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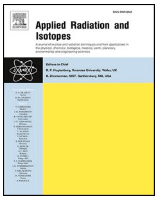

Physical and dosimetric characteristic properties of BeO OSL for clinical dosimetric measurements

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1. Introduction

In vivo dosimetry is the measurement of patient radiation doses during radiation therapy to be sure that treatments are performed as planned. The comprehensive verification of the treatment preparation and delivery chain could be done with in vivo dosimetry. The overall results of patient dose measurements provide the information necessary to evaluate accuracy of dose planning and radiation delivery. Possible errors in calculation and machine parameters could be eliminated using an in vivo dosimeter (IAEA Human Health Reports Series no, 2013). Semiconductor diodes, thermoluminescent dosimeters (TLDs), radiochromic film and metal-oxide-semiconductor field-effect transistors (MOSFET) are commonly used in vivo dosimetry systems for clinical radiation therapy. Although MOSFETs and diodes allows real-time reading, its dependence on temperature and angle of incidence emerges as a serious disadvantage. The short lifetime caused by saturation is another important problem about them (Soubra et al., 1994). Radiochromic film dosimetry is not easy and requires many cautions. Non-linear dose response and energy dependence are its serious limitations (Butson et al., 2003). TLDs' complex heating and annealing process prevents instantaneous dose reading. Optically stimulated luminescence dosimeters (OSLDs) avoids problems caused by heating of TL dosimeters (McKeever and Moscovitch, 2003).

Compared to TLD (most commonly used in clinical practice: LiF:Mg, Ti), OSLD has advantages such as high sensitivity, fast reading time, and easy-to-use reader. It has the ability to read the same information over and over again with the same accuracy (Akselrod et al., 2006). OSLDs is well known and widely used in luminescence dating and personal dosimetry. OSLDs uses the ability of OSL materials such as carbon-doped aluminum oxide (Al_2O_3:C) and beryllium oxide (BeO) to accumulate the absorbed dose and then release it as light when stimulated by another light source of a suitable wavelength (Akselrod et al., 2006). The material, stimulated by ionizing radiation, becomes a metastable state revealed by electrons and holes. Optical stimulation allows electrons and holes in the crystal to recombine at the luminescence center and excited at the luminescence center of the crystal. OSL consists of photons that these excited luminescence centers radiate as they move to the ground level (Yukihara and McKeever, 2011; Yukihara and Stephen, 2011). The use of OSL in medical dosimetry is being investigated by many researchers. The American Association of Physicists in Medicine (AAPM) presented a methodology for point dose measurements in medical physics measurements with TLD and OSL in Task Group 191 report (American Association of Physicists in Medicine AAPM Task Group 191, 2019). Investigation on OSL utilized in clinical dosimetry proceeds in three principle regions: improvement of new OSL materials, usage of merchant OSL systems, and advancement of new ideas and applications (Yukihara and Kron, 2021). Various materials have been produced and studied for OSL material. Al_2O_3:C is widely used for dosimetric measurements. However, new studies on BeO revealed that BeO OSL can be a valuable alternative of Al2O3: C OSL (Pradhan et al., 2008). It becomes more preferable for radiotherapy applications due to its characteristics such as low energy dependency, linear response at higher doses and higher optical sensitivity and effective atomic number close to the tissue (BeO Zeff = 7,13; Al_2O_3:C Zeff = 11,28; water Zeff = 7,4) (McKeever and Moscovitch, 2003).

With the expending technology in radiotherapy, such as Intensity Modulated Radiotherapy (IMRT), Image Guided Radiotherapy (IGRT), Stereotactic Radiosurgery (SRS), dosimetric measurement processes have become difficult and the need for advanced measurement techniques has increased. Precision and accuracy are important considerations in radiotherapy applications. The requirement of %5 accuracy is stated by the International Atomic Energy Agency (IAEA) (IAEA, 2000) and The International Commission on Radiation Units and Measurements (ICRU) (International Commission on Radiation Units and Measurements, 1976). It means that the precision of the dosimetric system to be used should be much higher. It is important to improve a highly accurate dosimetry protocol for radiotherapy dosimetry, as uncertainties in the dosimetry system contribute to uncertainty in measurement

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results.

In the work, the physical and the dosimetric characteristics of BeO OSLDs properties have been figured out before using it occasionally in clinical practice in radiotherapy. A series of measurements was performed to analyze the accuracy of the BeO OSL system. Some factors were obtained as mentioned in IAEA report 8 (IAEA Human Health Reports Series no, 2013) and AAPM TG 191(American Association of Physicists in Medicine AAPM Task Group 191, 2019), appropriate measurements were compared with an ionization chamber.

2. Materials/methods

2.1. Treatment unit, phantoms and ionization chambers

In this study, OSLs were irradiated by using 6 MV, 10 MV, and 15 MV photon beams with the Elekta Versa HD linear accelerator (Elekta Oncology Systems, Crawley, UK). The output dose of the linear accelerator was calibrated by using the absorbed dose calibration protocol of the IAEA TRS-398 (IAEA, 2000) in the water at the depth of dmax. Monitor units per cGy for a 10 × 10cm^2 field size at a source-to-surface distance (SSD) of 100 cm was calibrated 1 cGy for 1MU.

PTW 30 × 30cm^2 RW3 slab phantoms (PTW, Freiburg, Germany) and PTW Octavius 4D phantom (PTW, Freiburg, Germany) was used at the measurements. The build-up thicknesses varied depending on the irradiated photon energy, back scatter thickness was 10 cm for all measurements. Electron density factor of the slab phantom for comparison with real water is calculated by using the graph on the user manual, which are 1,009, 1015 and 1,0215 for 6 MV, 10 MV and 15 MV respectively. Bolus (Radon Medical, Ankara, Turkey) was used to filling the cavity around the OSL dosimeters.

