Original Article

Comparison of the Absorbed Dose of Target Organs in Conventional and Digital Lateral Cephalometric Radiography

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Abstract

Background and Aim: Due to the widespread use of lateral cephalometric radiog raphy especially in orthodontic therapy and orthognathic surgery, obtaining radiog raphs of high quality with the least amount of radiation exposure is of utmost i mportance. The aim of this study was to compare the absorbed dose of head and neck target organs in conventional and digital lateral cephalometric radiography.

Materials and Methods: In this experimental study, RANDO phantom was used for absorbed dose estimation in thyroid, parotid, pituitary and submandibular glands, bone marrow and ocular lens. The phantom was exposed 60 times: 30 times with CRANEX Tome, Soredex and 30 times with CRANEX D, Soredex with standard exposure set tings. TLD (GR-200) dosimeters were used to measure organ doses. A total of 69 TLDs were used with 9 TLDs for background radiation. T-test was used for statistical analysis.

Results: The mean absorbed dose of target organs was 0.04±0.005 mSv for conven tional and 0.01±0.002 mSv for digital technique. The difference in absorbed dose in all target organs except for the thyroid gland (p=0.08) between the two techniques of conventional and digital was statistically significant. (p=0.01).

Conclusion: Use of digital lateral cephalometric system causes a significant reduction in absorbed dose compared to the conventional film-screen system

Key Words: Lateral cephalometric radiography, Absorbed dose, Conventional radiography, Digital radiography

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Introduction

Minimizing the absorbed dose of target organs receiving X ray radiation is a major concern for dentists and especially oral and maxillofacial radiologists. Critical organs such as the thyroid gland, active bone marrow, salivary glands and brain are present in the head and neck region and are susceptible to the late effects of X radiation [1-3].

Possible late effects of diagnostic X ray radiation are worrisome not because of high radiation doses, but because of unnecessary irradiations. Preventing the risk of ionizing radiation and use of methods and equipment that approximate the exposure conditions to ideal is an important step in protection against radiation and dose reduction in diagnostic radiography [4].

Some studies have stated that, in contrast to digital intra-oral radiography, no significant dose reduction occurs by replacement of extra-oral conventional systems with digital radiography [2,4,5]; whereas, some others have reported a significant

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dose reduction when using extra-oral digital radiography systems [6-9].

Due to the extensive use of lateral cephalometric radiography especially in orthodontic treatments and orthognathic surgery, it is especially important to obtain radiographs with the highest quality and minimum absorbed dose of patients and clinicians [10]. CRANEX Tom conventional lateral cephalometric radiography (Cranex Tome Ceph; Soredex, Helsinki, Finland) and CRANEX D PAN digital lateral cephalometric radiography (CRANEX D PAN/Ceph, Soredex, Helsinki, Finland) have been recently introduced to the market and have not been compared in terms of absorbed dose of organs. Thus, the present study sought to compare the absorbed dose of sensitive organs in the head and neck region between conventional and digital lateral cephalometric radiographies.

Materials and Methods

In this experimental crossover study a head RANDO phantom (Radiation Analog Dosimetry System, Alderson Research Lab, Inc. Stamford, Connecticut) was used (Figure 1).

Figure 1. RANDO phantom

RANDO phantom is a tissue-equivalent phantom made of isocyanate plastic surrounding a human skull. Nasopharynx, oropharynx and cavities such as sinuses are filled with air. The phantom was divided into parallel segments of 2.5 cm thickness. Segment number zero was at the highest point at the top of the head. Cylindrical cavities measuring 5x25 mm were prepared in different parts of the phantom and dosimeters were placed inside them [6, 7].

Figure 1. RANDO phantom

Cranex Tom (Soredex, Helsinki, Finland) and Cranex D (Soredex, Helsinki, Finland) were used in this study for conventional and digital cephalometric radiography, respectively.

TLD dosimeters were used to determine the absorbed dose in sensitive organs in the head and neck area (thyroid gland, parotid gland, ramus bone marrow, pituitary gland, ocular lens and submandibular gland).

Dosimeters used in this study were lithium fluoride thermoluminescent dosimeters [LiF: Mg, Cu, P (GR-200)] (Harshaw Chemical Company, Cleveland, Ohio) that were disc-shaped measuring 4.5 mm in diameter and 0.9 mm in thickness. Studies have shown that these dosimeters are very accurate and efficient for dosimetry of small reproducible values and can be repeatedly used [7, 8, 10, 11].

