the abdominal and neck regions. This finding indicates that changes in dose rate depend not only on the total administered activity but also on individual biological and physiological clearance factors, such as metabolic rate, the size of residual thyroid tissue, and the tissue distribution of RAI. Collectively, these results quantitatively define a practical safety margin for dental professionals. Patients who received less than 185 MBq of ^{131}I may be safely examined and treated for up to 3.12 hours, beginning two hours after discharge from the clinic, without exceeding the annual dose limit of 1 mSv. However, to ensure that dentists' radiation exposure remains below the daily public dose limit of 4 µSv, dental visits should be postponed for at least three days.

Table 1. Demographic and thyroid cancer–specific clinical characteristics of patients scanning with radioactive iodine

Gender	Age	Weight	fT_3	fT_4	TSH
(n=23)	(years)	(kg)	(pg/mL)	(ng/dL)	(µIU/mL)
Female (n=14)	58.2±21.1	63.5±7.9	0.32±0.01	0.41±0.05	61.2±11.3
Male (n=9)	64.3±17.2	73.7±12.0	0.72±0.08	0.32±0.03	66.5±12.2
Normals			2.0-4.4	0.93-1.7	0.27-4.2

fT_3: free T_3, fT_4: free T_4, TSH: Thyroid stimulating hormone

Table 2. Dose rates measured from the neck region in thyroid cancer patients receiving 185 MBq radioactive iodine for diagnostic whole-body scanning

Distance (cm)	Day 0 (µSv/h)	Day 1 (µSv/h)	Day 3 (µSv/h)
5	584±120	295±38	10±3
15	312±52	120±42	6±3
30	175±36	48±11	3±2
60	18±6	4±2	2±1
100	11±4	1±0.1	0.1±0.001

Table 3. Dose rates measured from the abdomen region in thyroid cancer patients receiving 185 MBq radioactive iodine for diagnostic whole-body scanning

Distance (cm)	Day 0 (µSv/h)	Day 1 (µSv/h)	Day 3 (µSv/h)
5	684±62	232±102	7±27
15	290±42	165±46	3±18
30	163±23	97±24	2±11
60	69±8	8±87	1±0.01
100	10±3	4±2	0.01±0.001

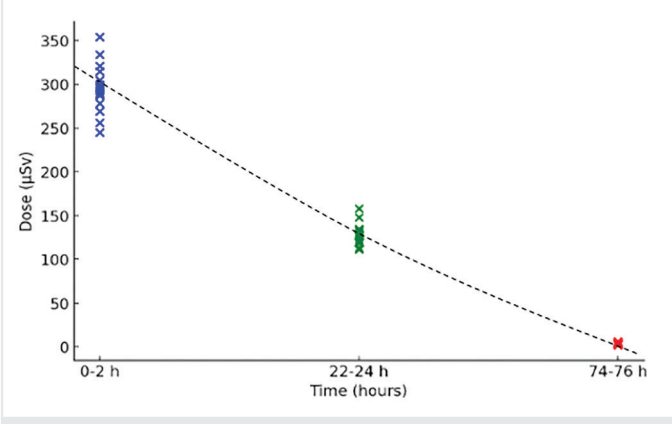

Figure 1. Variation in radiation exposure doses for the dentist

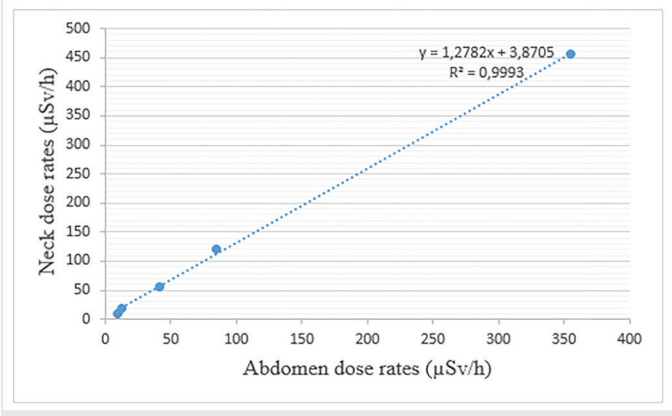

Figure 2. Correlation of dose rates measured from the neck and abdominal regions

Statistical Evaluation

The differences in dose-rate measurements obtained from patients after stress and rest imaging at 10–30 minutes, 1 h, 2 h, and 3 h post-injection were evaluated using the Wilcoxon paired-sample test. The corresponding p values were 0.001, 0.01, 0.01, and 0.01, respectively, indicating statistically significant differences at all time points.