Absolute dose measurements were made with a 0.6 cc cylindrical ion chamber, PTW 30013 Farmer (PTW, Freiburg, Germany) calibrated at the Turkish Atomic Agency (TAEK). PTW Roos 34001 parallel plate ionization chamber (PTW, Freiburg, Germany) was used for the percentage depth dose (PDD) measurements.

The measurements were taken by placing BeO OSLs at the maximum dose depth which are 15 mm, 20 mm and 30 mm for 6 MV, 10 MV and 15 MV and ion chamber at the reference depth for each energy at the source surface distance (SSD) at 100 cm.

2.2. OSL calibration

BeO OSLDs (12 × 12 × 4 mm^3 including encasement material) were first annealed at 700 °C for 3 h. They were placed in a plastic mold with 1,07 gr/cm^3 density and given an identification (ID) number. In the optical eraser section, the eraser process was performed for 30 min and the base level was determined in the reader. BeO OSLs were irradiated with a 50 cm diameter Cs-137 source at a distance of 100 cm according to the ISO IEC 4037 1-2-3standards. (ISO IEC 4037-1-2-3, 1997a; ISO IEC 4037-1-2-3, 1997b; ISO IEC 4037-1-2-3, 1999) Homogeneity of the irradiation profile is below 2% both for the x and y directions. The OSL decay curve was obtained and defined by matching each curve with the ID numbers of the OSLs. Irradiated BeO OSLDs were read by using Pdose OSL dosimetry system (RADKOR Personal Dosimeter Measurement and Assessment Laboratory, Ankara, Turkey) which is consists of reader-eraser unit and software. This reader uses green LEDs for optical stimulation and operates in CW-mode with a stimulation time of 1.0 s. A photomultiplier tube measures the OSLD signal emitted from the OSL and the amount of stimulation imparted to the crystal, is proportional to the irradiation dose. The readers' special software enables the user to save dose records and evaluate dosimeters into the reader automatically.

The OSLs are designed for single use in order to store patient-specific in vivo measurements. This feature allows patient data to be read again when needed. In this study all measurements done by single used BeO OSLs and stored. A total of 662 OSL were used, 180 OSL for linearity and energy dependency test, 30 OSL for sensitivity test, 36 OSL for dose rate dependency tests, 60 OSL for angle of incidence tests, 48 OSL for field factor measurements, 60 OSL for SSD correction factor, 248 OSL for PDD measurements.

2.3. Linearity and energy dependency test

The physical properties of the dosimetry material affect the linearity of the dose response curve. It is desirable that a good dosimeter has a linear response over a wide dose range and independent from energy. Otherwise, linearity and energy correction factors or high degree polynomial equations could be applied for fitting.

168 OSL were irradiated for the linearity and energy dependency tests. 4 OSL for each slide was irradiated with 6 MV, 10 MV and 15 MV photon energy using 20, 50, 75, 100, 150, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 cGy. The average and standard deviation of OSL reading were calculated from four OSL dosimeters for each photon energy. The OSL readings were compared with the ionization chamber measurements. The dose response nonlinearity correction factors mentioned in the IAEA report 8 (IAEA Human Health Reports Series no, 2013) were determined.

For the energy dependency factor all measured values were normalized to the mean value for the three photon energy and the factor was calculated as the ratio of the normalized values to the 6 MV.

2.4. Sensitivity test

10 OSL dosimeters were irradiated for each energy to a dose of 200 Monitor Units (MUs) with SSD 100 cm. Dosimeters are located at the build-up thickness. By normalizing OSL readings to the mean dose, the inter-disc sensitivity value and standard deviation were calculated.

2.5. Dose rate dependence

The effect of change in dose rate to the readings were investigated in the range of 50, 300 and 600 MU per minute for three photon energies at maximum dose depths. OSL dosimeters were irradiated with 200 cGy with SSD 100 cm 12 OSL for each energy totally 36 OSL were used at dose rate dependence tests.

2.6. Angle of incidence test

Angle of incidence test for the OSL dosimeters was performed by using Octavius 4D phantom in Source to Axis Distance (SAD) of 100 cm at the isocenter of the phantom and center of the OSL dosimeter as can be seen on Fig. 1. OSLDs (60 OSL used for this test) were irradiated to 2 Gy dose using 10 × 10 cm^2 field size of 6, 10 and 15 MV photon energies for gantry angles 0, 30, 45, 60, and 90°. The angle of incidence correction factors was calculated with respect to 0°.

2.7. Field factor measurement

The field size measurements were performed by the square field sizes 5 cm × 5 cm, 10cmx10cm, 15 cm × 15cm and 20cmx20cm. The field size correction factors were calculated as the ratio of 10cmx10cm to the other field sizes.

2.8. SSD correction factor

SSD correction factor measurements were performed at 80, 90, 100, 110 and 120 cm SSD distance with 10cmx10 cm collimator opening. The OSL dosimeter readings were corrected for SSD to the depth dose maximum using the formula mentioned in IAEA report 8 (IAEA Human Health Reports Series no, 2013). SSD correction factor were determined from corrected OSL measurements corresponding to the standard treatment distance SSD 100 cm.

