

A Study of Wedge Angles Produced by 60° Motorized Wedge of Elekta Synergy Platform Linear Accelerator for 6 MV Photon Beam

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1. ABSTRACT

Accurate treatment planning in radiation therapy will be invaluable for cancer patients. Wedge filters are used to eliminate hot spots and create a uniform dose distribution inside the target volume. The wedge angle of a wedge filter is defined as the angle between the isodose line at 10 cm depth and the perpendicular line to the beam central axis. This study was conducted to determine the accuracy of wedge angles of virtual wedge filters produced by the 60° wedge filter of the Elekta Synergy Platform LINAC. Isodose curves at 10 cm depth in water were plotted for the wedge angles 10° to 60°, steps of 5° for 10×10 field size for 6 MV energy and the wedge angles were calculated by using the gradient of the graph. The results show a variation up to 5° for calculated wedge angles compared to the applied wedge angles which is higher than $\pm 2^\circ$ of uncertainty. This may have occurred due to the beam hardening effect and the scattering effect of the radiation beam with a wedge filter. The results show that the actual wedge angle for Elekta 60° motorized wedge is closer to the calculated angle which is around 56°. Therefore, it is better to use calculated wedge angles for manual radiotherapy treatment planning.

2. INTRODUCTION

2.1 Introduction to Radiation Therapy

Cancers account for the second highest deaths due to non-communicable diseases (approximately 9.3 million) per year [1]. Surgery, chemotherapy and radiation therapy are the three major treatment modalities used to treat cancers.

Radiotherapy is divided into two major techniques, External Beam Radiation Therapy (EBRT) (Radiation beam delivered from a machine outside the body) and Brachytherapy (Radioactive sources are placed inside the body).

Treatment planning is mainly carried out by a medical physicist or a dosimetrist. The main objective of radiotherapy planning techniques is to achieve a uniform dose distribution inside the target volume while delivering a dose as low as possible to the healthy tissues surrounding the target.

The ICRU (International Commission on Radiation Units and Measurements) report 50 recommends target dose uniformity within +7% and -5% relative to the prescribed dose delivered to a well-defined prescription point within the target.

Some important steps of treatment planning are initializing treatment beams, shaping Multi Leaf Collimators (MLCs), adding shielding blocks and treatment aids (wedges, compensators) as necessary, and dose calculation for the treatment plan and analysis and comparing different plans by considering organs at risk doses and dose volume histograms (DVH), select and approve of the treatment plan and send for treatment.

2.2 Medical Linear Accelerator

The linear accelerator (LINAC) is a device that uses high-frequency electromagnetic waves to accelerate charged particles such as electrons to high energies through a linear tube. The high-energy electron beam itself can be used for treating superficial tumors, or it can be made to strike a target to produce X-rays for treating deep-seated tumors [2].

2.3 Use of Wedge Filters in Radiotherapy

Wedge filters such as physical, enhanced dynamic, and motorized are one of the most important beam modifiers. It is placed in the path of photon beams to modify their isodose distributions to achieve homogeneous isodose distributions inside the target volume. Two main uses of wedge filters are, to modify the isodose distribution and for the treatment of relatively low-lying lesions.

2.4 Isodose Curves and Wedge Angle of a Wedge Filter

The isodose curves are usually drawn at regular intervals of absorbed dose and are expressed as a percentage of the dose at a specific reference point. Figure 1 shows the isodose charts for $10 \times 10 \text{ cm}^2$ open field (a) and 30° wedge field (b) when 100 cGy (1 Gy) is prescribed to 5 cm depth at 100 cm source to water surface distance (SSD) for 6 MV energy photon beam.

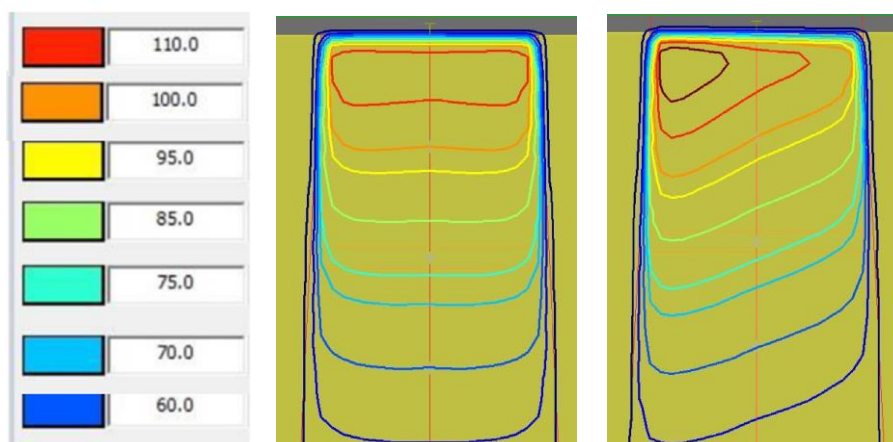


Figure 1: Isodose charts for $10 \times 10 \text{ cm}^2$ open field and 30° wedge field

