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Measuring Absorbed Dose from Medical X-ray Equipment Using Optically Stimulated Luminescence Dots

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ABSTRACT

In this paper, we measured and analyzed the dose correction factor, absorbed dose linearity, peak voltage X-ray response, angular dependence. Exposure dose correction factor, absorbed dose linearity, and peak voltage linearity using the medical X-ray generator were all in accordance with IEC-62387-1 (2007). The reference to the dosimetry direction at 0, 30, and 60 degrees relative to baseline radiation exposure was -29% (± 30 °) and + 67% (± 60 °). The values measured at 30 ° were -8% lower than the standard and -18% lower than the standard at 60 °. Therefore, the effect of direction should be corrected when using OSL dot dosimeter.

Keywords: OSL Dots, Low Energy X-Ray, Dose Correction Factor, Absorbed Dose Linearity, Peak Voltage X-Ray Response, Angular Dependence

Ⅰ. INTRODUCTION

In the OSL (Optically Stimulated Luminescence) technology utilizing aluminum oxide (Al_2O_3) detector material, light is used to stimulate the luminescence from materials previously exposed to ionizing radiation, the total luminescence emitted being proportional to the absorbed dose of radiation to which the material was exposed.[1-2] Since OSL uses an intense light source with minimal UV content without heating in the process of dose measurement and annealing of the dosimeter, it is advantageous that the properties of materials are not changed at all and the tests for the same materials can be carried out repeatedly.[3-5] For measuring the recommended patient dose and therapeutic dose in Radiology Imaging Test, the number of cases when an optically stimulated dosimeter is used is on the increase; however, there are few basic studies on it, as compared to a thermo-luminescence dosimeter and a glass dosimeter.

In this study, we measured and analyzed correction factor, the absorbed dose linearity, the tube voltage linearity, the change of absorbed dose by the change in angle, and the coefficient of variation in repeatable read doses as found in the OSL dots dosimeter when being exposed to irradiation using medical X-ray producing equipment.

Ⅱ. MATERIAL AND METHOD

1. X-ray producing equipment

As a radiation exposure system, DKⅡ-525RF of X-ray diagnostic generator (Dong Kang Medical Systems, Gyeonggi-do, Korea) installed at Nambu University is used. The X-ray tube maximum current range in this system is 500 mA and the X-ray tube maximum voltage ranges is 125 kVp.

10500AMT TRIAD TnT Dosimeter Kit (Fluke

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Biomedical, Everett, WA, USA) used as Reference Dosimeter includes Dosimeter (Model 35050AT), 15 cm^3 Ion Chamber, and 150 cm^3 Ion Chamber.

2. OSL dots and microStar

A commercial microStar (Landauer, Glenwood, IL, USA) reader used for the experiment measures radiation exposure with aluminium oxide detectors (Al_2O_3:C) readout by Optically Stimulated Luminescence (OSL) technology.

3. Dose Correction Factor

Dose correction factor is the ratio of the 21 reference values to the 21 measured values in an OSL dots luminescence dosimeter. Since the efficiency of absorbing radiation varies in an OSL dots dosimeter, I measured the absorbed dose using microStar reader by having OSL dots exposed to the reference dose of irradiation. In the case of correction factor larger than 1, the absorbed dose is overestimated as compared to the reference dose. In the case of correction factor less than 1, the absorbed dose is underestimated as compared to the reference dose.

4. Absorbed Dose Linearity

For the testing of dose linearity, a total of 21 dosimeters are grouped into 7 sections by 3 per each group to measure each dose. In terms of the condition of X-ray exposure, X-ray tube voltage and X-ray tube current are fixed at 80 kVp and 200 mA respectively, and time is increased to 0.1, 0.2, 0.3, 0.4, 0.6, 0.8, and 1.0 second respectively to measure the absorbed dose. By subtracting the indication on dosimeter before being exposed to irradiation from that after being exposed to irradiation, the weight value is acquired, and from the mean value of these quantities, the response to each dose is calculated.