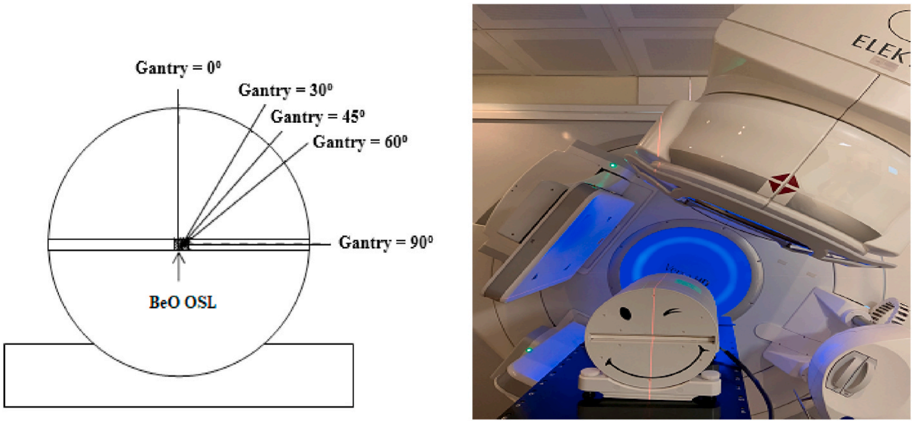

Fig. 1. Photograph and diagram of the experimental set-up used to measure angular response of OSL discs in cylindrical phantom under photon beam from Elekta Versa HD.

Percentage depth dose measurement

Measurements of percentage depth dose were carried out using BeO OSL dosimeter and PTW ROOS parallel plate ion chamber for 6, 10 and 15 MV photon beams at different depths in the PTW RW3 water equivalent slab phantom using 10 × 10 cm^2 field size and SSD 100 cm. The measurement depths were 0, 1, 2, 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90,100, 110, 120,130, 140 and 150 mm for 6 MV, additional 25 mm depth was measured for 10 and 15 MV photon energies.

Gerbi and Khan (1990) has developed a correction method to give the true value of the over response doses measured by the parallel plate ion chambers by using the extrapolation ion chamber measurements. The overdose response of the parallel plate ion chamber in the buildup region were corrected by using the dose correction function:

$$P'(d, E) = P(d, E) - \xi'(0, E)\, l e^{-(d/d\max)},\ \xi(0, E) = [-1666 + (1{,}982 IR)] \times (C - 15{,}8)\ (\%/mm) \quad (1)$$

ξ(0, E) = energy dependent ionisation chamber overresponse correction factor, IR = ionization ratio at depths of 20 cm and 10 cm, which is measured at a fixed source-detector distance and 10 × 10 cm^2 field size. IR values are 0,675, 0,731 and 0,763 for 6 MV, 10 MV and 15 MV photon beams, respectively.P' = corrected percent depth dose, P = measured depth dose, E = energy, d_{max} = maximum dose depth, C = sidewall-collector distance (4 mm for PTW Roos), l = plate separation (2 mm for PTW Roos),α = 5.5, constant, d = depth of the chamber front window (d = 0 for surface),

Different materials were used to make BeO OSL and parallel-plate ion chamber, so each has its own effective measuring depth. By considering the water equivalent thickness (WET) which represents the thickness of water (in g/cm^2) for build up region measurements, a more accurate comparison could be done (Vera and Garcia-Molina, 2014).

Depth and percentage depth dose curves both for parallel-plate ion chamber and BeO OSL were obtained by using the data so obtained for all photon energy.

3. Results

3.1. Linearity and energy dependency test

The BeO OSL dose response in a range of doses from 20 to 1000 cGy is shown in Figs. 2–4 for 6, 10, and 15 MV photon energies. Linearity up to 400 cGy and slight supralinearity at higher doses were observed. By normalizing OSL dose to the ionization chamber dose values, k_{lin} linearity factors were calculated and shown in Table 1. More accurate dose measurement results could be achieved by correcting the supralinearity using k_{lin} factor, especially for the higher doses.

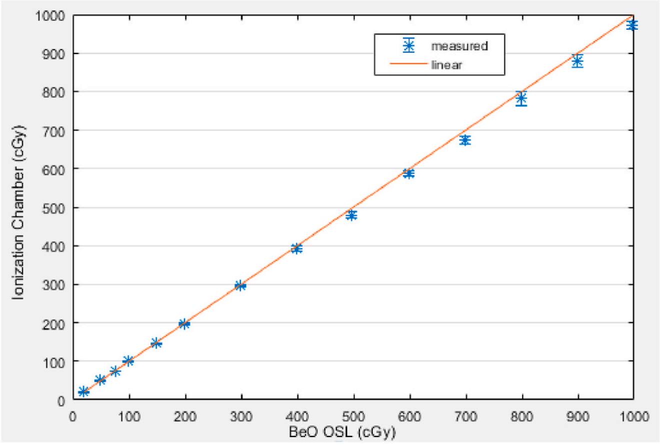

Fig. 2. The BeO OSL dose response in a range of doses from 20 to 1000 cGy of 6 MV. The solid line represents an ideal linear dose response.

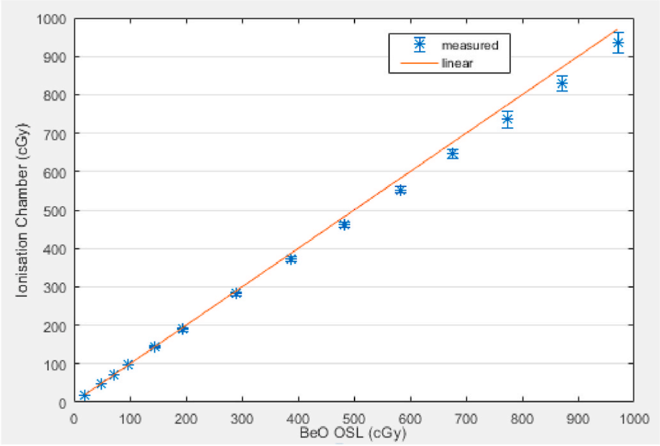

Fig. 3. The BeO OSL dose response in a range of doses from 20 to 1000 cGy of 10 MV. The solid line represents an ideal linear dose response.