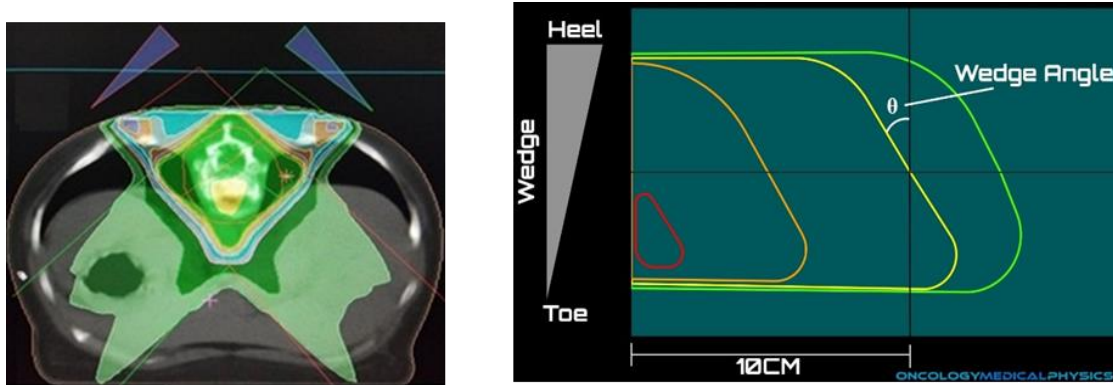


Figure 2: Use wedge filters to treat tumors and defining the wedge angle [4]

The wedge angle (θ) of a wedge filter is defined as the angle between the isodose line at 10 cm depth and the perpendicular line to the beam central axis (Figure 2) [3]. Wedge filters with wedge angles in the range from 10° to 60° are commonly available.

In radiotherapy planning different wedge filters with wedge angles up to 60° are used due to the variation of body contour of the patient, to achieve a uniform dose distribution inside the target volume. Therefore, it is essential to verify the accuracy of wedge angles of the virtual wedge filters produced by the 60° motorized wedge filter of the LINAC. The dosimetric parameters given by the manufacturer are clinically not used by the medical physicists without proper checks or verification. Therefore, during the acceptance testing and commissioning process, physical and dosimetric parameters are measured to check whether they are within the tolerance levels. In the commissioning process of a LINAC, data are obtained only for open fields and the 60° motorized wedge fields to create the radiation beam model for the treatment planning system (TPS).

The main objective of this study was to determine the accuracy of wedge angles of the virtual wedge filters produced by the 60° motorized wedge filter based on the variation between the applied wedge angles and the wedge angles produced (calculated) by the 60° motorized wedge filter of Elekta Synergy Platform LINAC. Because it is essential to verify the accuracy of wedge angles of virtual wedge filters for accurate radiotherapy planning.

The specific objective was to plot the isodose curves for the wedge angles 10° , 15° , 20° , 25° , 30° , 35° , 40° , 45° , 50° , 55° and 60° for $10 \times 10 \text{ cm}^2$ field size to calculate the wedge angle produced by the linear accelerator for 6 MV energy photon beam.

3. METHODOLOGY

LINAC machine (Elekta Synergy Platform) of Teaching Hospital Karapitiya was used for this study. IBA FC65-G ionization chamber, IBA DOSE1 electrometer, IBA CC13 ionization chambers, IBA Blue Phantom² and IBA myQA accept software were the other instruments used for the study.