5. Peak Voltage X-ray Response

For the testing of energy characteristics, a total of 21 dosimeters are grouped into 6 sections by 3 per each group to acquire the indication on each dosimeter. In terms of X-ray exposure condition, X-ray tube current and time are fixed at 200 mA and 2.0 seconds respectively to measure the absorbed dose by varying X-ray tube voltage from 40 to 50, 60, 70, 80, and 90 kVp. By subtracting the indication on dosimeter before being exposed to irradiation from that after being exposed to irradiation, the weight value is acquired, and from the mean value of these quantities, the response to each energy is calculated.

6. Angular Dependence

In terms of angular dependence, three OSL dot dosimeters are used repeatedly in order to minimize the effect of dosimeters. When the dosimeter has been properly positioned, the phantom is rotated counter- clockwise ('- direction') or clockwise ('+ direction'), when viewed from above the phantom, about the vertical centerline of the phantom face to the proper angle for the irradiation. By subtracting the indication on dosimeter before being exposed to irradiation from that after being exposed to irradiation, the weight value (increased value) is acquired, and from the mean value of these quantities, the response to each incidence angle is calculated. With the response to incidence angle of 0 degree at the reference point, the percentage of reference values is acquired by subtracting the reference value from the response to each direction.

Ⅲ. Results

1. Dose Correction Factor

In terms of correction factor for the 21 dosimeters, its 12 values are larger than 1 and its 9 values are smaller than 1. Correction factor varies from 0.8 to 1.32; its 15 values are 0.05 or smaller. In the case of correction factor larger than 1, the absorbed dose is overestimated as compared to the reference dose. In the case of correction factor less than 1, the absorbed dose is underestimated as compared to the reference dose.

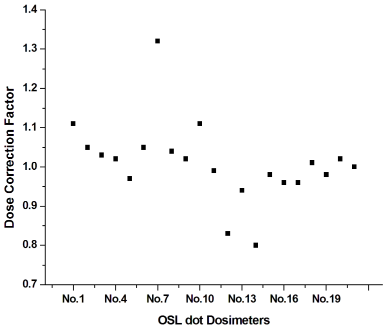

Fig. 1. Correction factor varies from 0.8 to 1.32; its 15 values are 0.05 or smaller.

2. Absorbed Dose Linearity

As X-ray tube voltage and X-ray tube current are fixed at 80 kVp and at 200 mA respectively, time is increased to 0.1, 0.2, 0.3, 0.4, 0.6, 0.8, and 1.0 second respectively. By subtracting the indication on dosimeter before being exposed to irradiation from that after being exposed to irradiation, the weight value is acquired, and from the mean value of these quantities, the response to each dose is calculated. The coefficient of correlation between the exposure dose and the absorbed dose is 0.9844 (P<0.0001): very high linearity. The exposure dose and the absorbed dose are related to each other as in the following equation.

$$Y = -0.38 + 0.19 \times X \tag{1}$$

where Y is the absorbed dose, X is the exposure dose.

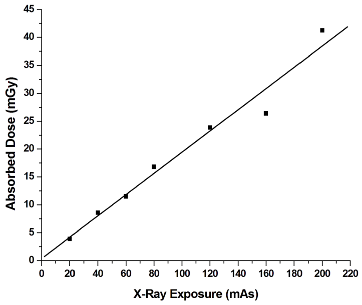

Fig. 2. The absorbed dose as a function of exposure dose. The correlation coefficient is 0.9844(P<0.0001).

3. Peak Voltage X-Ray Response

As X-ray tube current is fixed at 200 mA with time fixed at 2 seconds, X-ray tube voltage is increased to 40, 50, 60, 70, 80, and 90 kVp respectively. By subtracting the indication on dosimeter before being exposed to irradiation from that after being exposed to irradiation, the weight value is acquired, and from the mean value of these quantities, the response to each energy is calculated.