Measurement values in the range of 50–1000 cGy for 3 photon energy were shown in Fig. 5. The mean and standard deviation of the BeO OSL dose values were also calculated and all measured values were normalized to the mean dose for the three photon and shown in Table 2. Our results show that there is no significant energy dependence in the

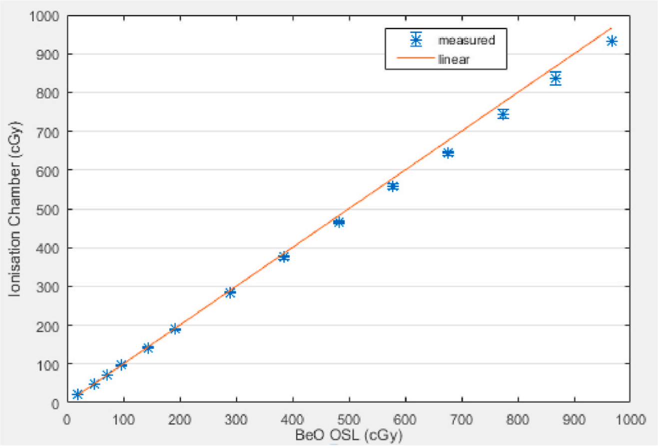

Fig. 4. The BeO OSL dose response in a range of doses from 20 to 1000 cGy of 15 MV. The solid line represents an ideal linear dose response.

Table 1
The BeO OSL k_{lin} factors in a range of doses from 20 to 1000 cGy of 6, 10 and 15 MV.

Dose(cGy)	k_{lin}	k_{lin}	k_{lin}
	6 MV	10 MV	15 MV
20	1	1,03	0,98
50,00	1	1	1,01
75,00	1,01	1,02	1,01
100,00	1	1	1
150,00	1,03	1	1,02
200,00	1,01	1,03	1,02
300,00	1,01	1,03	1,02
400,00	1,01	1,04	1,03
500,00	1,04	1,05	1,04
600,00	1,02	1,05	1,04
700,00	1,04	1,05	1,05
800,00	1,02	1,05	1,04
900,00	1,02	1,05	1,04
1000,00	1,03	1,04	1,04

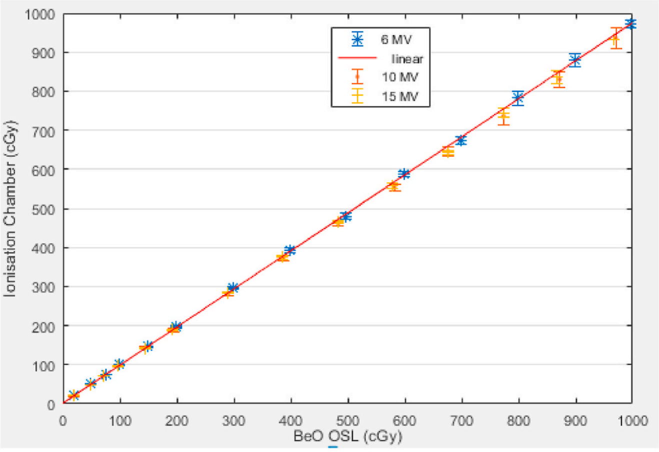

Fig. 5. The BeO OSL dose response in a range of doses from 20 to 1000 cGy of 6, 10 and 15 MV. The solid line represents linear fit curve of 6 MV results.

photon dose-response curves for the energy 6, 10 and 15 MV.

Table 2
Normalized dose response values and the standard deviations of the BeO OSL for 6, 10 and 15 MV.

Dose (cGy)	6 MV	10 MV	15 MV	Standard Deviation
50,00	0,99	0,98	1,00	±0,01
75,00	0,99	0,99	1,00	±0,01
100,00	1,00	1,00	1,00	±0,00
150,00	1,00	1,01	1,00	±0,01
200,00	1,01	1,01	1,00	±0,01
300,00	1,01	1,02	1,00	±0,01
400,00	1,01	1,02	1,00	±0,01
500,00	1,01	1,02	0,99	±0,02
600,00	1,01	1,02	0,99	±0,02
700,00	1,01	1,01	0,99	±0,01
800,00	1,01	1,01	0,99	±0,01
900,00	1,01	1,01	0,99	±0,01
1000,00	1,01	1,01	0,99	±0,01

3.2. *Sensitivity test*

Table 3 shows the measurement doses for the inter-disc sensitivity variations of BeO OSL dosimeters irradiated with a dose of 200 cGy. The sensitivity of individual OSL dosimeters had a standard deviation of 1% for 6 and 10 MV, 2% for 15 MV. This shows good stability of the BeO OSL dosimetry system.

3.3. *Dose rate dependence*

BeO OSL measurements in the dose rate between 50 and 500 MU/min were shown in Fig. 6 for 6, 10 and 15 MV photon energies. Since the commonly used dose rate in radiotherapy applications is 500 MU/min, measurements at the other dose rates were normalized to 500 MU/min measurements. It is observed from the graph that the variation in response of BeO OSL is within the standard deviation for different dose rates which means there is no noticeable dose rate effect for the BeO OSLD system.

3.4. *Angle of incidence test*

The effect of incidence angle to the measurement dose is shown in Table 4 and Fig. 7 for BeO OSL. 0° gantry angle was accepted as reference and the measurements of the BeO OSL at different gantry angle normalised to 0° gantry angle. The variations in normalized doses were within 3% at 30, 45, 60 and 90°. According to our results, the use of gantry angle correction factor would increase the measurement accuracy at irradiation angles over 45°.

3.5. *Field factor measurement*

Figs. 8–10 shows BeO OSL field factor measurement results for 6, 10 and 15 MV photon beams with ionization chamber field factors. BeO OSL field factor values were found to be compatible with the ionization chamber measured factors. There were less than 2% difference between the ionization chamber and OSL doses for all sizes.

