Absorbed Radiation Doses During Tomographic Examinations in Dental Implant Planning: A Study in Humans

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ABSTRACT

Objective: The aim of this human study was to evaluate the radiation doses in the buccal cavity and face, during panoramic, spiral conventional tomography, and helicoidal computerized tomography exams.

Material and Methods: Lithium fluoride TL detectors (TLD-100) were placed on the skin at anatomic points such as parotid glands, submandibular glands, thyroid glands, and crystalline to assess the skin entrance dose in 19 patients who were to undergo dental implant surgery.

Results: In the panoramic exam, maximum doses were observed near the parotid glands at 1.57 (±18%) mGy on the right and 1.89 (±18%) mGy on the left. In the spiral conventional tomography exam, the maximum dose was 4.41 (±21%) mGy near the right and left parotid glands, whereas near the right or left submandibular glands, the maximum doses reached 40.7 (±18%) mGy. In the helicoidal computerized tomography for mandibular and maxilla exams, the maximum dose was 40.9 (±15%) mGy near the parotid glands and 41.0 (±18%) mGy near the submandibular glands. Near the thyroid and eye lens, doses were lower than 0.23 (±21%) in all exams.

Conclusion: Regardless of the exam target area, the submandibular and parotid glands represented the most irradiated organs. This data suggests that efforts should be made by professionals to improve and optimize methods in order to reduce doses without losing the information necessary for treatment planning.

KEY WORDS: dental implants, human study, parotid gland, radiation dose, thyroid gland, TLD dosimetry, tomography

INTRODUCTION

Several long-term investigations have documented the high predictability of dental implants in partially and fully edentulous patients.[1,2] Nonetheless, procedures for the placing of dental implants and the elimination of potential morbidity, associated with treatment plan failure, demand techniques from high-resolution diagnostic exams and reliability of planning prior to the implementation of a dental implant.[3,4]

Because of a limited amount of information in conventional radiographies, the conventional and computerized tomographies have also been introduced to analyze the edentulous and partially edentulous maxilla and mandibula, prior to the implementation of the dental implant.[5,6]

In this context, the development of basic international standards of radiological protection were published by the International Atomic Energy Agency on 2004[7] which recommended the establishment of radiodiagnostic reference levels within the context of optimization, which include values of doses absorbed by the air, the tissue, the surface of a simple standard customer phantom or in a representative patient. The measurements of representative doses given to patients have

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been recommended due to the fact that radiodiagnostic reference levels have also been adopted as a regulating instrument for the optimization of medical exposure.

Despite relevant studies in the literature,[3,5,8–11] it is still difficult to correlate the experimental data because of the variability of radiographic technique parameters, operational parameters, radiographic areas, and the relatively few details available regarding experimental methodology and the system of measures.

Therefore, the aim of this study was to evaluate and to compare absorbed doses in critical organs of the neck and head from patients undergoing panoramic radiographies, spiral conventional tomographies, and helicoidal computerized tomographies when planning dental implants using the thermoluminescent dosimetry technique (TL).

MATERIALS AND METHODS

Patients

The selection of patients to participate in this study was based on the recommendation of radiographic exams, with the core aim of evaluating the anatomic region for the placement of dental implants. Two groups of patients were examined over a 3-month period. The first group consisted of seven patients who underwent panoramic radiography and spiral conventional tomography (Cranex® Tome, Soredex, Helsinki, Finland). The second group consisted of 12 patients who underwent the helicoidal computerized tomography (CT Twin®, Elscint, Haifa, Israel). All the patients gave their informed consent. Ethics and Research Committee School of Dentistry, Pontifical Catholic University of Minas Gerais, Brazil, approved this study.

Dosimetry in Patients

Doses absorbed in the thyroid, parotid, and submandibular gland regions as well as in the crystalline were obtained by measuring a dose upon entering the skin at defined anatomic points. Three TL detector crystals were strategically placed at each selected anatomic point (Figure 1).