First, the dosimeters were heated in an electric furnace at 240°C for 20 min to be set to zero. Then, they were exposed to a specific amount in caesium-137 (Cs-137) gamma ray source (with 662 Kev energy) and placed in an electric furnace again and heated up at 100°C for 10 min. This process is called preheating and is done for elimination of low temperature peaks and fading correction in dosimeters. After preheating, dosimeters were read by a TLD reader (4000, Harshaw) in nitrogen gas atmosphere. To calculate the dosimeter calibration factor, the known exposure dose was divided by the dosimeter response and the dosimeters were calibrated as such. Afterwards, the dosimeters were set to zero again and placed in phantom cavities. Two dosimeters were used for each site. The phantom was fixed on a platform. After achieving the correct position of the phantom in the cephalostat, radiographs were obtained. The phantom placed in the Cranex Tom, Soredex conventional lateral cephalometric device was irradiated at exposure settings of 70 kVp and 10 mA for one second. These exposure settings are recommended by the manufacturer for an average person. A DC high frequency generator with a frequency range of 30-110 Hz was also used. In order for the TLD to be readable by the analyzer device, this procedure was repeated for 10 times. The conventional film used

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was 18x24 cm Kodak T-MAT E Dental film (USA) with relative speed of 400. The phantom was then placed in Cranex D PAN/Ceph, Soredex digital lateral cephalometric radiography device and irradiated for 10 times under exposure settings of 66 kVp and 10 mA for 5.8 s exposure time (recommended factory setting for an average person). In the digital system, 18x22 cm 48 micron pixel CCD sensor was used instead of film-screen system. The device generator was DC high frequency with 40 kHz frequency. Pixel size of the obtained image was 96 micron.

Exposures in the digital and conventional techniques were done in 3 sequences of 10 times each. After exposure of dosimeters in the phantom, they were read and the absorbed dose of organs in the location of which dosimeters had been placed was calculated by multiplying the dosimeter response by the calibration factor [6, 9]. After calculations, absorbed dose of each TLD was reported in mSv [6, 9]. A total of 69 TLDs were used in this study out of which 9 TLDs were used for estimation of background radiation. Calculation of absorbed dose of each organ was done using the following formula:

TL (net)=TL (gross)-TL (BKG)

Dose (mSv)=TL (net)xcf.x RL0/RL

Using the abovementioned formula, the absorbed organ dose was calculated. In order to calculate the share of dose received by each organ in the body out of the whole body absorbed dose, the absorbed dose of each organ was multiplied by the tissue weighting factor. The obtained effective dose was reported in mSv [6]. In the present study, calculations when reading the dosimeters were done based on tissue calibration and reported as organ dose; which separately reports the absorbed dose by each organ. In the mentioned formula, TL (gross) or thermo luminescence (gross) is the overall reading of the dosimeter and includes the zero-dose reading, noise of the device and black current of the device (black current in the photon multiplying tube of TLD reader). When the TL (BKG) or TL (background)(response of some dosimeters that are prepared along with other dosimeters but are not exposed and read along with the radiated ones) is subtracted from the TL (gross), the TL (net) is obtained which is the response obtained after dosimeter exposure.

CF or calibration factor is equal to 0.004 (mSv/nc) is the factor used for calibration of TLD reader and TL (net) is multiplied by the CF and RL0/RL (device stability factor) to obtain organ dose. RL0 or reference light 0 is the light present in the TLD reader and is read when calibrating the background and radiated dosimeters to ensure the stability of device. For the device used in our study, this value was reported as 127.5 by the IAEA. RL recorded when reading the dosimeters was 126.3.

By dividing RL0/RL a factor is obtained that shows the stability of device. If an error or an electrical shock occurs when reading the dosimeters, it can be fixed using this factor. Data were analyzed using SPSS (SPSS Package, GLM for windows, SPSS Inc., Chicago, IL) version 10 software. T-test was also used for statistical analysis.

Results

Independent t-test showed that the difference in absorbed dose in all target organs except for thyroid (P=0.08) between the two techniques of conventional and digital was statistically significant (P=0.01). The mean absorbed dose of organs was 0.04±0.005 mSv in the conventional and 0.01±0.002 mSv in the digital technique. The obtained results are demonstrated in Table 1 and Diagram 1.

The mean absorbed dose of understudy organs in the right side of phantom (film side) was significantly less than the absorbed dose in organs in the left side of phantom (X ray tube side) (P=0.01). The highest mean absorbed dose in both methods of conventional and digital radiography was in the left parotid and the lowest amount was in the thyroid gland.