3.1 Plotting Isodose Curves at 10 cm Depth for Different Wedge Angles

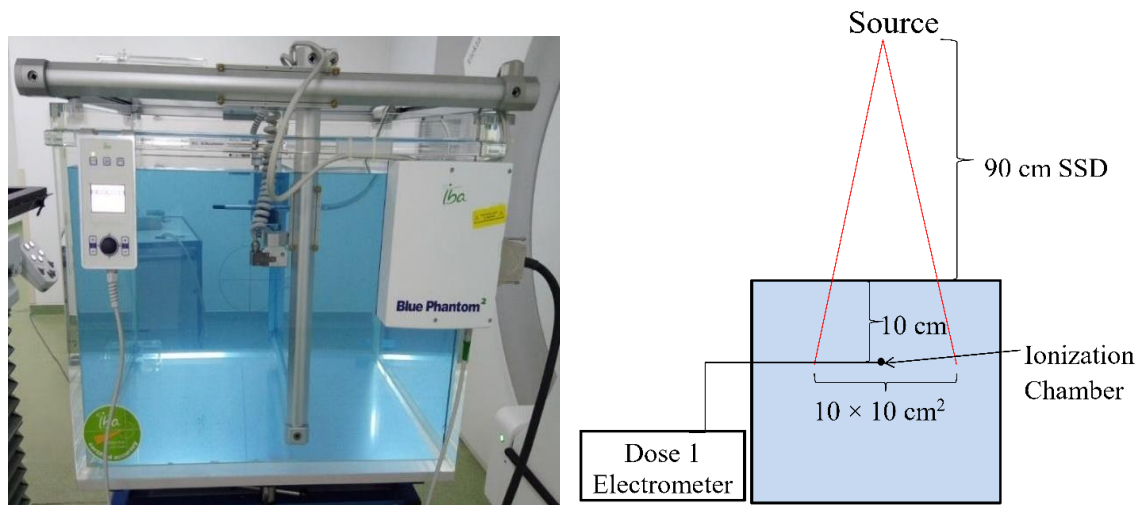


Figure 3: Set up for isodose curve measurements

The isodose curves were plotted for $10 \times 10 \text{ cm}^2$ field size for the wedge angles of the virtual wedge filter and the wedge angles were calculated as follows.

The SSD was set as 90 cm. The FC65-G ionization chamber was centered on the $10 \times 10 \text{ cm}^2$ radiation field. Then the chamber was moved to 10 cm depth in water (Figure 3). The ionization chamber was connected to the DOSE1 electrometer. The open field and wedge field monitor units (MUs) were calculated in 90 cm SSD to deliver 1 Gy dose at 10 cm depth for the following wedge angles by using the MONACO TPS (Table 1).

Table 1: Open field (O) and wedge field (W) MUs for different wedge angles for 6 MV photon energy for $10 \times 10 \text{ cm}^2$ field size

	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°
W	46.8	71.2	96.7	123.8	153.3	185.9	222.9	265.6	316.5	379.2	460.0
O	110.1	103.5	96.7	89.5	81.7	73.0	63.1	51.7	38.2	21.5	-

The experimental setup (Figure 3) was formed and the chamber was exposed to the open field MUs and wedge field MUs (Table 1) separately to produce the virtual wedge with the 10° wedge angle and the depth dose at 10 cm depth in the central axis was measured with an electrometer. Then the chamber was moved to a known Y-axis coordinate stated in the table in Figure 4. The chamber was exposed again to the open field MUs and wedge field MUs and the isodose point (point with the same depth dose to the point at 10 cm depth in the central axis) was obtained by moving the chamber along the Z-axis. This procedure was repeated several times until the correct isodose point was obtained. Thereafter the chamber was moved to the next Y-axis coordinate and the relevant Z-axis coordinate was obtained. The procedure was repeated to obtain 7 (x,y) coordinates for a single wedge angle. The same procedure was followed for the rest of the angles up to 60°.

When the gantry and collimator angles are at 0° the toe (less thickness) side of the wedge filter lies towards the +Y direction. To obtain isodose points equal to 10 cm depth point

in the central axis, the ionization chamber was moved only in Y and Z directions. (There was no movement of the ionization chamber along the X direction). Then isodose points were plotted on a graph (Figure 4).

