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An experimental study on the determination of gantry angle and SSD dependencies of TLD and MOSFET dosimeter systems

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► ***Technical Note***

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ABSTRACT

Background*:** The purpose of this study was to investigate the various gantry angle and SSD dependencies of TLD and MOSFET dosimeters. ***Materials and Methods*:** LiF (Mg) TLD and MOSFET were used in this study. Dosimeter systems were calibrated and then irradiated at various gantry angle and SSD by applying 6 MV photon energy. ***Results: Based on the results, MOSFET changes were found to be in 2% range between ±50º gantry angles and the rate of dose change was found to be increasing as gantry angle was at the extremes of graph. This increase was especially obvious in tail end of the asymmetric axes. Change in the gantry angle dependency of TLD was -2% till ± 60º gantry angle and -5% between 60º to 90º. Dependency of SSD was ±1% for TLD and MOSFET. ***Conclusion:*** Results indicate that properties of dosimeters must be well known by users for accurate determination of the entire doses on the patient. These observations may lead to better treatment quality and prevention of probable dose errors.

Keywords: *TLD, MOSFET, SSD, gantry angle, photon energy.*

INTRODUCTION

To control the prescribed dose in radiotherapy, it is very important to know that the target volume receives the defined dose accurately. *In vivo* dosimetry in radiotherapy is a well-established practice used worldwide as a component of a quality assurance program to ensure that all cancer patients treated with a curative aim receiving the prescribed dose within a precision of ±5% [1]. Those systems are used for accuracy and reliable dose control of patient treatment. *In vivo* dosimeters determine dose fault before the treatment is started and this case could obviate the broken time [2].

Several *in vivo* dosimeters are available, but basically dosimeters of diode and thermoluminescent (TLD) are used in *in vivo* dosimetry [3]. Among the other radiation measurement devices, there are metal oxide semiconductor field effect transistor (MOSFET), radiochromic film dosimeter, convectional portal films, plastic scintillator dosimeter, electronic portal imaging and gel dosimeter [4, 5].

Thermoluminescent dosimeters are based on the principle that a crystal with thermoluminescence properties becomes radiated through ionising and absorbs energy, which, in turn, is released in the form of thermoluminescence radiation as the crystal is exposed to temperature. The thermo-luminescent radiation emitted from this phenomenon is proportional to the amount of radiation dose reflected on the crystal [6, 7].

MOSFET is semiconductor radiation detector. There are types of p and n junction. As semiconductors are exposed to radiation, holes and electrons are formed; so the amount of the collected charge is proportional to the amount of radiation [7, 8].

MOSFET and TLD dosimeters are used for measurements of entire and exit dose but working principles are different. Each system has its own advantages and disadvantages.

Showing the dose value on the monitor for MOSFET after irradiation may be regarded as an advantage. High dose sensitivity, stability and reproducibility are among other advantages, however the dependence of energy and temperature and radiation injury in electronic system are the disadvantages of MOSFET. Required secondary reading system for dose determined, effects of environment such as temperature, light and pressure etc. and dose reduction due to latency time are major drawbacks, but low cost is superiority of TLD systems [6, 9-12].

Dosimeter systems rely on the gantry angle, dose, field, radiation energy and source skin distance (SSD). Dosimeter user recognizes the systems and knows the characteristics that may affect the measurement results which are very important for dose accuracy and treatment quality [13]. This study was designed to investigate the effects various gantry angle and SSD on TLD and MOSFET dosimeter systems.

MATERIALS AND METHODS

In this study, Lithium Fluoride (Magnesium) (LiF-Mg) TLD and MOSFET (Nuclear Association) systems were used. Dosimeter systems were irradiated with 6 MV photon energy (Linear Accelerator-Elekta) on the water equivalent solid phantom (mass density is 1,045gr/cm^3, electron density is 3, 43×10^{23} e/cm^3, dimensions are 40×40^2 cm for RW3-PTW). Prior to the study, energy quality, symmetry and flatness was adjusted with water phantom (PTW) for LİNAC (Linear Accelerator) and then output was set as 1 cGy was equivalent 1 MU for 6 MV photon energy. Then dosimeter systems were calibrated and dependencies of gantry angle and SSD (Source Skin Distance) to the systems were evaluated.