Calibration of TL Detectors

For the evaluation of the absorbed dose, termoluminescent (TL) detectors of LiF– Mg, Ti, as regards homogeneity and reproducibility – were selected and evaluated. For this, the detectors were submitted to 10 irradiation

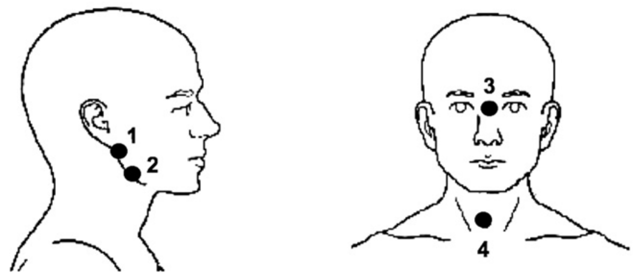

Figure 1 Reference points used to evaluate the adsorption of radiation doses: 1 – parotid gland, 2 – submandibular gland, 3 – lens, and 4 – thyroid to measurements of absorbed radiation doses.

cycles at ^{137}Cs, under electronic balance conditions, with 10 mGy of kerma in the air. The standard thermal technique was adopted for the detectors, and the temperature and time conditions were recommended for the TDL Harshaw, Model 4500 (Thermo Fisher Scientific Inc., Waltham, MA, USA) reader. The system of TL dosimetry was calibrated in terms of the dose absorbed in the air. Initially, the calibration was carried out in clusters of ^{137}Cs. Later, the procedure was carried out using five types of x-ray clusters reproduced in a VMI model Pulsar Plus 800 (VMI Industria e Comércio Ltda, Belo Horizonte/ Minas Gerais, Brazil) x-ray machine, which most closely resembled radiographic technique conditions. The dosimetry of the clusters were carried out using a Radical ionization chamber, model 10X5-6 (Radcal Corp., Monrovia, CA, USA) with international standard tracking through calibration, in clusters of diagnostic x-rays, as previously reported.[12,13]

RESULTS

Calibration of TL Detectors

As regards the reproducibility, all detectors used were reproducible in up to 4.9% (SD), the value of which was considered upon calculation of the combined uncertainty. Initially, the calibration was carried out in clusters of ^{137}Cs, obtaining a calibration factor of 0.0241 nC/ mGy (±2.2%). The simulation of the x-ray clusters generated by the VMI machine, through the XCOMP5R program, allowed for the adoption of calibration factors for the specific TL dosimeters for each radiographic technique (Figure 2). For the spiral conventional tomography and panoramic tomography techniques, the energy dependency correction factor, in relation to the ^{137}Cs, was 1.18 (±0.8%), whereas for the helicoidal computerized tomography was 1.28 (±0.4%). Such

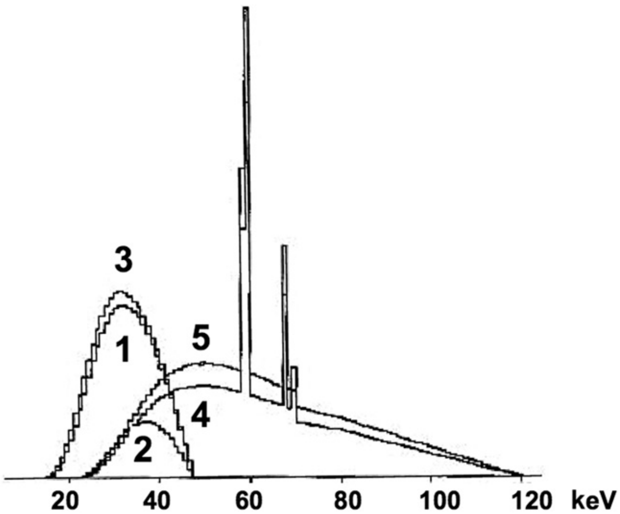

Figure 2 Energy spectrum simulated for x-ray machines with a tungsten target. Score: 1, 2 – panoramic radiography; 3 – spiral conventional tomography; 4, 5 – helicoidal computerized tomography.

factors emphasize that if the energy dependency of the TL system is not considered and corrected among the clusters of x-rays and ^{137}Cs, the dose values in patients would be underestimated in nearly 18% in the spiral conventional tomography and panoramic tomography techniques and in nearly 28% in the helicoidal computerized tomography.