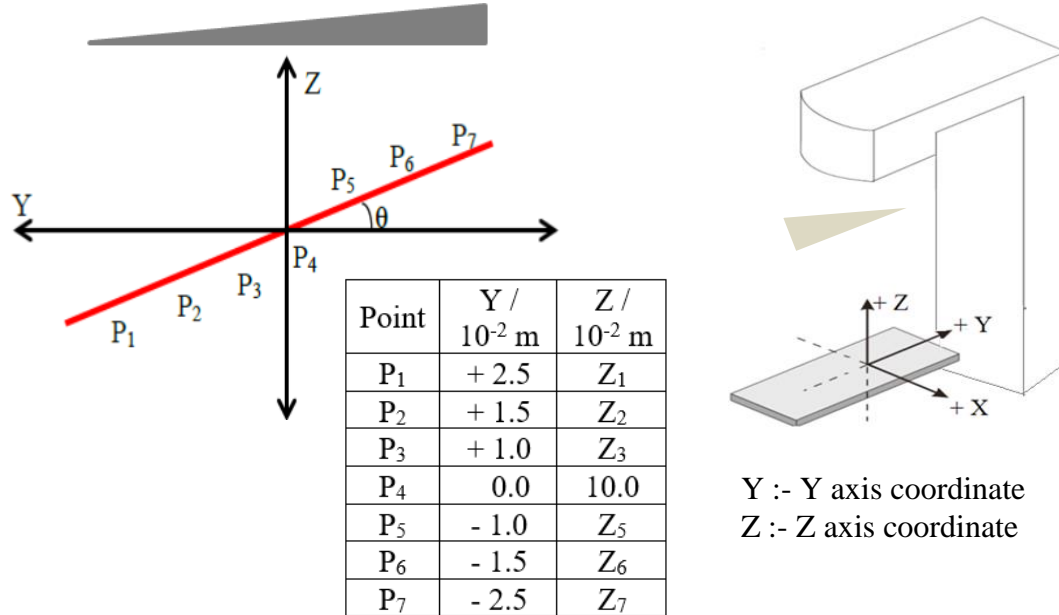


Figure 4: Isodose measurement points and Coordinate system for LINAC

$$\text{Gradient of the graph} = \tan \theta \quad (1)$$

$$\text{Wedge angle } (\theta) = (\text{Gradient of the graph}) \quad (2)$$

3.2 Verification of Calculated Wedge Angle Line for 60° Wedge Filter

The following experiment was conducted to confirm the actual wedge angle for the Elekta 60° motorized wedge filter. The setup was formed as Figure 3. CC13 field chamber and reference chamber were positioned appropriately. The CC13 field chamber was exposed continuously to a radiation field of $10 \times 10 \text{ cm}^2$ with the 60° wedge filter. Figure 6 was plotted by moving the field ionization chamber along the 60° and the 55.6° (calculated wedge angle) (Table 2) angle lines to the central axis separately by using myQA application software

4. RESULTS AND DISCUSSION

4.1 Applied Wedge Angles and Calculated Wedge Angles for $10 \times 10 \text{ cm}^2$ Field

In this study, the actual wedge angles were calculated using the gradient of the graph according to Equation (2) based on the definition of the wedge angle of a wedge filter.

