DETERMINATION OF ABSORBED DOSES FROM VARIOUS RADIOGRAPHICS TECHNIQUES REQUIRED FOR DENTAL IMPLANTS

Determinação da dose absorvida em várias técnicas radiográficas utilizadas para implantes dentários

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Abstract

The diagnostic and treatment benefits of various radiographic techniques, including those used routinely for dental implants, need to be evaluated against the complications and exposure risks involved. The aims of this study were to measure the amount of ionizing radiation absorbed by various critical tissues of the body in order to determine the risks of a radiographic procedure and to compare the amount of radiation absorbed by various tissues during radiographic procedures for dental implants. This in vitro study was performed on a humanlike X-ray phantom head using lithium thermo-luminescent dosimeters. The amount of radiation absorbed by critical tissues was more during the generation of a CT scan as compared to the use of linear tomography. The absorbed dose using these two techniques was more than when panoramic radiography was used. Organs defined as critical in this study were the eyes, thyroid glands, salivary glands, brain, bone marrow and skin. The amount of radiation absorbed by the thyroid gland during a mandibular CT scan was relatively high and therefore the use of a protective collar is recommended. The amount of radiation absorption in the parotid glands was more than the other two major salivary glands and also more than all other critical organs during a mandibular CT scan, an anterior and posterior linear tomographic survey or while taking a panoramic radiograph. The maximum amount of absorption in the parotid gland was in the maxilla CT, insignificant in relation to 10 grays, the dose resulting in acute inflammation of the gland. The maximum amount of radiation absorbed in the skin was during a mandibular CT scan which was lower than the dose resulting in erythema. The maximum amount of radiation absorbed was in during a mandibular CT scan..

Keywords: Radiaton protection; Panoramic radiograph; Linear tomography; CT scan; Absorbed dose.

Resumo

Os benefícios de diagnóstico e tratamento obtidos com várias técnicas radiográficas, inclusive as usadas rotineiramente para implantes dentários, devem ser avaliadas em relação aos riscos de exposições e possíveis complicações decorrentes. Os objetivos deste trabalho foram medir a radiação ionizante absorvida por vários tecidos críticos do corpo, para determinar os riscos dos procedimentos radiográficos e comparar a quantidade de radiação absorvida por vários tecidos durante procedimentos radiográficos para implantes

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dentários. Este estudo in vitro foi executado numa cabeça-modelo para raios X usando dosímetros termoluminescentes de lítio. A quantidade de radiação absorvida por tecidos críticos foi maior durante a tomografia computadorizada, quando comparada com a tomografia linear. A dose absorvida durante estas duas técnicas foi maior do que durante a panorâmica. Órgãos definidos como críticos neste estudo foram os olhos, tireóide, glândulas salivares, cérebro, medula óssea e pele. A quantidade de radiação absorvida pela tireóide durante a tomografia computadorizada foi relativamente alta e assim o uso de colar protetor é recomendado. A quantidade de radiação absorvida pelas parótidas foi maior do que as duas outras glândulas salivares maiores e também maior do que todos os outros órgãos críticos durante o escaneamento tomográfico mandibular, a série tomográfica linear ou na tomada de radiografia panorâmica. A quantidade máxima de absorção na parótida foi na tomografia computadorizada maxilar, insignificante em relação a 10 Gy, a dose que resultaria em inflamação da glândula. A quantidade máxima de radiação absorvida pela pele foi durante a TC mandibular, que foi menor do que a dose de eritema.

Palavras-chave: Proteção radiológica; Radiografia panorâmica; Tomografia Linear; TC; Dose absorvida.

Introduction

The discovery of X-rays in 1895 and the rapid application of this phenomenon as a diagnostic tool to the field of medicine was the preliminary step in the new world of medical Imaging. With the invention of the computer and its use in the evaluation of images and image manipulation, the computed tomography (CT) scan evolved to present clear images of different points in the body. The latest generation CT scans can present tridimensional pictures of a desired anatomical location. This is especially true of hard tissue. The role of CT scans in diagnosis, treatment plan and surgery, including dental implants, is well known (1)

In intraoral and panoramic radiographs, the location of a dental implant is evaluated bidimensionally. In tomography this is done tridimensionally. Such images present valuable data for diagnosis as well as for treatment planning with regard to size, location and shape of mandibular canals, maxillary sinuses, mylohyoid and alveolar ridges, which is not possible in traditional radiographic film techniques. There is little data on the radiation absorption while obtaining images of dental implants (2). In this study the radiation absorbed by six critical tissues during various radiographic techniques required for dental implants was measured and compared with each other.