The uncertainty of the values of doses absorbed in patients was estimated by means of the combination of the most relevant uncertainty components of the procedure, which are relative to the reproducibility of the TL detectors (4.9%); to the calibration factor of the ionization camera (4.3%); and, mainly, to the variation of the measure of the dose in patients with TL detectors (maximum value of 11.5%).

Dose Absorbed in the Panoramic and Conventional Tomography Exams

The panoramic radiography equipment uses the principle of rotational tomography, where the head of the x-rays produces a straight line (2 mm in thickness), whose height is collimated only to cover the height of the film (15 cm). In the panoramic exam, the higher doses were found in the parotid gland regions: 1.57 (±18%) mGy on the right side and 1.89 (±18%) mGy on the left, resulting from the positioning of the organs in the regions which coincide with the rotational center of the image formation (Table 1). Because of its location, these points were irradiated directly through the primary cluster, whereas for other evaluated areas, such as the thyroid gland and the crystalline, the contribution to the dose is due to the secondary radiation, as they are more distant from the focal area, presenting a lesser dose value ranging from 0.032 ± 33% to 0.237 ± 21% mGy.

In the conventional tomography, the maximum dose in the parotid gland region (right or left), in the evaluated programs, was 4.41 (±21%) mGy. In the submandibular gland region (right or left), the maximum dose was 40.7 (±18%) mGy. When the tomography was performed in the left upper frontal area, the left parotid gland and the left submandibular regions presented greater doses (0.227 ± 23% mGy and 0.323 ± 33% mGy, respectively). The same occurred in the right parotid and right submandibular regions, which presented greater doses when the cuts were made on the right side, through the right upper frontal program. The dose values were 0.586 ± 20% mGy for the right parotid region and 9.129 ± 20% mGy for the right submandibular gland region. In the left lower molar region, the value of the absorbed dose in the left parotid gland was 8.66 ± 16% mGy, whereas in the left submandibular gland, the value of the absorbed dose was 40.7 ± 18% mGy (Figure 3).

In the three areas evaluated using the spiral conventional tomography technique, the crystalline presented maximum doses which ranged from 0.041 ± 28% to 0.180 ± 27% mGy. The thyroid gland region presented doses which ranged from 0.080 ± 40% to 0.662 ± 34% mGy.

The results showed that the organs located in the evaluated areas, or near them, effectively presented higher doses because of the fact that this technique used a primary cluster of collimated x-rays, guided and limited only by the side in question.

Doses Absorbed in the Computerized Tomography

In the computerized tomography of the mandibula and the maxilla, the maximum dose in the parotid region was 40.9 ± 15% mGy and 41.0 ± 18% mGy in the submandibular gland region (Figures 4 and 5). In the crystalline and thyroid regions, the doses were less than 0.237 ± 21% mGy.

The computerized tomography was the technique which offered a greater dose to the patients, as compared with the conventional and panoramic tomographies. In the computerized tomography of the mandibula, the

TABLE 1 Maximum Absorbed Dose (mGy), in the Organ Regions of the Patients During the Spiral Conventional Tomography (Cranex Tome), in the Left Upper Frontal (LUF), Right Upper Frontal (RUF), and Left Lower Molar (LLM)