Discussion

The activities of RAI used for thyroid carcinoma follow-up are generally not higher than those used for diagnostic purposes. However, the 364 keV gamma photons emitted by ^{131}I are relatively high in energy, which may lead to greater radiation exposure. Since all patients had undergone total thyroidectomy prior to RAI therapy, the rapid clearance of RAI from the body can be considered advantageous. Nevertheless, when capsular invasion or distant metastases are detected, evaluation of metastatic sites may increase ambient radiation exposure. In such cases, the biological retention time of RAI increases, and therefore, radiation protection measures become even more critical. Importantly, there is no evidence in the literature suggesting that radiation emitted from RAI-treated patients leads to secondary malignancies (9).

The potential radiation exposure levels encountered by a dentist treating a thyroid cancer patient recently discharged following therapeutic RAI administration were assessed. For the general public, the daily average equivalent dose, derived from the annual public dose limit, corresponds to 2.7 μSv; dentists are classified in the same reference category in accordance with ALARA principles. Based on the measured dose rates, this study established distance and time constraints designed to ensure compliance with international radiation safety standards, keeping exposure below the annual limit of 1 mSv (1000 μSv) and the daily limit of 2.7 μSv. Compared with the annual permissible dose limit of 1 mSv, the measured doses remained within safe limits. However, given the daily dose limits, delaying dental visits for at least three days after RAI administration appears necessary. In practice, a dentist is unlikely to treat only such patients throughout the year because background radiation from natural sources, air travel, and other daily activities (e.g., X-ray screening) also contributes to cumulative radiation exposure.

In dental practice, the use of high-speed instruments such as ultrasonic scalers, air turbines, and air–water sprays generates aerosol particles containing saliva, blood, and microorganisms. Previous studies examining aerosol exposure among dental professionals have shown that clinical procedures are typically performed at approximately 30 cm from the patient, but often within a 5–60 cm range. These studies reported that aerosol exposure decreases as distance increases but increases with longer procedure duration (10). In the present study, dose-rate measurements were performed at distances of 5–30 cm, which most accurately reflect clinical conditions for dental practitioners. The measured values within this range corresponded to the highest external radiation doses, confirming that the experimental geometry effectively mimicked the true clinical scenario.

This study was designed as an experimental investigation to simulate a scenario in which a dentist performs a procedure on a patient who has undergone RAI therapy. However, in clinical practice, dentists may treat multiple patients within a year who have previously received RAI therapy. In such circumstances, it is evident that the cumulative occupational dose may exceed 1 mSv. Therefore, asking patients during the appointment scheduling process whether they have recently received RAI therapy for thyroid cancer would be beneficial from a radiation safety standpoint. Furthermore, exposure to airborne radioiodine is a potential source of contamination. Ibis et al. (11) highlighted contamination hazards associated with the release of ^{131}I in sweat, saliva, breath, and urine following RAI therapy. The authors emphasized that because of the relatively high activity levels detected in the saliva, urine, and skin of such patients, all individuals who come into contact with them should be informed of the associated contamination risks (11). A similar consideration applies to our study, as close-range dental procedures performed on these patients may lead to increased cumulative doses through contamination. However, contamination-related dose contributions were not quantified in our study; therefore, minimizing occupational exposure remains of particular importance. Furthermore, exposure to airborne radioiodine is a potential source of contamination. Ibis et al. (11) highlighted contamination hazards associated with the release of ^{131}I in sweat, saliva, breath, and urine following RAI therapy. The authors emphasized that, due to the relatively high activity levels found in the saliva, urine, and skin of such patients, all individuals who come into contact with them should be made aware of the associated contamination risks (12). A similar consideration applies to our study, as close-range dental procedures performed on these patients may lead to increased cumulative doses through contamination. However, contamination-related dose contributions were not quantified in our study; therefore, minimizing occupational exposure remains of particular importance.

Although no previous study has specifically investigated radiation safety for dentists working with RAI-treated patients, several reports have focused on radiation protection for family members and close contacts of such individuals. The ICRP recommends that the annual effective dose for members of the public who are not occupationally exposed to radiation should not exceed 1 mSv (6). Similarly, both the International Atomic Energy Agency and the Council Directives of the European Atomic Energy Community set the annual effective dose limit for public exposure at 1 mSv (11). The United States Nuclear Regulatory Commission has also adopted this limit, thereby reinforcing global harmonization of radiation protection standards (13).

Discharge criteria for patients receiving RAI therapy are typically based on dose-rate measurements taken at 1 meter from the patient; however, there is no universally accepted fixed threshold. The permissible dose-rate limits vary across countries — for instance, in the United States, the threshold is 70 μSv/hour, while in Türkiye the threshold is 30 μSv/hour (14,15).

