Investigation of Dosimetric Characteristics of a MOSFET Detector for Clinical Electron Beams

MOSFET Dedektörün Dozimetrik Karakteristik Özelliklerinin Klinik Elektron Demetleri için İncelenmesi

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ABSTRACT

Objective: Studying of the fundamental dosimetric characteristics of metal oxide semiconductor field effect transistor (MOSFET) detectors to evaluate its use in clinical electron beam irradiations.
Materials and Methods: In this study, GE-MS Saturne-43 linear accelerator was used . At first, Mosfet dedectors were calibrated for all electron energies. The fundamental dosimetric characteristics such as dose-linearity, reproducibility, angular dependence and field size dependence of MOSFET detectors were studied for 4,6,9,12,16 and 18 MeV electron energies.
Results: Good linearity of the MOSFET dedector in the dose range of 10-500 cGy showed that it could be reliable detector for all electron applications. The energy dependence of a MOSFET dedector was within 3.0% for 6–18 MeV electron beams and 8% for 4 MeV ones. The results of the measurements performed using a spherical wax mini fantom demonstrate that the angular dependence of the MOSFET detector is small. MOSFET reproducibility is within 2%.
Conclusion: This study shows that MOSFET detectors are suitable for dosimetry of electron beams in the energy range of 4–18 MeV. From the results observed it can be concluded that by applying proper calibration and correction factors, MOSFET may be used as in vivo detector for the dose verification for patients undergoing electron beam radiotherapy.

Key Words: Mosfet, in vivo dosimetry, electron beam, radiotherapy

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ÖZET

Amaç: Metal oksit yarıiletken alan etkili transistör (MOSFET) dedektörlerin klinik elektron demetlerinde kullanımını değerlendirmek amacıyla temel dozimetrik özelliklerinin incelenmesi.
Yöntem: Çalışmada Ge marka Saturne 43 model lineer hızlandırıcı kullanıldı. Öncelikle, MOSFET dedektörler tüm elektron enerjileri için kalibre edildi. 4,6,9,12,16 ve 18 MeV elektron enerjileri için MOSFET dedektörün doz lineerliği, tekrarlanabilirliği, açıya bağımlılığı ve alan bağımlılığı gibi temel dozimetrik özellikleri incelendi.
Bulgular: MOSFET dedektörün 10-500 cGy doz aralığında iyi bir lineerlik göstermesi, tüm elektron uygulamaları için güvenilir bir dedektör olabileceğini gösterdi. MOSFET dedektörün enerji bağımlılığı 6-18 MeV elektron enerjileri için % 3.0 ve 4 MeV için % 8 idi. Küresel bir balmumu mini fantom kullanılarak gerçekleştirilen ölçümlerin sonuçları, MOSFET detektörünün açısal bağımlılığının küçük olduğunu göstermektedir. MOSFET tekrarlanabilirliği % 2'dir.
Sonuç: Bu çalışma, MOSFET dedektörlerinin 4-18 MeV enerji aralığındaki elektron demetlerinin dozimetrisi için uygun olduğunu göstermektedir. Gözlemlenen sonuçlardan, uygun kalibrasyon ve düzeltme faktörleri uygulayarak MOSFET'in, elektron ışını radyoterapisi uygulanan hastalarda doz doğrulama için in vivo detektör olarak kullanılabileceği sonucuna varılabilir.

Anahtar Sözcükler: Mosfet, invivo dozimetri, elektron demeti, radyoterapi

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INTRODUCTION

AAPM (American Association of Physicist in Medicine) and ESTRO (European Society of Therapeutic Radiology and Oncology), like many organizations, radiotherapy is recommended that patients should be confirmed to the dose given (1,2). Therefore, in vivo dosimetry has become a very important part of the quality assurance program in radiotherapy (3). Generally, TLD(Thermoluminescence dosimeters) and semiconductor diodes are used in patient dose verification (3). However, measurements using with TLD are not suitable for showing the patient dose at the moment and has many disadvantages. Likewise, large correction factors are needed at different angles, fields, and dose rates, although semiconductor diodes show the patient dose at the moment. Moreover, all of these effects are greater in electrons than in photons.

The clinical use of the TLD is limited to certain limits. It is difficult to make the samples is to be used immediately to prepare and quick calibration and are affected by environmental factors. The repeatability of measurements using TLD is not very good. This patient dosimetry is a huge problem and there is also a practical application in dosimetry studies routinely. Mosfet (Metal Oxide Silicon Semiconductor Field Effect Transistor) is a successful system for dose verification. A simple calibration procedure, instant reading, not depending on environmental conditions are just some of the advantages of using this technique (4).