Materials and Methods

In this study using protective facilities against radiation provided by the Atomic Energy Organization of Iran, a humanlike anthropomorphic phantom was used (Alderson-Rando, CA, USA). This phantom was a male skeleton with a specific weight and height with isocyanide plastic used as soft tissue on the skeleton. The phantom was divided breadth wise into 33 segments of 2.5 cm each, 10 of which were used in this study. Each of the segments had holes to insert the dosimeters needed for measurement of the ionizing radiation used in the study. The TLD-100 dosimeters (HarShaw Chemical Co., Cleveland, OH, USA) were made of thermo-luminescent lithium fluoride square shaped crystals with dimensions of 1/8" x 1/8" x 0.035 inches and were reusable. A total of 30 dosimeters were used in each stage with two dosimeters used to monitor background radiation.

The dosimeters were initially calibrated at the Central Dosimetry Laboratory of Karaj, Tehran, Iran. Calibration was accomplished by exposing the 30 dosimeters to a specific quantify of radiation in the laboratory generated within an ionization chamber. The rate of absorbed radiation was calculated in centigrays. After dosimeter calibration, the various stages were as follows:

1. Standard anealing stage: all dosimeters were exposed to 400o C for a period of one hour, followed by two hours at 100o C to remove any residual dosage indication. Thermolyne furnace (Vinten Instrument Ltd, Surrey, UK) was used for this purpose.

2. Radiation stage: For panoramic and linear tomography a Planmeca 2002 CC Proline machine (Asentajankatu, Helsinki, Finland) (Fig 3).

A Somatom (Siemens, DRH) machine was used for performing the CT scans. This stage is described in two parts;

Selection of the region for placement of the dosimeters:

As it is impossible to measure the amount of radiation in all regions of the body, corpse or phantom, those parts of tissue where the amount of radiation absorbed indicates the amount of absorption by that tissue in the body are selected. For example, active bone marrow is present in various regions of the body. The mean amount of radiation absorbed by the bone marrow of the body is calculated by measuring the amount of radiation absorbed by the bone marrows in certain regions of the skull and neck which contains active bone marrow.

- Methods of performing the above mentioned techniques: Panoramic radiographs were taken using the Planmeca 2002 CC Proline machine (Asentajankatu, Helsinki, Finland) at an exposure of 18 seconds at 9mA and 76 kV. In each stage, 10 exposures were performed so that the absorbed radiation could be read by the machine. Both anterior and posterior tomograms were obtained. Anterior tomography exposure settings were 4.5 seconds at 9 mA and 70kV. The total number of exposures was 20. Posterior tomography settings were 4.5 seconds at 9 mA and 74 KV. A total of four cuts, each 2 mm thick were obtained

The settings for the CT scan exposures were 210 mA, 52.5 mA and 125 kV. A total of 34 cuts were obtained of the mandible. The gantry angle was adjusted at zero. The mandible was scanned from the base upward. The lower margin of the mandible was placed vertically on the scan table and the scan plane was parallel to the lowermargin of the mandible. The slices were 2 mm thick at distance of 1 mm apart. A similar protocol was used for scanning the maxilla. The phantom was placed in such a manner that the upper alveolar ridge was vertical on the scan table and the hard palate was parallel to the scan plane. The maxilla was scanned with 33 slices; 3 slices below the upper alveolar ridge up to 3 slices posterior to the hard palate. (Figs. 6,7)

2. Preheat stage: After irradiation, the dosimeters were removed from their locations and the plastic covers were removed very carefully. After recording their readings they were subjected to 100 degrees Celsius for a period of 10 minutes.

3. Dosimeter value reading stage: After removal of the dosimeters from the furnace, they were allowed to cool down and selected individually using a pair of forceps and placed in the reading machine (Thermoluminescence Detector Model 200c, Harshaw, OH, USA). Then, they were heated till 280 oC to release the absorbed energy in the form of light rays from the dosimeters. These rays were measured by a photo multiplier tube and presented as a number value (nano Coulombs)

After registering the value, the machine was allowed to cool down to 40?C, and the dosimeter was replaced by the next one for measurement. The dose absorbed by each dosimeter was calculated in mGy.

The amount of radiation absorbed by each tissue was calculated by adding all the values of the dosimeters placed in that region and dividing it by the number of dosimeters.