3.6. *SSD correction factor*

Figs. 11–13 shows that the response of various SSDs against the SSD 100 cm for BeO OSL dosimeters with ionization chamber results. It is observed that BeO OSL measurements are in a good agreement in ionization chamber within the 1% for all SSD values.

3.7. *Percentage depth dose measurement*

The percentage depth dose measured using BeO OSL and parallel plate ionization chamber for 10 × 10 cm^2 field of 6, 10 and 15 MV photon beams at different depths in slab phantom is shown in Figs. 14–16.

Table 3
The inter-disc sensitivity variations of BeO OSL dosimeters irradiated with a dose of 200 cGy for 6, 10 and 15 MV.

BeO OSL No	6 MV		10 MV		15 MV	
	Dose (cGy)	Sensivity Factor	Dose (cGy)	Sensivity Factor	Dose (cGy)	Sensivity Factor
1	198,75	0,99	199,67	1	201,46	1,01
2	198,98	0,99	200,34	1	204,85	1,02
3	201,54	1,01	200,75	1	201,55	1,01
4	199,34	1	202,47	1,01	197,16	0,99
5	200,37	1	203,51	1,02	200,87	1
6	201,93	1,01	198,57	0,99	192	0,96
7	201,26	1,01	202,03	1,01	200,63	1
8	199,18	1	199,08	1	203,39	1,02
9	199,52	1	199,29	1	200,15	1
10	199,08	1	198,55	0,99	197,96	0,99
Mean dose(cGy)	**199,99**	**1**	**200,43**	**1**	**200**	**1**
Std. Dev.	**1,18**	**0,01**	**1,73**	**0,01**	**3,6**	**0,02**

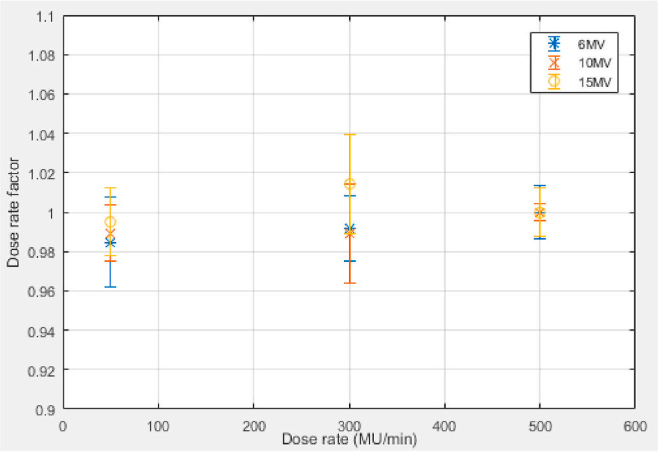

Fig. 6. Relative variation in the response of BeO OSL with varying dose rate of 6, 10 and 15 MV photon beam. The response was normalised with respect to the value recorded for the dose rate of 500 MU per min.

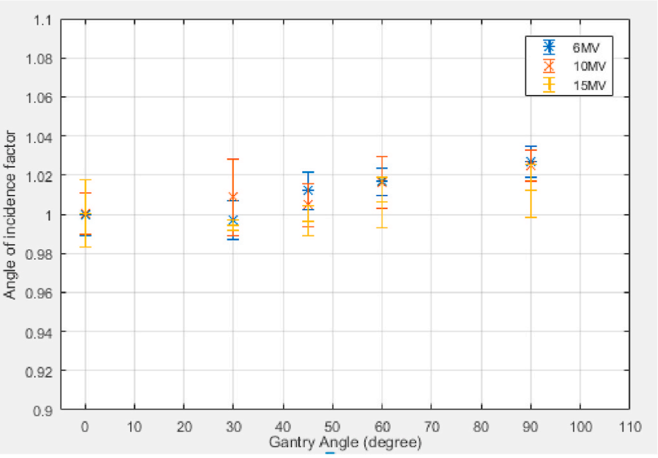

Fig. 7. Angular response of BeO OSL in 6,10 and 15 MV photon beam.

Table 4
Angular response and angle correction factors of BeO OSL in 6,10 and 15 MV photon beam.

Gantry angle (⁰)	6 MV		10 MV		15 MV	
	Dose (cGy)	Factor	Dose (cGy)	Factor	Dose (cGy)	Factor
0,00	200 ± 1,62	1,00	200,03 ± 1,72	1,00	200,06 ± 2,90	1,00
30,00	199,4 ± 1,51	1,00	201,73 ± 3,15	1,01	198,89 ± 0,48	0,99
45,00	202,42 ± 1,46	1,01	200,99 ± 1,77	1,00	199,33 ± 1,30	1,00
60,00	203,35 ± 1,05	1,02	203,24 ± 2,16	1,02	201,2 ± 2,25	1,01
90,00	205,41 ± 1,20	1,03	205 ± 1,28	1,03	202,42 ± 2,32	1,01

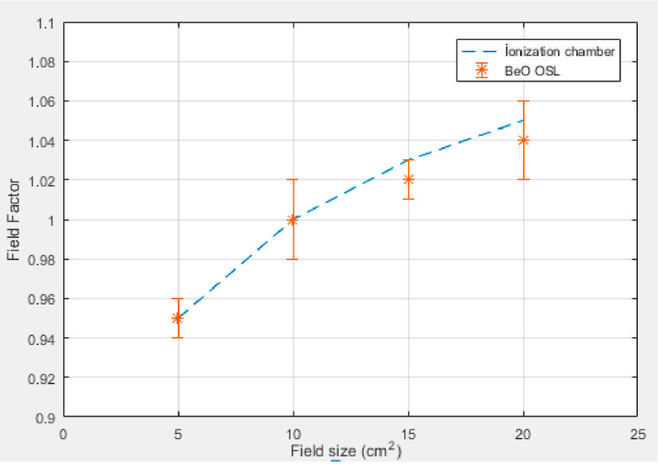

Fig. 8. BeO OSL and ionisation chamber-measured field factors of 6 MV photon beams.