	Dose (% mGy ± SD)		
	Areas		
Organ region	LUF	RUF	LLM
Thyroid	0.124 ± 22	0.080 ± 40	0.662 ± 34
Right parotid	0.056 ± 47	0.586 ± 20	0.051 ± 30
Left parotid	0.227 ± 23	0.076 ± 23	8.66 ± 16
Right submandibular	0.041 ± 65	9.129 ± 20	0.053 ± 24
Left Submandibular	0.323 ± 33	0.027 ± 39	40.7 ± 18
Crystalline	0.180 ± 27	0.180 ± 28	0.041 ± 28

areas which received the highest absorbed dose were the parotid gland regions on both the left and right sides, as well as the submandibular gland regions on both the left and right sides. The doses ranged from 11.6 ± 23% to 38.3 ± 15% mGy for the right parotid gland region, whereas for the left parathyroid gland region, the doses ranged from 3.3 ± 26% to 35.4 ± 17% mGy.

The doses in the submandibular gland regions presented the highest values: in the right submandibular gland region, the doses ranged from 36.5 ± 17% to 40.9 ± 15% mGy, while in the left submandibular gland region, the doses ranged from 32.1 ± 16% to 41.0 ± 18% mGy. In the thyroid gland region, the doses ranged from 1.1 ± 23% to 3.7 ± 22% mGy. The crystalline region presented the lowest doses, with values ranging from 0.467 ± 19% to 0.755 ± 19% mGy.

DISCUSSION

The present study evaluated the absorbed radiation doses in several regions after different radiographic exams to dental implant planning. Clark and colleagues[8] determined the average dose for the anatomic region, during linear tomography and computerized tomography, and the results were compared with reports from previous literature as regards panoramic radiography techniques and intra-oral techniques. The measures of absorbed doses were carried out in a customer phantom using thermoluminescent dosimeters of LiF. The equipment used for the linear conventional tomography was the unit of Quint Sectograph x-rays (Quint Sectograph Corp., Los Angeles, CA, USA). The average dose of the salivary glands (parotid, sublingual, and submandibular) was 0.278 mGy, when the exam was carried out in the inferior molar region. In these

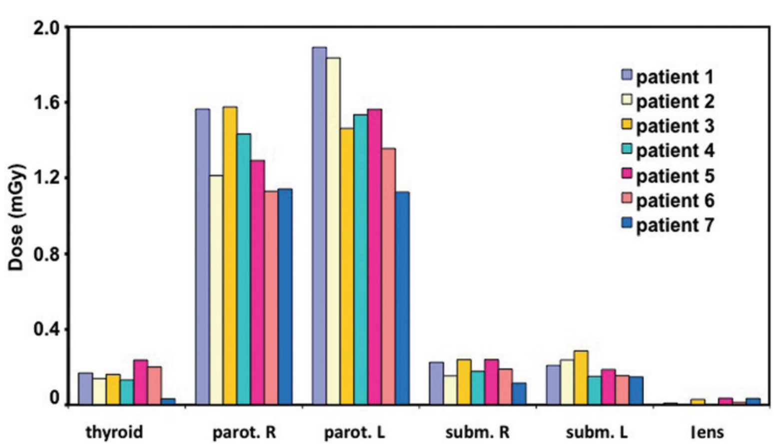

Figure 3 Dose (mGy) in the organ region during the panoramic exam (Cranex Tome), prior to the conventional tomography, of the seven patients. parot. = parotid; subm. = submandibular.