These dosimeters are used in many radiotherapy and radiological applications. It has a small area (0.04 mm^2) and many advantages, gives instant information about the dose and is suitable for multiple measurements at the same time. Also, the MOSFET is used for invivo dosimetry of IMRT (5) and skin dose measurements. Dong et al. and Bower et al. have reported on the use of a MOSFET dosimeter for diagnostic radiological applications (6).

Manigandan et al. have reported on the use of MOSFET for electron beams in the range of 4-18 MeV (7). They demonstrated that the energy dependence of a MOSFET response was within ±3% for 6-18 MeV electron beams and 5.5% for 4 MeV ones. Also, MOSFET showed excellent linearity against doses measured using an ion chamber in the dose range of 20-630 cGy.

Mosfet is a dose verification system which is used to measure the accuracy of the dose given to the patient in radiotherapy, brachytherapy, radiology and treatment plan verification.

The working principle of this system is based on the measurement of the voltage accumulated in the MOSFETs in the irradiation process. This voltage is a function of the absorbed dose (6). Bloemen et al have reported that MOSFET dedectors placed on the patient's skin without additional build-up is well suited technique for dose verification in electron beams (8).

The lifetime of the MOSFET is 20000 mV. It should not be used after the 18.500 mV (4). Because, the usage of this mosfet causes the more than 5% errors. In addiation, When at the useage of the after 16000 mV and the measuremnets are made repeatedly, the error can ocur in up to 8% in readings beacuse of the creep-up effect that have been reported (4).

In this study, the fundamental dosimetric characteristics such as dose-linearity, the angle dependency, reproducibility, field size dependence of MOSFET detectors were investigated for clinical electron energies ranging from 4 to 18 MeV. Also, we aimed to determine the dependency of the calibration factors for MOSFET dosimeter.

MATERIAL and METHODS

MOSFET is a metal oxide semiconductor known as enhanced type of field effect transistor (FET). In study, two TN-502-RD standart MOSFET detectors were used for measurements, produced by Thomson and Nielsen Electronics Ltd (Ottawa, Canada). For the measurements, the Mosfet AutoSense system (TN-RD-60) was used (Figure 1).

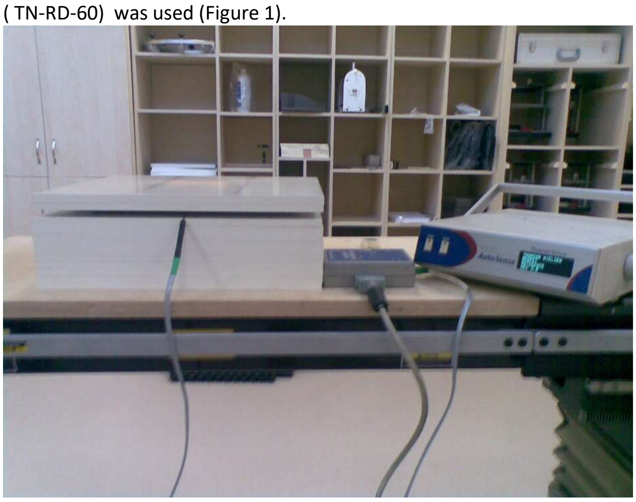

Figure 1. The set-up of Mosfet AutoSense system

Mosfet calibration was performed for electron energies using 10x10 cm^2 field size and 100 cm SSD. For all measurements were made using both of the surfaces of dosimeter as flat and round side (Figure 2).

Figure 2. The both of surfaces of MOSFET dosimeter

Three measurements were performed and the results were averaged and calibration factors were defined. (Table 1).

Table 1. The calibration factors of two MOSFET dosimeter

Electron Energy	CF (MOSFET 1) (mV/ cGy) Flat side	Round side	CF (MOSFET 2) (mV/ cGy) Flat side	Round side
4 MeV	0.94	0.91	0.96	0.96
6 MeV	0.95	0.95	1.01	0.99
9 MeV	0.97	0.98	1.01	1.00
12 MeV	0.99	0.99	1.00	1.03
16 MeV	1.03	1.03	1.04	1.02
18 MeV	1.02	1.02	1.01	1.03

After calibration prosedure, the other measurements were made placing with the round side of the detector facing the beam on the center of the 30x30x10 cm^3 RW3 solid phantom. In our institute, linear accelerators of this type are equipped with continuous variable trimmer systems. The collimating system of the linac is composed of the primary collimator and primary collimator of them can be mounted and which move simultaneously with the primary collimator opportunity X1, X2, Y trimmers.