Discussion

The present study aimed to assess the effect of direct digital lateral cephalometric radiography (CCD) and the conventional technique on the absorbed dose of the target organs. A significant difference was found in this respect between the two techniques and use of digital lateral cephalometric radiography caused a significant dose reduction compared to conventional technique.

This dose reduction was correlated with the theoretical estimated dose reduction. Using the total

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Table 1. The mean and standard deviation of absorbed dose (mSv) in the understudy target organs in two methods of conventional and digital radiography

Variables	Conventional Mean± SD	Digital Mean± SD	t	P.V
Pituitary gland	0/03±0/003	0/01±0/001	9/04	0/001
Eye (film side)	0/02±0/003	0/001±0/001	9/83	0/001
Eye (X ray tube side)	0/05±0/002	0/01±0/002	24/8	0/0001
Parotid (film side)	0/01±0/004	0/0006±0/0005	3/68	0/02
Parotid)X ray tube side)	0/15±0/01	0/07±0/01	6/18	0/003
Ramus bone marrow (film side)	0/02±0/009	0/006±0/001	3/4	0/02
Ramus bone marrow (X ray tube side)	0/08±0/01	0/01±0/004	9/26	0/001
Submandibular gland (film side)	0/03±0/004	0/004±0/001	9/6	0/001
Submandibular gland (X ray tube side)	0/1±0/01	0/03±0/007	6/34	0/003
Thyroid gland	0/002±0/001	0/0006±0/0005	2/23	0/08

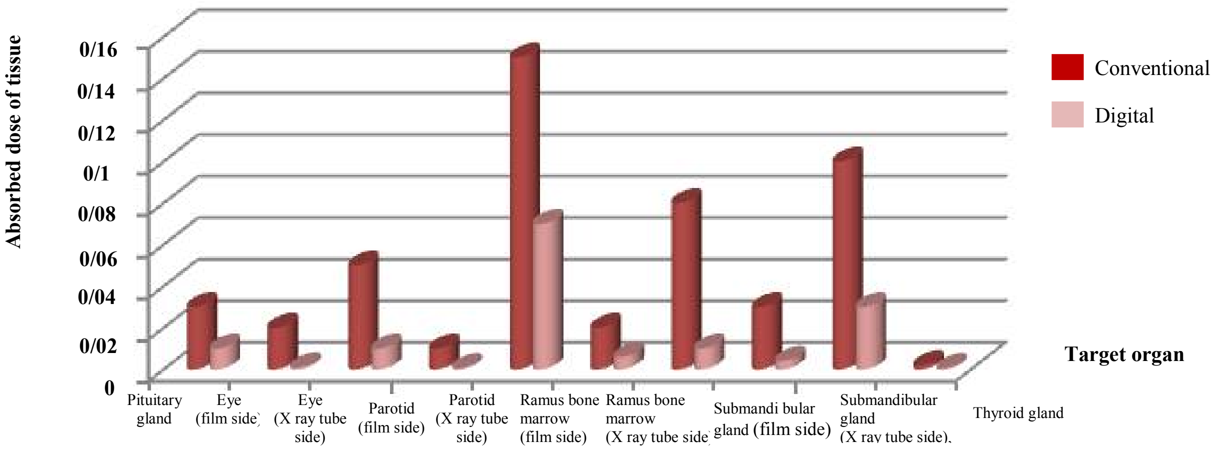

Diagram 1. The mean absorbed dose (mSv) of the understudy organs in the two methods of conventional and digital radiography

width of the scanned area by digital lateral cephalometric radiography system (180 mm) and height of the fan-shaped X ray in the sensor plane (4.6 mm) the ratio of the total exposure time to the effective exposure time can be calculated (180÷4.6=39.13). Thus, the total exposure time of 5.8s to obtain a digital radiograph is equal to the effective exposure time of 0.114s (5.8÷39.13) for each part of the head. Conventional cephalometric radiography with a sensitive film-screen system and relative speed of 400 requires an exposure time of one second for an adult. Assuming that other parameters of exposure are constant, absorbed dose is proportionate to the effective exposure time. Thus, dose reduction is feasible by using digital lateral cephalometric radiography [6, 7].