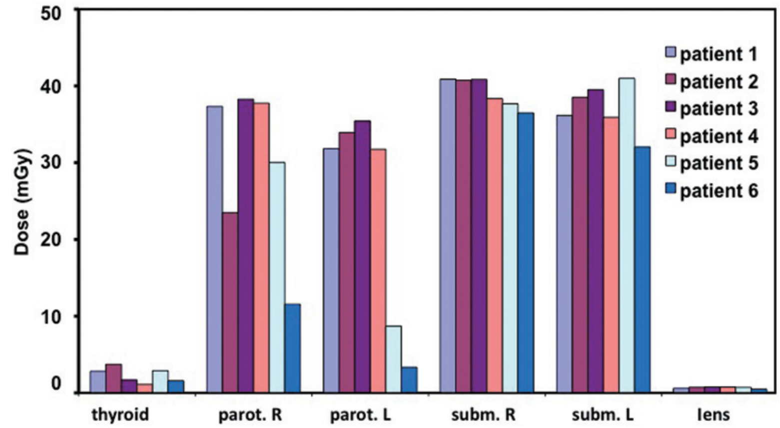

Figure 4 Dose (mGy) in the organ region in all patients during the computerized tomography of the mandible. parot. = parotid; subm. = submandibular.

organs, the doses were greater then the results obtained in the eyes (0.009 mGy), in the medular bone (0.005 mGy), and in the thyroid gland (0.044 mGy). Upon entering the skin, the value of the absorbed dose was 0.304 mGy.

In other study, Serhal and colleagues,[13] upon assessing the absorbed dose using thermoluminescent dosimeters on a cadaver and using the Cranex Tome unit, reported that, in the molar program below the parotid and submandibular glands, which could be found beside the tube during the exam, presented the highest dose values, that is, 6.87 and 6.45 mGy. On the other hand, the organs on the opposite side of the tube presented lesser dose values, that is, 0.04 mGy for the parotid gland, 0.27 mGy for the submandibular gland, and 0.03 mGy for the thyroid gland.

The absorbed dose in the submandibular gland region, which can be found on the exam side of the lower molar program, observed in our study and compared with the values obtained in findings from earlier studies (Table 2) are because of the fact that in the conventional tomography, the cluster presents a posterior–anterior direction as well as a small focus-object distance. In the frontal exam, the lateral rotation of the head and straight collimation of the cluster effectively removes the parotid and submandibular glands from the exposure to the primary cluster of x-rays.

Ekestube[3] also observed that when the spiral conventional tomography and hypocycloidal exams are performed in the maxilla, as compared with other organs, the crystalline presents the highest dose (0.15 and 0.07 mGy), while the thyroid gland presents the lowest

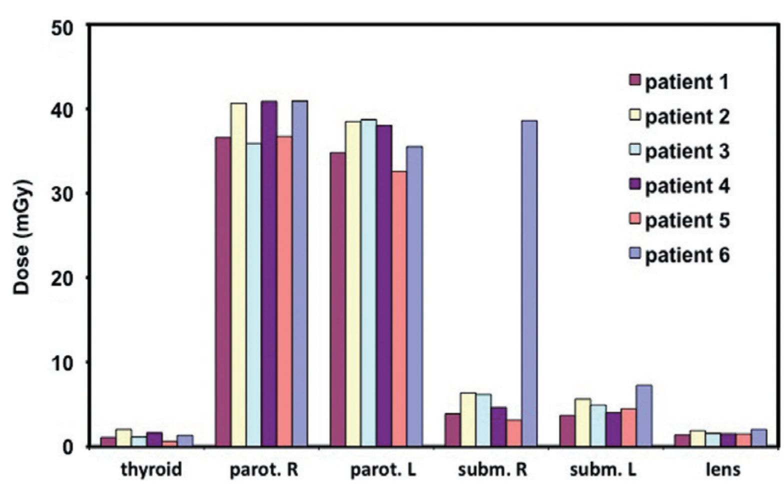

Figure 5 Dose (mGy) in the organ region in all patients during the computerized tomography of the maxilla. parot. = parotid; subm. = submandibular.