Dose Linearity

The dose-linearity of Mosfet dedector in the range of 10 cGy-500 cGy was studied for all electron energies (Figure 3).

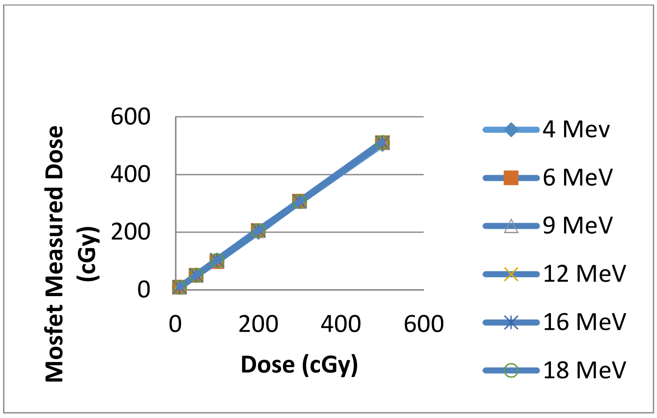

Figure 3. Linearity of the MOSFET dosimeter in the range of 10-500 cGy measured for 4,6,9,12,16,18 MeV electron energies.

Reproducibility

The reproducibility of the Mosfet dedector at dose 200 cGy was studied for 6 MeV electron beam. After 30 minutes waiting, the Mosfet was repeatedly exposed to 5 times in a day. (Figure 4).

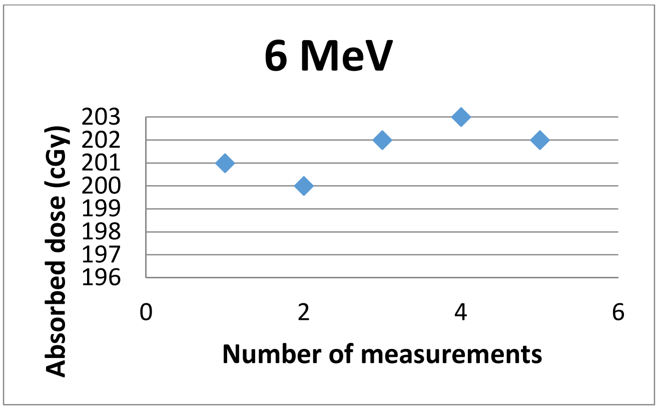

Figure 4. Reproducibility of MOSFET for 200 cGy for 6 MeV electron beam.

Field size dependence

To evaluate the field size dependence of Mosfet dedector, output factors were measured for all energies chancing field size from 5x5cm² to 25x25 cm² (Table 2).

Table 2. Field size dependence of MOSFET for all energies chancing field size from 5x5cm² to 25x25 cm²

Field size (cm²)	4 MeV	6 MeV	9 MeV	12 MeV	16 MeV	18 MeV
	Absorbed dose (cGy)					
5x5	206	202	204	206	208	206
10x10	203	205	203	205	200	203
15x15	207	198	207	204	202	205
20x20	202	198	204	206	206	199
25x25	206	199	204	202	208	201

Angular dependence

To evaluate the angular dependence of Mosfet dedector, a spherical wax mini fantom was used. The Mosfet was placed at the center of the phantom with 2 radius. The center of the phantom was positioned in the middle of the 10x10 cm² field size at 100 cm SSD, with the round side of the detector facing the beam at 0^0 gantry angle. The six different gantry angles were used for measurements and 6 MeV electron energie was used. (Figure 5).

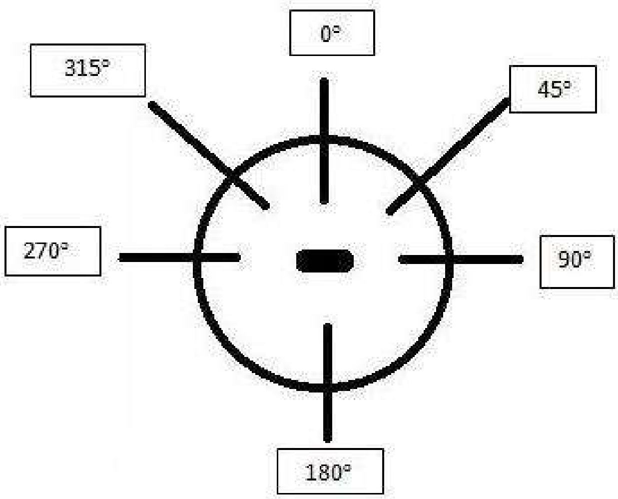

Figure 5. Experimental set-up for the determination of the angular dependence of the MOSFET

The variation in the mosfet response relative to 0^0 K_θ was calculated using the following equation :

$K_\theta = \frac{R(\theta=0)}{R(\theta)}$

where $R(\theta = 0)$ and $R(\theta)$ are the responses of the MOSFET at 0^0 and at gantry angle θ, respectively. (Figure 6).