In a study conducted by Kaeppler et al, in 2007 with the aim of comparing the effects of indirect digital lateral cephalometry (psp) and conventional film-screen lateral cephalometry on patient's absorbed dose, it was found that use of digital system caused a reduction in absorbed dose which is in accord with our study results [6]. In a study conducted in 2001 to compare the diagnostic accuracy of digital and conventional cephalometric imaging on three human cadavers, Gijbels et al. showed that exposure settings with higher kV and lower mAs yielded the lowest effective dose in organs. They

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found that digital cephalometric images at different exposure settings had a significantly higher diagnostic quality than conventional images [13]. Furthermore, they demonstrated that small variations in exposure settings do not decrease the diagnostic quality of digital cephalometric radiographs but cause a reduction in diagnostic quality of conventional cephalometric images. This finding shows that exposure settings with higher kVp and lower mAs yield dose reduction in digital cephalometry [13].

In our study, digital cephalometric radiography showed less absorbed dose compared to conventional technique at exposure settings of an average person.

In another study in 2004 by Gijbels et al, a comparison was made between direct (CCD) and indirect (PSP) digital lateral cephalometric radiography and it was revealed that the direct digital system yielded a higher dose than the PSP system; whereas, the diagnostic quality of the two were equal. Difference in absorbed dose of target organs between the direct (CCD) and indirect (PSP) digital lateral cephalometric radiography may be attributed to the difference in nature of exposure technique between the two systems. In direct digital imaging technique a linear scan is performed; whereas, in the indirect digital technique a short shot exposure is done (Figure 2). Longer duration of scanning can also increase the risk of artifacts due to patient movement especially in children [5].

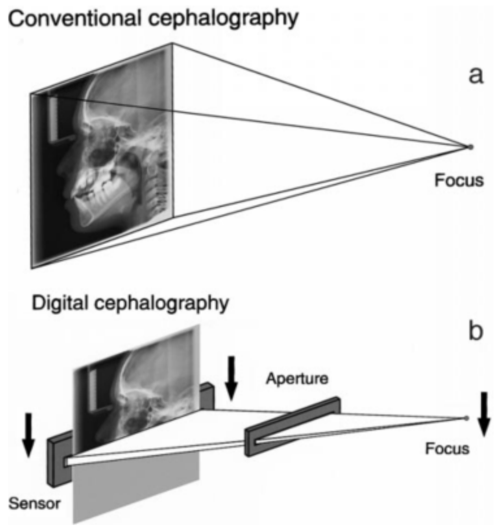

Figure 2. A: Conventional film-screen lateral cephalometry
B: Digital lateral cephalometry with CCD sensor

In another study conducted by the same group of researchers (Gijbels et al,) in 2005,digital panoramic and the conventional system were compared and they concluded that although digital panoramic devices yield a wide range of patient radiation doses, digital systems still had lower effective doses than analogue panoramic units. This finding is in agreement with our study result [9].

In another study by Visser et al, in 2001 similar results were obtained and it was revealed that direct digital lateral cephalometric radiography cuts the patient's dose in half compared to conventional screen-film technique with a relative speed of 400. Direct-digital cephalometry is superior to the conventional technique in terms of radiation protection [7].

Some studies [3, 4, 5] have failed to find a difference in absorbed dose of organs between extra-oral digital imaging system and film- screen conventional technique. In another study by Poppe et al, in 2007, no significant dose reduction was observed in digital panoramic radiography compared to the conventional technique. However, they used Dose-area product (DAP) meter for dose estimation which is a quick and precise tool for the measurement of skin dose in a specific radiation field. For this purpose, an ionization chamber is placed against the X ray tube output and the estimated dose is reported in Gy /cm^2, mGy /cm^2 or cGY /cm^2 [4]. Assessment of organ specific dose by DAP cannot be directly performed; whereas, by using RANDO phantom and TLD we can calculate the absorbed dose of each organ directly and with s higher precision than DAP [5, 14]. Also, due to the wider dynamic range in digital images and the ability for post-processing of digital software , even in case of reduction of exposure parameters diagnostic quality is still maintained [8, 15]. This is not true for conventional images [8, 15] indicating the possibility of dose reduction in digital imaging systems compared to the conventional types.

Inevitable X ray exposure due to natural and manmade resources is about 4 mSv per year [7]. Compared to the mentioned value, the effective dose of lateral cephalometric radiographies ranging between 1-2 μSv seems insignificant. However, the principle of ALARA (as low as reasonably achievable) should be kept in mind.

X ray susceptibility is age-dependent and children and adolescents have higher susceptibility to it

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than adults [8, 16]. Since lateral cephalometric radiography is more commonly obtained in children and adolescents, use of digital extra-oral imaging system is recommended.

Conclusion

A significant difference existed in absorbed dose of organs between the conventional and digital cephalometric radiographies and use of digital system caused a significant dose reduction compared to the conventional film-screen system.

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