TABLE 2 Absorbed Doses (mGy) in the Critical Organs of the Maxillofacial Region in Tomographies Reported Both in the Literature and in the Present Study

			Absorbed Dose (mGy)			
			Region			
Literature	Exam	Area	Thyroid	Parotid	Sub-mandibular	Crystalline
Present study	Panoramic		0.237	1.892	0.286	0.035
	TC spiral	h	0.124	0.076* 0.586†	0.041* 9.12†	0.180
		b	0.662	0.051* 8.66†	0.053* 40.7†	0.041
	CT spiral	f	2.1	40.9	7.3	1.9
		i	3.7	38.3	41.0	0.755
Lecomber[5] (2001)	Panoramic		0.031	0.195	0.163	0.006
	TC	b	0.009	0.535	0.291	0.044
	CT	c	1.571	29.860	27.184	1.293
Serhal et al.[13] (2001)	TC	b	0.03	0,04* 6.87†	0.27* 6.45†	
		e	0.02	3,87* 0.92†	0.45* 1.93†	
		h	0.02	1,33* 0.04†	0.09* 0.09†	
		i	0.02	0,03* 7.78†	0.09* 0.55†	
		a	0	0,01* 5.00†	0.02* 0.40†	
		j	0.01	0,01* 2.43†	0.06* 2.62†	
Ekestube[3] (1999)	CT	c	0.6	3.1	2.5	1.5
		d	1.6	3.4	27	0.6
		e	4.0	0.8	16	5.5
	TC spiral	f	0.03	4.3	0.44	0.15
		g	0.17	0.31	5.3	0.02
	TC hypocycloidal	f	0.01	0.14	0.31	0.07
		g	0.13	0.07	2.8	0.03

Legend:
*OP (opposite side of the tube). †TS (side of the tube).
a = maxillary molar; CT = computerized tomography; TC = conventional tomography; b = mandibular molar; c = maxillary axial; d = mandibular axial; e = mandibular frontal; f = maxilla; g = mandibula; h = maxilla frontal; i = maxillary premolar; j = mandibular premolar.

dose (0.03 and 0.01 mGy). If the spiral conventional tomography and hypocycloidal exams had been performed on the mandible, the result would have been the opposite (0.02 and 0.03 mGy in the crystalline and 0.17 and 0.13 mGy in the thyroid gland, in each exam, respectively), in agreement with our results.

The difficulty in measuring the doses due to the impossibility of precision in the positioning of the simulator on the dental appliance can lead to variable radiation of the TL detector. In the present study, these variations in the dose may be related to the anatomic differences among patients, the positioning of the patients during the exam, and the positioning of the TL detectors. During the conventional tomography, four slices with a 2 mm thickness were performed. Consequently, because of the dimensions of the detectors, any alteration in relation to these variables may cause the TL detectors to irradiate in a nonuniform manner.

According to the results presented herein, it could be observed that during the computerized tomography, the parotid gland and submandibular gland regions were the locations which received the highest doses. These results can be compared with the doses from the panoramic radiography, resulting in high doses in the salivary glands (parotid and submandibular) because of the fact that the rotational "scanning" center coincides with the location of these regions, agreeing with previous data.[3,5,8,14]

The doses in the crystalline region may possibly be related to the indirect irradiation of these organs because of the spreading of secondary radiation when the cuts are performed in its proximities.

Complementary, the distribution of absorbed doses (mGy) in the critical organs of the maxillofacial region in tomographies reported both in the literature and in this study could be observed in Table 2. The variation in the doses between the left and right sides may well be related to the positioning of the patient, to the anatomic normal asymmetry of the patients, as well as to the positioning of the detectors.

Finally, considering that the diagnostic reference levels have still not been established for these radiographic exams, the measurements of the dose upon entering the skin of the patients, defined as absorbed doses in the region of critical organs, constitutes a relevant contribution to aid in the choice of such levels. An effort made by medical professionals in the research and choosing of methods of dose reduction, without causing a loss in the information necessary for treatment planning, can optimize the procedures.

CONCLUSION

All techniques evaluated presented considerably higher dose values in the salivary glands (parotid and submandibular) when compared with the thyroid gland and to the crystalline. The helicoidal computerized tomography, as compared with the panoramic radiography and to the spiral conventional tomography, was the technique which caused the highest dose to the patients.

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