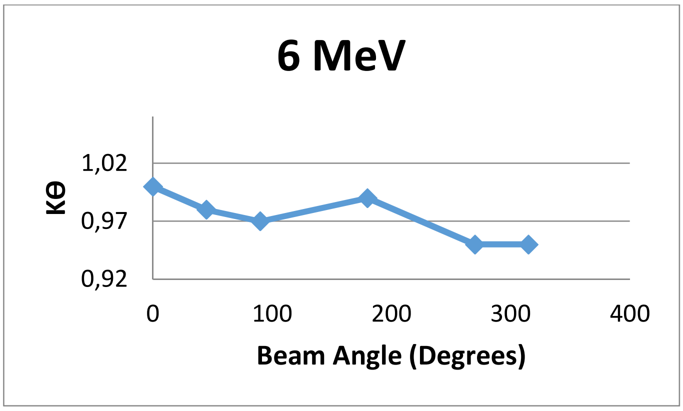

Figure 6. The dependence on the angle of the MOSFET for 6 MeV electron energie.

In study, because of the dose rate of the linac (200 MU/min) is stable, the dose rate dependence of the Mosfet could not be measured.

RESULTS

Under the same conditions, two Mosfets with the same characters were irradiated at different positions and using different energies. As can be seen from Table 1, irradiation position and energy used irradiation affect the calibration factors. The maxiumum difference between the calibration factors were found around 3% for 6,9,12,16,18 MeVelectron energies to 4 MeV was found around 8% difference between of the other electrons energies. In fact, the manufacturers has been reported that the energy dependence of 1-20 MeV electron range around 5%. But the features specified by the manufacturer, as seen in our study we found out consistent results for 4 MeV. Figure 3 showed that the response to the dose of the Mosfet is linear for electron energies. For the 50 cGy and above the 50 cGy dose, the error was found 3%. For the 10 cGy dose, the error rate reached 8% increasingly. The figure 4 shows the values that were measured to investigate the reproducibility of the Mosfet for 6 MeV. As can be seen from the table, the maxiumum difference is about 2%. Table 2 shows the values measured to examine the MOSFET field dependence. The error of readings between the low electron energies and small field sizes were found around 3%. The error in the reading at high energies and large field sizes were reached 5%.

Finally, figure 6 shows the dependence on the angle of the MOSFET for 6 MeV electron energie. K^θ values vary between 0.95 and 1.00. From these results, MOSFET depends on the angle slightly.

DISCUSSION

In our study, it was examined to investige the dosimetric properties of MOSFET dedector for use in clinical dosimetry for electron energies. MOSFET has a good linearity in the range 10-500 cGy dose for electron enegies. Only, For the 10 cGy radiation dose, MOSFET must be calibrated carefully and the calibration factor should be used in the measurements. MOSFETs were found to be dependent on the angle slightly.

The response of Mosfet dedector at different angles is not the same and differs from electron energies. MOSFET has two faces as the round and flat side. The flat side of Mosfet should be used, although there are not very large differences between these measurements with two faces. This is called the standard position. In the studies, it was stated that the round side of mosfet is more sensitive to radiation. It has been reported that there may be a visible dependence of the angle if the round side of the mosfet is irradiated in a face-to-face with the radiation source. The most effective way to reduce this effect, the MOSFET is to keep away from the source of radiation directly to this section. Despite not seen much of a change in the range of 6-18 MeV electron energy dependence, the same result could not be reached for 4 MeV. The observed results showed that field size dependence of the MOSFET is minimal and the MOSFET can also used for in vivo dosimetry of the patients treated with small fields.

CONCLUSIONS

Referring to the results, when the calibration and correction factors are used, MOSFET is a simple and effective systems that can be used in the quality control program for electron energies. Ease of use, patricularly placement on a patients skin, and the permanent record of the dose reading (with the ability to confirm the reading multiple time if neceassary) are particular strenghts of this dosimeter design. These dedectors are fast, reliable,small and user friendly. Because of these advantages, MOSFET may be used as in vivo dosimeter for electron beam radiotherapy.

Conflict of interest

No conflict of interest was declared by the authors.

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