The coefficient of correlation between X-ray tube voltage and the absorbed dose is 0.9615 (P<0.05): very high linearity. X-ray tube voltage and the absorbed dose are related to each other as the following equation shows.

$$Y = -5.96 + 0.14 \times K \tag{2}$$

where Y is the absorbed dose, S is the X-ray tube voltage.

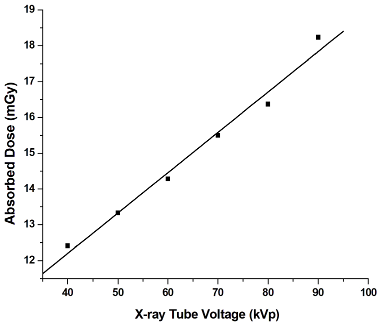

Fig. 3. The dose as a function of X-ray tube peak voltage. The correlation coefficient is 0.9615(P<0.05).

4. Angular Dependence

Dosimeters are exposed to irradiation with their directions varied from 0˚ to 30˚, 60˚, 90˚, 180˚, 210˚, 240˚, 270˚, 300˚, and 330˚ respectively. As the measured value is 1 at the incidence angle of 0 degree, the relative values for each angle are shown. IEC (International Electrotechnical Commission., 2007) references for the directions of dosimeter at 0 degree, 30 degrees and 60 degrees with regard to reference radiation exposure are -29%(±30˚) and +67%(±60°). At 30 degrees, the measured value is -8% lower than the reference dose, and at 60 degrees it is −18% lower than the reference dose.[6]

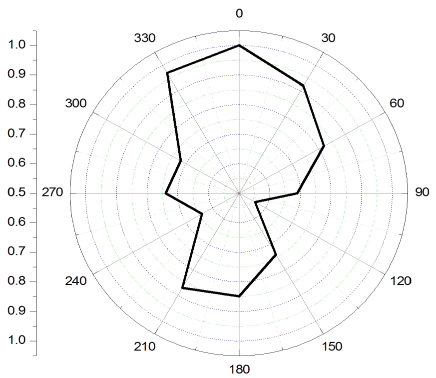

Fig. 4. The OSL dosimeter response as a function of angle.

Ⅳ. DISCUSSION

Correction factor, the absorbed dose linearity, the tube voltage linearity, the change of absorbed dose by the change in angle, and the coefficient of variation in repeatable read doses measured in the optically stimulated OSL dots dosimeter using the diagnostic X-ray producing equipment maintain the international standard. Dose correction factor, absorbed dose linearity, peak voltage linearity are all within the criteria of IEC-62387-1(2007). In the OSL dots dosimeter, the fact that the efficiency may vary according to the device and the direction dependence are considered. An OSL dots dosimeter has only one measuring device, so its degree of accuracy and precision is lower than the individual dosimeter with 4 devices and filters. It is required that comparative measurements be made in the future as compared to TLD and PLD having the different measuring mechanisms.

Acknowledgements

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광자극선량계의 저에너지 엑스선 특성비교

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요 약

본 논문에서는 OSL 도트 선량계의 교정인자, 흡수선량 선형성, 피크전압 선형성, 각도 변화에 의한 흡수선량 변화를 측정하고 분석했다. 의료용 X 선발생 장치를 사용하여 조사에 노출 선량 보정 계수, 흡수선량 선형성, 피크 전압 선형성은 모두 IEC-62387-1 (2007) 기준을 만족하였다. 기준 방사선 노출과 관련하여 0도, 30도 및 60도에서 선량계 방향에 대한 기준은 -29 % (± 30 °) 및 + 67 % (± 60 °)이었다. 30도에서 측정된 값은 기준보다 -8 % 낮고 60도에서 기준보다 -18 % 낮게 나타났다. 그러므로 OSL 도트 선량계 사용 시 방향에 따른 영향을 보정하여야 한다.

중심단어: OSL 도트, 저에너지 엑스선, 교정인자, 흡수선량 선형성, 피크전압 선형성, 방향성