The American Thyroid Association recommends that patient discharge be contingent upon the dose rate at 1 meter falling below the regulatory limit for retained ^{131}I activity. However, while this limit may still be exceeded, adult family members and caregivers are advised to remain at least 1.8 meters from the patient; if close contact is unavoidable, interactions should be limited to a few minutes. This approach is based on the ALARA principle—"As Low As Reasonably Achievable"—which

emphasizes minimizing radiation exposure as far as practicable (16). The duration of these restrictions largely depends on factors such as the amount of residual thyroid tissue, the retained RAI activity, and the biological clearance rate of the radionuclide. Such evaluations are generally conducted in consultation with a radiation safety officer.

In thyroid cancer follow-up, two parameters are indispensable for clinical assessment: serum Tg levels and WBS. Stimulated Tg, measured under elevated TSH levels, serves as a highly sensitive biomarker for detecting residual or recurrent disease, while WBS plays a critical role in identifying the anatomical localization of residual thyroid tissue or metastatic foci (17). In this study, serum Tg levels were consistent with patients' pathological characteristics and with the administered treatment doses. Furthermore, laboratory parameters—including percentage uptake, fT_3, fT_4, and TSH—were consistent with the Society of Nuclear Medicine and Molecular Imaging Procedure Standard and European Association of Nuclear Medicine Practice Guidelines, which recommend achieving a TSH level >30 mIU/L prior to RAI administration to maximize iodine uptake. In our patient cohort, all TSH levels exceeded 60 mIU/L and were accompanied by decreased fT_3 and fT_4 values, confirming adequate thyroid stimulation and the establishment of a hypothyroid state.

This study is the first experimental, quantitative assessment of radiation doses dentists may receive during interactions with thyroid cancer patients who have recently undergone RAI WBS. The findings define practical radiation safety thresholds, including safe timing and distance parameters, for dental procedures. This evidence-based framework fills a critical knowledge gap between nuclear medicine and dental radiation protection, offering valuable guidance for maintaining safe clinical practice without delaying necessary patient care.

Study Limitations

At the treatment clinic where this study was conducted, a radioiodine activity of 185 MBq was used for whole-body scanning in patients with thyroid cancer. However, similar studies may be performed using radioiodine activities below 185 MBq. These results may also be applied to therapeutic doses once the amount of radioiodine in the patient's body decreases below the 185 MBq threshold. The daily dose limit of 2.7 µSv used in this study was derived from the public annual dose limit of 1 mSv; practices that could lead to an increase in dose were excluded. For more detailed investigations, the sample size may be increased

Conclusion

Dentists should inquire about patients' recent treatments to avoid exceeding dose limits. Therefore, dental interventions for these patients should be postponed until at least the second day after discharge, when radioactive decay and biological clearance sufficiently reduce external dose rates. However, when daily dose limits are taken into account, it appears necessary to delay dental visits for at least three days following RAI administration. For these patients, the allowable chairside exposure time was estimated at approximately 3.12 hours without exceeding safety limits. Nevertheless, dental procedures may be considered safe provided that the working time is kept as short as possible, procedures are performed at the greatest feasible distance from the patient, and radiation protection principles—such as the use of lead aprons and thyroid shields—are strictly followed. However, these safety recommendations do not account for potential cumulative occupational exposure that may arise when multiple treated patients are examined in rapid succession. Moreover, contamination-related exposure pathways, such as saliva, aerosols, and exhaled breath, were not quantitatively assessed. It may be recommended that pregnant dentists extend this waiting period to at least three days to comply with the more stringent annual occupational dose limit of 0.5 mSv. Overall, the findings of this study provide experimentally validated safety criteria for dentists managing patients who have recently undergone WBS with RAI. This research, By defining precise time–distance parameters between the dentist and the patient, significantly strengthens radiation protection practices and enhances interdisciplinary awareness between nuclear medicine and dental healthcare services.

Ethics

Ethics Committee Approval: The study protocol was approved by the İstanbul Kent University Clinical Research Ethics Committee (approval number: 2025-07, date: 10.09.2025).

Informed Consent: Written informed consent was obtained from all participants prior to inclusion in the study.

Footnotes

Authorship Contributions: Surgical and Medical Practices - E.T.A., M.D.; Concept - M.D.; Design - E.T.A., M.D.; Data Collection or Processing - E.T.A., M.D.; Analysis or Interpretation - M.D.; Literature Search - E.T.A.; Writing - E.T.A., M.D.

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