4. Discussion

The accurate and precise dosimetry is important for delivering treatment to a patient as prescribed. Therefore, it is necessary to know well the dosimetric properties of the system used. The aim of the study is figure out the performance of BeO OSLDs in terms of its dosimetric and physical properties with photon energies used in radiotherapy before using it in clinical practice. This evaluation included their dose response curve linearity, dependence of beam energy, the sensitivity of the OSLD at different beam energies, dose rate dependency, directional dependency, output factors, SSD factors and finally PDD curves with respect to ionisation chamber.

Linearity is one of the most desirable properties of the dosimetry systems. The reading value of the ideal dosimetry system is expected to be linear with the irradiation dose. However, deviation from linearity is observed with the increasing dose depending of the characteristics of the dosimeter. It is important to determine in which region the dosimetry behaves non-linearly and use linearity correction factors if possible. The non-linear dose response of OSL is explained by a competition between

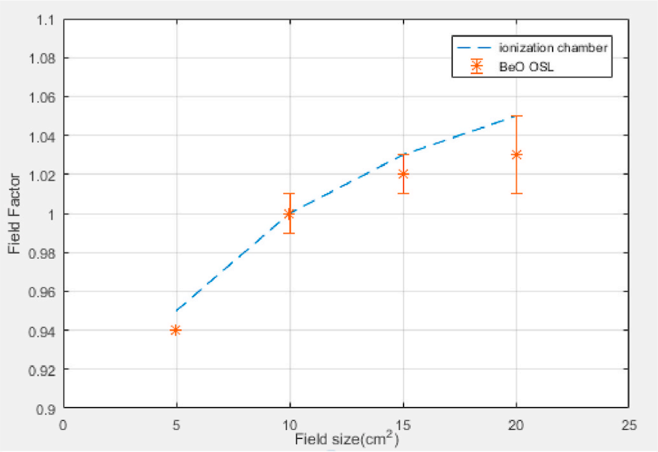

Fig. 9. BeO OSL and ionisation chamber-measured field factors of 10 MV photon beams.

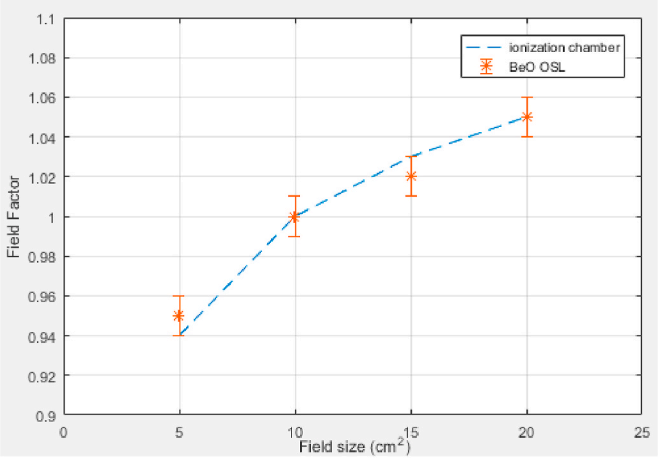

Fig. 10. BeO OSL and ionisation chamber-measured field factors of 15 MV photon beams.

various traps (competitors) during the irradiation or readout process (Chen and Leung, 2000). Our linearity test results up to 400 cGy show that the dose response is linear in agreement with Schembri and Heijmen who used Al_2O_3:C OSLD in their study (Schembri and Heijmen, 2007). As known from the study of Yukihara and McKeever (2008), type of the OSLDs, the properties of the reader, and the irradiation history of the detector affect the linearity of the dose response (Yukihara and McKeever, 2008). Our results at doses above 400 cGy were more consistent with Santos using BeO OSLD in his study, which found the dose response slightly linear (Santos et al., 2015).

Generally the responce of a dosimeter changes with radiation quality which is expressed as the energy dependence and it requires correction factor. The use of the energy correction factor is very important in radiotherapy, especially in the use of the dosimeter system made of non-tissue-equivalent materials. The BeO OSL has an atomic number close to the tissue that provides an advantage in terms of energy dependence. According to our results which are shown in Fig. 5 and Table 2 there is no energy dependency of BeO OSLD system for the 6,10 and 10 MV photon energies which is in agreement with results of Aznar et al. (2004) and Viamonte et al. (2008).

The reproducibility of the measurements under same conditions could be specified as sensitivity of the dosimetry system. Table 3 shows the reading of individual BeO detectors each irradiated with 200 cGy under same conditions. Sensitivity factors and standard deviations are calculated for all energies and found to be within the 2%. Our results agree with Schembri and Heijmen (2007).

An ideal dosimetry is expected to have the same responce to varying dose rates. However, dose rate may change the readings. It is important to figure out it and do the corrections if necessary. As can be seen in Fig. 6 our dose rate test results agree with Schembri and Heijmen (2007) which also show that there is no significant dose rate effect for Al2O3:C OSL dosimeters.

The directional or angular dependence of the dosimeter is explained as the difference in responce of the dosimeter with the angle of incidence. In in-vivo dosimetry directional dependence is important cause different beam orientations are used in patient treatments. In many studies on OSL (Aznar et al., 2004; Jursinic, 2007), it has been stated that the dose response is independent of the beam incidence angle. However, the plastic mold in which the OSL is placed and the OSLs were not hemispherical but flattened, causing the OSL response dependent to incidence of beam at irradiation angles over 45°.