The settings for the CT scan exposures were 210 mA, 52.5 mA and 125 kV. A total of 34 cuts were obtained of the mandible. The gantry angle was adjusted at zero. The mandible was scanned from the base upward. The lower margin of the mandible was placed vertically on the scan table and the scan plane was parallel to the lower

Results

The amounts of radiation absorbed by the various organs during panoramic radiography, linear tomography and CT scans are presented in Tables 1, 2 and 3, respectively.

Table 1 - Mean absorbed dose by various organs in different techniques (micrograys) (X±2 SD)

Techniques Organs	Panoramic	Linear Tomography		C T scan	
		Anterior	Anterior	Mandibule	Maxilla
Eyes	Avg=17.75	Avg=268	Avg=844	Avg=792.5	Avg=502.5
Left	19.5±0.44	396±7.86	840±16.18	910±20.0	105±7.2
Right	16±0.06	140±12.4	848±10.94	675±15.8	900±13.62
Thyroid	54±2.00	184±13.34	112±7.34	1870±38.08	402±3.16
Sublingual gland	135±3.74	408±15.42	174.2±10.24	10150±29.14	1087±12.48
Submandibular gland	Avg=278.5	Avg=439.2	Avg=588.6	Avg=15085	Avg=1032.5
Left	315±5.1	764±16.44	1084±11.04	1532±31.62	1425±12.24
Right	242±3.16	114.4±7.02	46.56±3.72	14850±103.18	1180±6.32
Parotids	Avg=1507	Avg=6441.20	Avg=4813	Avg=8170	Avg=24722.5
Left	1549±7.48	12496±26.38	9520±38.72	504±27.38	27930±31.62
Right	1465±5.84	386.4±12.20	106±6.32	11300±25.48	21515±14.06
Hypophysis/Brain	299±4.48	281±7.62	193.6±5.94	2960±20.44	3352±21.4
Surface exposure	491±5.84	3876±24.04	2692±23.02	10917±39.72	10706±17.72

Table 2 - Mean absorbed doses by bone marrow in different techniques (micrograys) ('X±2SD) Techniques

Techniques Organs	Panoramic	Linear Tomography		C T scan	
		Anterior	Anterior	Mandibule	Maxilla
Mandible	Avg=30.5	Avg=2112	Avg=2788	Avg=18111	Avg=1570
Left	48.95±1.42	4304±9.70	7772±14.76	2589±24.66	1712±20.74
Right	35.75±2.50	1368±12.88	214±7.88	22310±92.46	1627±20.74
Symphysis	6.8±1.08	664±9.28	378±13.34	29435±77.78	1370±23.46
Cervical spine	Avg=134.75	Avg=429.32	Avg=885	Avg=972.50	Avg=540
C2	235±3.16	464±9.28	1290±15.82	1540±29.16	870±22.68
C6	34.5±2.00	394.64±3.84	480±15.56	405±15.82	210±9.06
Anterior skull (Calvarium)	Avg=3.37	Avg=59.61	Avg=148.65	Avg=1017	Avg=883.75
Left	3.22±0.48	46.65±5.56	41±8.72	1110±12.24	809±15.74
Right	4.09±0.34	33.40±2.76	73.6±6.10	835±15.82	950±23.46
Anterior	3.96±10.94	104±-4.48	76±7.88	620±25.50	593±15.42
Posterior	2.23±0.26	54.4±5.76	404±8.94	1503±10.58	1183±13.34

Table 3 - Maximum and minimum absorbed doses by organs in radiographies required for dental implants

Maximum dose (micrograys)	Minimum dose (micrograys)	Organ
CT of Maxilla (900)	Panoramic (17.75)	Eyes
CT of Mandibule (1870)	Panoramic (54)	Thyroid
CT of Maxilla (27930 left side)	Anterior tomography (106 Rt side opp. to examination)	Parotid
CT of Mandibule (15320 left side)	Posterior tomography (46.56 Rt side opp to examination)	Submandibular
CT of Mandibule (10150)	Panoramic (135)	Sublingual
CT of Maxilla (3352)	Anterior linear tomography (193.6 micrograys)	Brain
CT of Mandibule (10917)	Panoramic (491)	Skin
CT of Mandibule (29435)	Panoramic (Posterior calvarium 2.23)	Bone marrow

In the present study, the doses absorbed by various organs using different radiographic techniques were as follows:

- Maxillary CT-Scan: The maximum absorbed dose was in the left parotid (side of examination) (27930 mGy) and the least absorption was in the sixth cervical bone (210 mGy);
- Mandibular CT Scan: The maximum absorbed dose was in the symphysis bone marrow (29435 mGy) and the least absorption was in the sixth cervical bone (405 mGy);
- Anterior linear tomography: The maximum absorbed dose was in the left parotid (side of examination) (9520 mGy) and the least absorption was in the left calvarium bone marrow (34.4 mGy);
- Posterior linear tomography: The maximum absorbed dose was in the left parotid (side of examination) (12496 mGy) and the least absorption was in the right calvarium bone marrow (41 mGy);
- Panoramic X ray: The maximum absorbed dose was in the left parotid (side of examination) (1549 mGy) and the least absorption was in the posterior calvarium bone marrow (2.23 mGy);

The maximum amount of absorbed dose was by the thyroid during the mandibular CT scan (1870 mGy) and the minimum dose absorbed was while taking panoramic radiographs. (54 mGy);

The maximum amount of radiation absorbed by the parotids during the maxillary CT scan was 27930 mGy (left parotid) and the minimum amount of radiation absorbed was 106 mGy during anterior tomography (right parotid)

The maximum amount of radiation absorbed by the mandibular salivary glands during the mandibular CT scan was 15320 mGy (left gland) and the minimum amount of radiation absorbed was 46.56 mGy during anterior tomography (right gland).

The maximum amount of radiation absorbed by the sublingual salivary glands during the mandibular CT scan was 10150 mGy and the minimum amount of radiation absorbed was 135 mGy using the panoramic technique.

The maximum amount of radiation absorbed by the hypophysis was during the maxillary CT scan (3352 mGy) and the minimum amount absorbed was during anterior linear tomography (193.6 mGy).

The maximum amount of radiation absorbed by the skin was during the mandibular CT scan (10917 mGy) and the minimum amount absorbed was in during the use of the panoramic technique (491 mGy).

The maximum amount of radiation absorbed by the bone marrow was during the mandibular CT scan in the symphyseal region (29435 mGy) and the minimum amount absorbed was while using the panoramic technique in the area of the posterior calvarium (2.23 mGy).

Discussion

The absorbed radiation in various anatomical regions of the body in this study have to be assessed on the basis of factors of all other dosimetry studies which include; position and location of the dosimeters, radiological accessories and protocols, method of measurement, reliability and accuracy of the dosimetry system. For example, the linear tomography technique is performed using different methods according to the position of the head, depth of slices and type of colimation. In addition, position of the TLD-100 (Thermo-luminescent Lithium-fluoride Dosimeters) capsules in relation to the angles of exposure and selected depth of slices for both anterior and posterior tomography have to be considered.

According to the values in the tables and statistical calculations, there was a significant difference in the mean values for all the organs except three regions (Sixth cervical, Left and anterior calvarium) in the three techniques. Therefore, on the basis of the mean values, the best method with the lowest mean value for a particular region can be determined. However, the advantages and positive points of each method should also be considered.

The maximum amount of dose absorbed by the eyes was during the maxillary CT (900 mGy) which is insignificant as compared to the dose responsible for cataract formation (two Grays). The minimum dose absorbed was during panoramic radiography (mean of 17.75 mGy).

As the thyroid is exposed to maximum amount of radiation during a mandibular CT scan even a low amount of dosage increases the risk of cancer two fold, the easiest and simplest way to decrease exposure of the gland is to use thyroid protection, even though the sensitivity of adult thyroid to radiation is very low.

Bone marrow is one of the tissues of the body most sensitive to radiation and the maximum amount of radiation absorbed by the bone marrow in this study was 0.029 Gy.

On comparison of the results of the present study with the study by Kassebaumet et al (3), the maximum amount of absorption during a mandibular CT scan in the present study was in the symphysis, while in the Kassebaumet study the maximum amount of absorption was in the right and left regions of the mandible. An interesting point to note is that during a maxillary CT scan the only region with high absorption is the parotid glands which could be due to the fact that the number of axial slices during a maxillary CT scan is less (23 slices in comparison to 34 slices) or that no dosimeters are placed in the maxilla alveolus as these regions are typically not considered to be rich in bone marrow.

In the CT scan of the present study, the kV was lower and mA was higher in comparison to the Kassebaumet study which could be the reason for more absorption in most of the organs in this study. It is necessary to state that the dose of radiation absorbed by the organs in linear tomography was less than CT scans in both the studies. Linear tomography utilizes a type of restricted radiation (collimated) to direct and limit radiation exposure to the desired area (4).