Dosimeter systems calibration

TLD calibration

Seventy TLD crystals were made by the following operations to become stable: Seventy TLDs were annealed 1 hour at 400ºC and then 24 hours at 100 ºC on the metal tray for removing residual effects. Annealed TLD was put into the hole with 6 mm diameter and 1 mm depth under plexiglass tray and then each annealed TLD was irradiated with 100 cGy radiation dose at 10×10 cm field, 100 cm SSD width and 5 cm depth. After irradiation, TLD was read with Winrems program consequently, traps were exhausted. This procedure was repeated 10 times more in a row. In this way, the stability, sensitivity and reproducibility of TLD's were increased. Fifteen TLDs were chosen within ± 0.1 % sensitivity from 70 TLD.

MOSFET calibration

MOSFET was introduced to LİNAC room in order that they could adopt to the environmental effects such as temperature, humidity and pressure. MOSFET was irradiated with 100-200 cGy dose on the isocenter of the solid phantom surface and dose values was saved. It is important that detector channel must be the same with calibration channel for MOSFET.

Gantry angle dependency of dosimeters

LINAC output may change dependent on the gantry angle. To prevent output changes from various gantry angle dependencies, ion chamber with build-up cap was irradiated 0º-90º and 0º-270º gantry angles at intervals of 10º degrees on 100 cm SSD with 100 MU radiation dose and reading values of electrometer were saved. Measurements were repeated three times more and the average was calculated to increase the stability. Graphics were drawn using EXCEL based on the results.

TLD

TLD's were put into the cylindrical phantom for determining the dependency of gantry angle. All crystals were irradiated in the same measurement circumstance and read on the TLD reader and then reading values were calculated in accordance with changed output value depending on gantry angles. Measurements were repeated three times more and calculated the average for increasing the stability. All values were normalized at the 0º gantry angle value [16]. TLD is the symmetric structure; so all measurements were done only uni-directional.

MOSFET

MOSFET has got build-up cap; so it was set onto surface of the solid phantom. There are two different directions which are symmetric and asymmetric axis of MOSFET [14] (figure 1). Therefore, measurements must be carried out in both directions but in the clinical application, y axis is placed in parallel with gantry rotation.

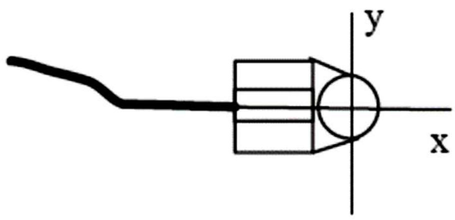

Figure 1. Symmetric and asymmetric axis of MOSFET (x: asymmetric axis, y: symmetric axis) [15].

MOSFET was irradiated for the same gantry angles and reading value was read on the electrometer and then process was repeated as in TLD irradiation. All average values were normalized at the 0º gantry angle value (180º MOSFET angle).

SSD dependencies of dosimeters

Different SSD is used in the treatment of patient so it is very important to determine the SSD dependency of dosimeters. Therefore, both dosimeters were irradiated 80 cm-100 cm SSD at intervals of 10 cm with 100 MU radiation dose. Each dosimeter reading values on the different SSD were adjusted in accordance with reading of ionization chamber to eliminate the dependence of Mayneord factor. Obtained values were normalized to 100 cm SSD value.

RESULTS AND DISCUSSION

Gantry angle dependencies of dosimeters

Gantry angle dependencies of dosimeters are shown in figure 2. MOSFET at symmetric and asymmetric axes and TLD were represented on single graphic; so the changes of two dosimeters could be observed. Changes of MOSFET were 2% between ±50º gantry angles. But the changes were more toward the edges. This increase was especially obvious in tail end of the asymmetric axes. Geometrical structure of MOSFET causes the changes. MOSFET has semi-spherical structure and active dose point is the center of MOSFET that is perpendicular to the beam direction. Reading value may change by moving away from the active dose point. Due to the shifting of the gantry angle, the reading dose increases with the contribution of scattered radiation and charges on the detector increase. According to AAPM report, variations are ±5% that exceed ±40º gantry angle. We have similar results with AAPM Task Group 62 and user guide [14, 15]. The dependency of detector response on gantry angle within the examined range of angles didn’t exceed 1.4% for photon also in Dybek’s study [16].

Change in the dependency of TLD to gantry angle was til ± 60º and -5% between 60º and 90º. Ramaseshan *et al.* reported that the angular dependency of the MOSFET was 18% for 6 MV X-ray beam [17]. Results of Rah *et al.* studies were found to be within 2.3% for the angular dependence of the MOSFET [18]. According to Scalchi *et al.,* for beam incidence ranging from 0° to 90°, the MOSFET response varied within 7% [19].