The curves in Figs. 8–10 obtained from measurements shows that the BeO OSL dosimetry system is nearly independent of the field size. BeO OSL can be used in relative output factor measurements especially for the small field measurements because of its small sizes. While Schembri and Heijmen (2007) found deviations of the overall mean response of OSL films within 2.5%, it was found smaller than 2% in our study.

Our BeO OSL measurements with different SSDs are in a good agreement with the ionization chamber within the 1% for all SSD values and also with those of Schembri and Heijmen (2007).

The BeO OSL curve were compatible with the ionization chamber in the buildup region and beyond the depth of dose maximum for 6 MV

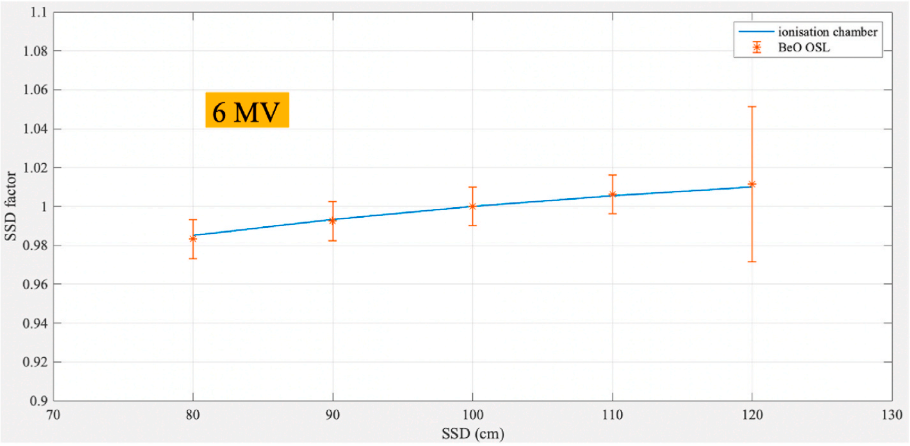

Fig. 11. Response of BeO OSL with varying source to surface distance (SSD) in 6 MV photon beam.

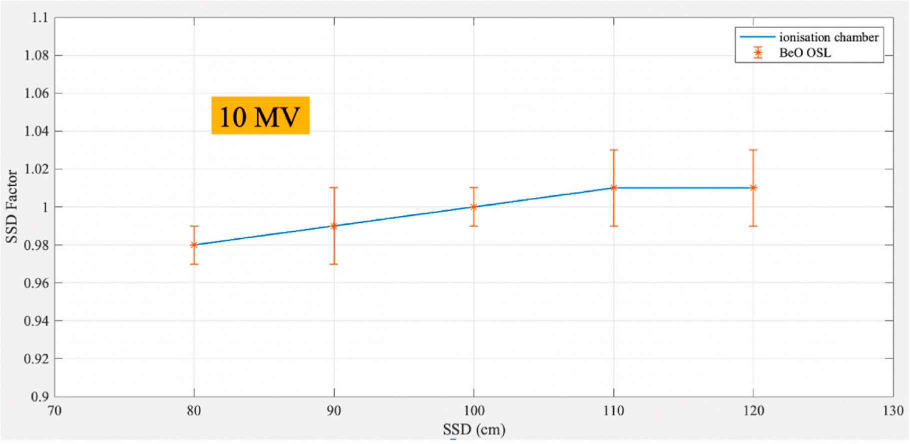

Fig. 12. Response of BeO OSL with varying source to surface distance (SSD) in 10 MV photon beam.

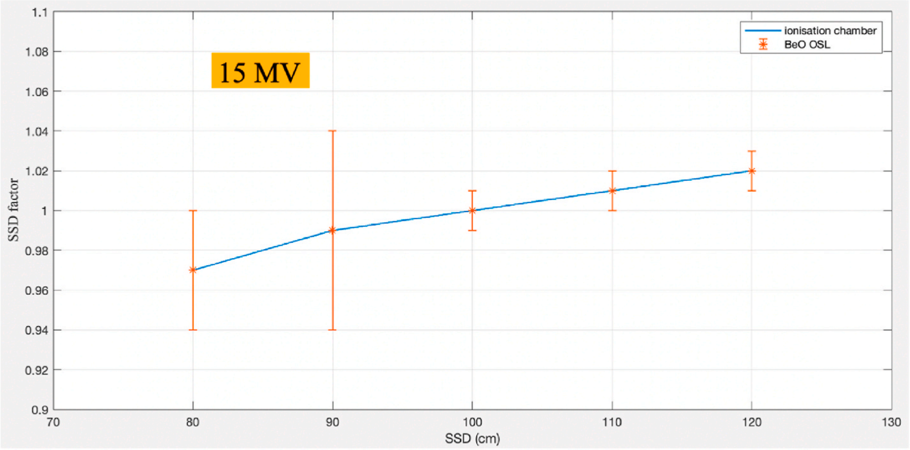

Fig. 13. Response of BeO OSL with varying source to surface distance (SSD) in 15 MV photon beam.