Regarding linear tomography in the present study; the collimation was such that the size of the image was 13 x 5 cm (height=13cm, wide=5cm) and usually four cuts on one film included both arches in the image, while in the study by Kassebaumet et al (3) a wider area was presented on the film. (12 x 10cm)

In the present study, the dose of radiation absorbed by most of the organs on anterior linear tomography was less, while the dose of absorbed radiation on posterior tomography was more then the study by Kassebaumet et al (3). As pointed out previously, the reasons could be attributed to a difference in techniques used for tomography, the exposure, types of machines used and the position of the phantom during the procedure.

The dose of absorbed radiation in the panoramic technique was lesser than CT and linear tomography in this study, which is similar to the study by Underhill et al (5). An important point worth mentioning is that even though the dose absorbed in panoramic technique is lower than the other two techniques, the information gained is less than the other two techniques. Therefore, while comparing the various techniques, both the quantity and quality of the gained information should be kept in mind. Even though the dose absorbed by various organs in the panoramic technique was more in this study (exposure factors) the maximum and minimum doses in both the studies were similar.

The salivary glands are among the least sensitive organs to radiation in the body and the parotids are more sensitive as compared to the mandibular and sublingual glands.

In the study by Clark et al (6), the maximum absorbed dose in both CT and linear tomography was in the salivary glands and the lowest absorbed dose was in bone marrow, which is similar to the findings of the present study.

In the study by Hayakawa et al (7) using two different panoramic machines the maximum doses absorbed were by the parotids, cervical spine and thyroid in the descending order. The same result was obtained in the present study which on comparison with the study by Underhill et al (8) shows that in new generation panoramic machines, fewer doses are absorbed by the organs. One of the reasons is that rotation angles of the X-rays from these machines in comparison with other techniques is more posterior and at a greater distance from the mandible.

The results of the study by Villari et al (9) of absorbed doses by critical organs in the neck, eyes and skull are similar to the present study.

In the study by Danforth et al (10) the maximum amount of dose absorbed using the panoramic technique was in the parotid glands, which is similar to this study. In the Danforth study, the level of absorption in the calvarium was not measured and the results were calculated from a mean of 5 exposures, but in the present study, the level of absorption in the rami was measured and the mean of
10 exposures was calculated.

In the study by Lecomber et al (11) which examined the levels of absorption using two panoramic techniques, cephalometry, linear tomography and CT (12) the maximum amount of radiation absorbed was in the salivary glands. These findings are similar to the present study.

Bousherhal et al (13) and Ngam (29) concluded that the amount of radiation absorbed during a CT scan is significantly higher than other radiographic techniques. These findings are similar to the present study. All of the mentioned studies confirm the findings of Martin and Preston (14) on patients with benign and malignant parotid tumors. In that study, there was a relationship between the formation of the tumors and previous medical and dental diagnostic radiation exposure such that 85% of the accumulated radiation in the parotids was due to previous dental radiographs.

Hayakawa et al (15) studied the amount of radiation absorbed using the panoramic technique in children and reported that in machines with special programs for children, the doses absorbed were decreased. Mah (16) studied the amount of radiation absorbed by tissues in a new CT scan machine and concluded that the amount of radiation absorbed by tissues in this new machine is lesser than the other older CT scan machines. The values obtained in this study confirm the findings of Mah.

Ngam et al (1) found that skin is a tissue that is resistant to the carcinomatous effects of radiation to a certain extent and levels of less than 3-5 grays are not detrimental. Therefore, the maximum amount of radiation absorbed by the skin during mandibular CT scans (0.01 Gy) is much below the threshold level for erythema and cancer (7) compared to the doses of radiation absorbed in during CT scans, lateral cephalometry, panoramic, occlusal and periapical radiography. The amount of radiation produced by CT was significantly more than all the other methods which is similar to this study. Therefore, whenever CT scan is advocated due to its positive points for a patient, the high amount of radiation exposure and costs must be considered.

Rustemeyer et al (18) suggested a new protocol for decreasing the radiation dose and attaining the best quality pictures with minimum possible radiation exposure. They reported that a reduction in dosage does not compromise the diagnostic value or quality of images and a reduction in radiation dosage without a corresponding reduction in diagnostic information is possible during a CT scan.

Conclusion

Whenever using ionizing radiation the possible adverse effects should always be kept in mind. Therefore, the positive diagnostic and treatment values of various radiographic techniques for dental implants need to be valued against the danger and risks posed by these techniques. Measurement of the radiation dose absorbed by various critical tissues can be one of the guides determining the use of these techniques. By using the above mentioned techniques correctly and ideally, maximum diagnostic information can be obtained with the minimum of complications, for example; the protocol mentioned in this study for upper and mandible CT scan can be used by hospital centers for patients referring to the CT scan department for dental implants, although more studies are required in the near future.

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