When gantry angle is moved away from 0º gantry angle, cross section of TLD is decreased, therefore cumulative radiation dose over TLD is reduced. This reduction is proved by the negative deviation. This is disadvantage for using different gantry angle of TLD such as oblique beam projections in breast and head and neck cases [12]. Cylindrical dosimeter such as glass dosimeter can be used to reduce the gantry angle dependency of TLD. For instance Rah et al. investigated glass dosimeter and found that variations in sensitivity for angles up to 80º from the central axis of the beam were within 1.7% for the glass dosimeter [18]. In another study by Araki *et al.* showed that the angular dependence of the glass dosimeter was approximately 1.0 % [20].

SSD dependencies of dosimeters

SSD is an important parameter for radiotherapy. Calibration is performed for 100 cm SSD in the daily use so dependence of different SSD distances must be regarded for dosimeters. Results are shown in figure 3. Changes were ±1% for TLD and 1% for MOSFET. Those values are acceptable and can be estimated because Mayneord factor was eliminated and focus of dosimeters was permanent. Similarly, SSD dependence of MOSFET and TLD dosimeters was less than 2.0% from 85 to 115 cm SSD for 15 MV X-ray beam found in Rah's study [18].

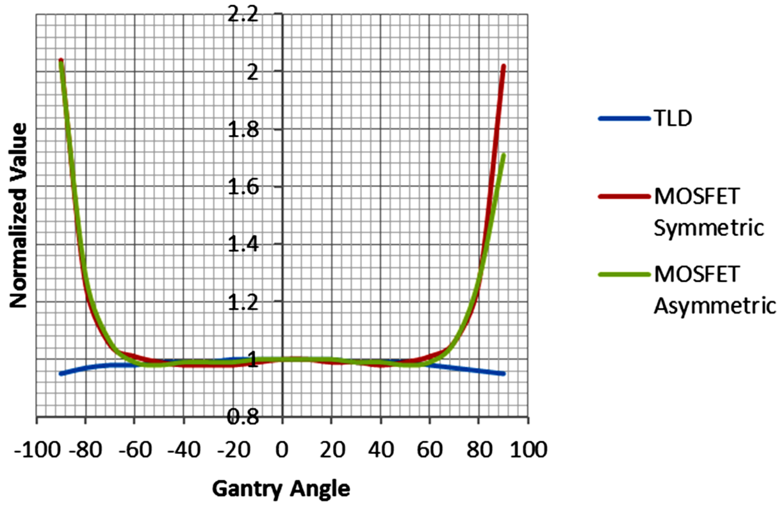

Figure 2. Gantry angle dependencies of MOSFET and TLD.

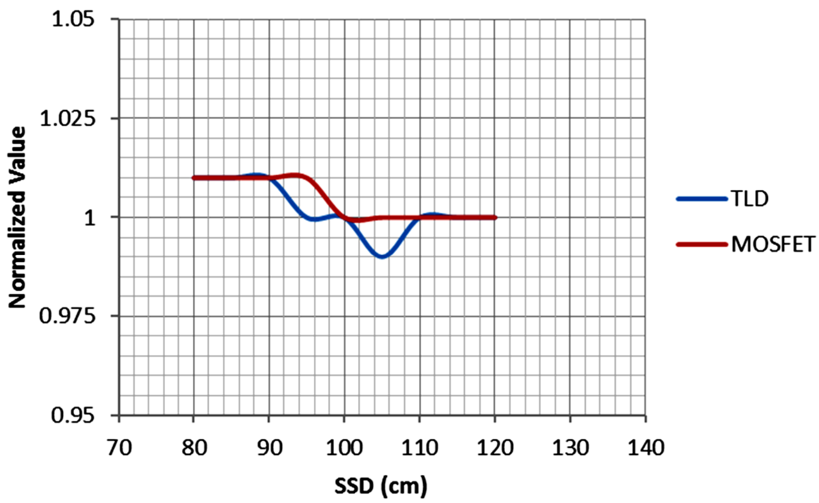

Figure 3. SSD Dependencies for TLD and MOSFET.

CONCLUSION

Changes related to SSD and gantry angle for dosimeters systems may be disregarded. But in oblique beam projections in breast and head and neck patients this parameters should be taken into consideration. It is very important for the users to be aware of the properties of dosimeters for accurate determination of the entire doses for the patient. Using the data, treatment quality may be increased and probable dose errors can be prevented.

Conflict of interest: *Declared none.*

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