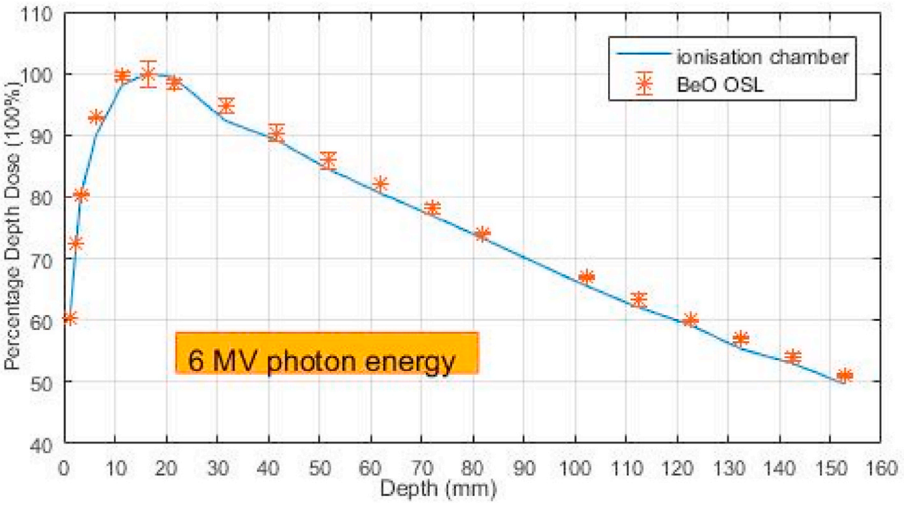

Fig. 14. BeO OSL and ionisation chamber-measured relative depth dose values in 6 MV photon beam.

photon energy. It is observed that the OSL measurements slightly higher than ionization chamber in the buildup region for 10 MV and 15 MV. This could be explained with the intrinsic build up differences between OSL and parallel-plate ion chamber.

5. Conclusion

In-vivo dosimetry is very important to reduce the risks of serious accidents might be during the radiation therapy and to be sure the patients were treated as planned. It is also an important tool for thoroughly

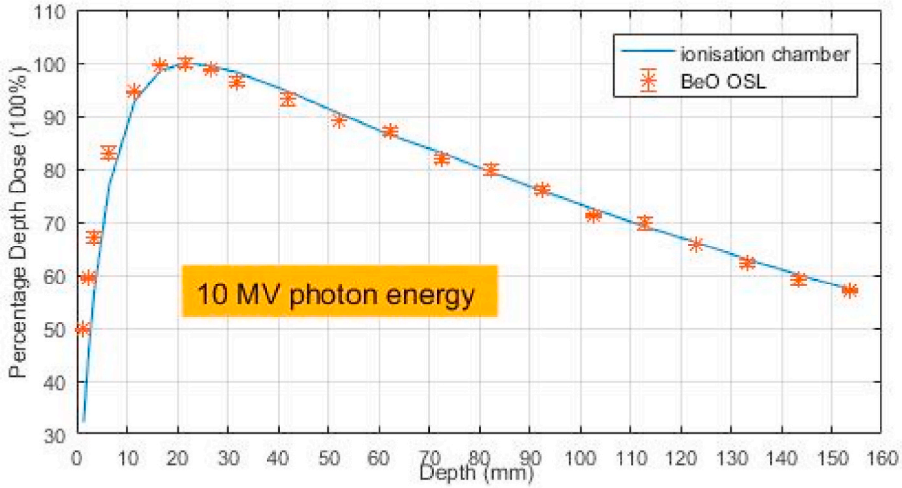

Fig. 15. BeO OSL and ionisation chamber-measured relative depth dose values in 10 MV photon beam.

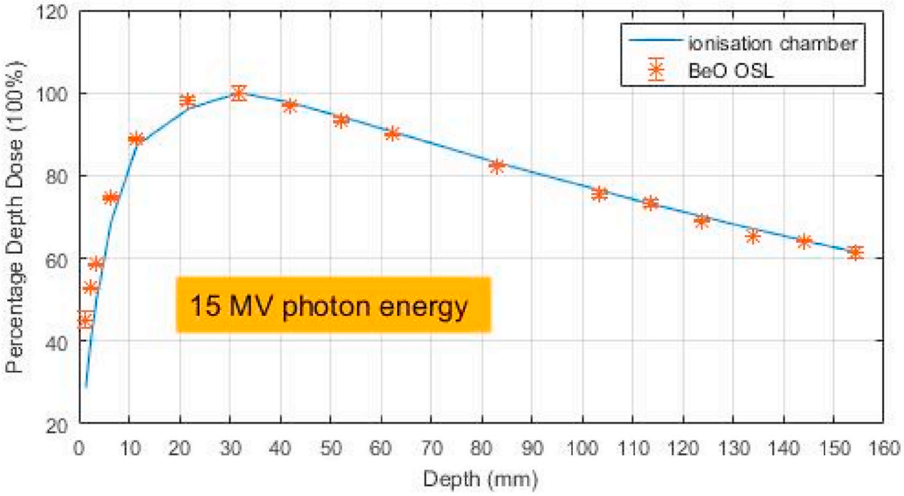

Fig. 16. BeO OSL and ionisation chamber-measured relative depth dose values in 15 MV photon beam.

evaluating the overall verification of the radiation treatment procedure. There are many in vivo dosimetry systems used for clinical radiation therapy. In this study, the physical and the dosimetric characteristics of BeO OSLDs properties have been evaluated before using it routinely in clinical practice in radiotherapy in 6, 10, and 15 MV photon energy from medical linear accelerator. The results described in the study show that the characteristics of these BeO OSL dosimeters are comparable to the ionisation chamber mostly used in radiotherapy. Measurements in field factor and SSD factor were found to be compatible with the ion chamber. Its energy dependence is less than 1% making it a good alternative for dosimetry. By using a linearity factor over 400 cGy doses and gantry angle for incidence angle greater than 45° the measurement accuracy could be increased. The stability of the system and dose rate independence making BeO OSL a good candidate for measurements in clinical radiotherapy. It is observed in the study that BeO OSL system has high potential to be used for in vivo dosimetry. It could be also a good alternative for point dose measurements with further studies in radiotherapy.

CRediT authorship contribution statement

Esil Kara: Writing – original draft, Investigation. **Ayse Hicsonmez:** Conceptualization, Methodology, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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