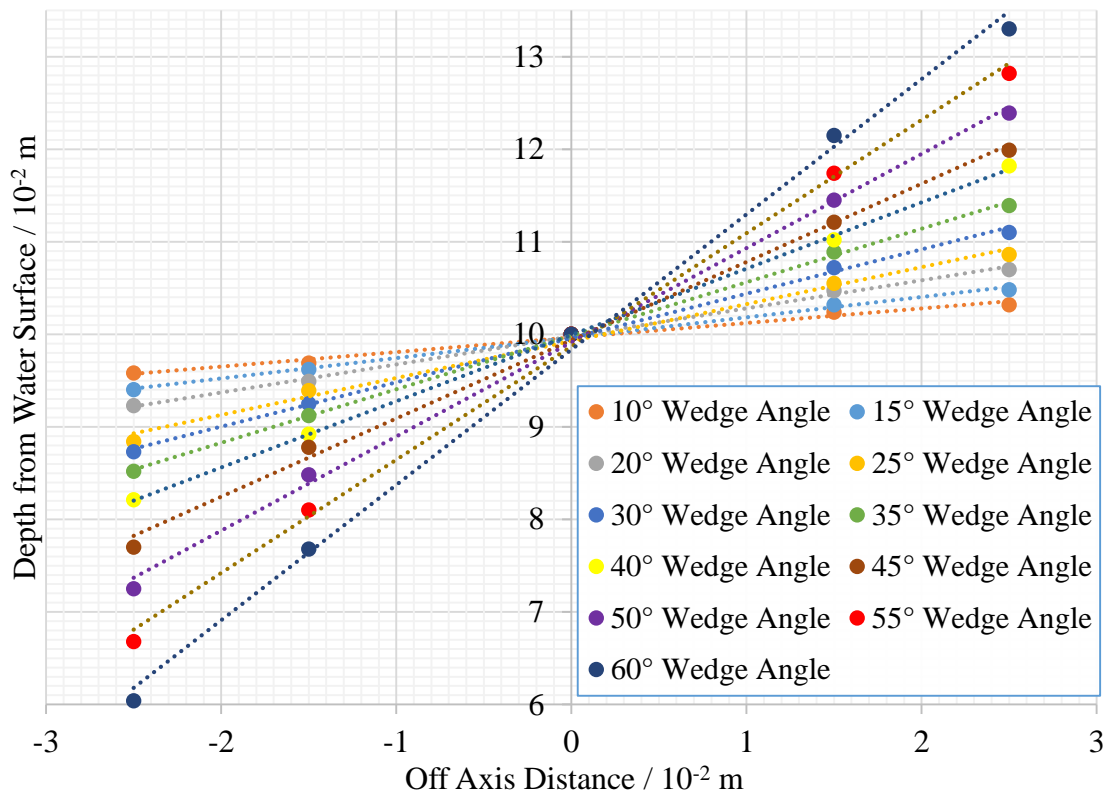


Figure 5: Isodose curves for different wedge angles for 10×10 cm² field size

Table 2: Applied (A) and calculated (C) wedge angles and difference of A and C (D)

A	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°
C	8.9°	12.4°	16.8°	21.5°	25.6°	30.0°	35.6°	40.2°	45.5°	50.8°	55.6°
D	-1.1°	-2.6°	-3.2°	-3.5°	-4.4°	-5.0°	-4.4°	-4.8°	-4.5°	-4.2°	-4.4°

For the wedge angles, 10° and 15° the difference between the applied wedge angle and calculated wedge angle was 1.1° and 2.6° respectively. However, the difference between the applied wedge angle and the calculated wedge angle was increased for higher wedge angles. For the wedge angles 20° and 25° the difference was increased to 3.5° and for the wedge angles greater than 25° the difference was increased up to 5°.

The difference between the calculated wedge angle and the applied wedge angle is higher than the uncertainty of $\pm 2^\circ$ given in IEC Report 977 [4]. However, the findings of the study of Mahdie [5] for Elekta motorized wedge give evidence that this difference can be higher than the uncertainty value of $\pm 2^\circ$. The reason for this variation can be the effect of beam hardening due to the attenuation and filtering of low-energy photons from the wedge filter and scattering of the photon beam with the wedge filter. When the wedge angle was increased the number of MUs required was increased. Then the beam hardening and scattering of photons with wedge material were increased and the dose along isodose curves can be changed. This difference could be reduced by modification of the wedge shape and developing the wedge material to reduce the beam hardening and scattering.

4.2 Verification of Calculated Wedge Angle Line at 10 cm Depth in Water

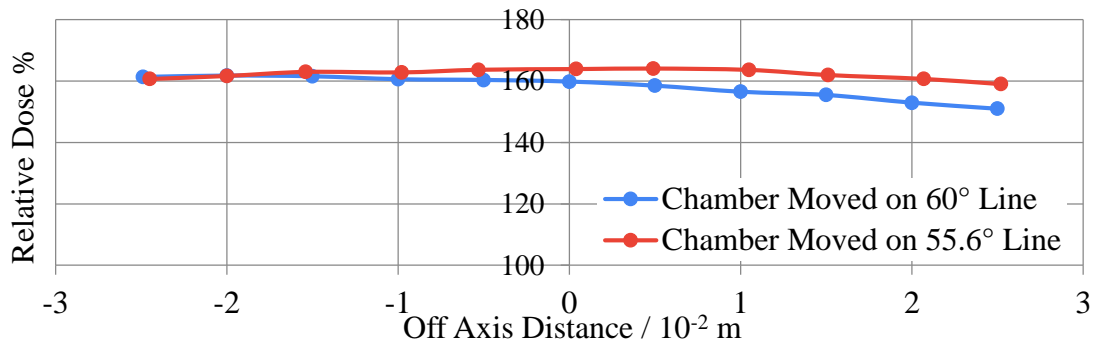


Figure 6: Isodose curves when the chamber moved on 60° and 55.6° lines

The actual wedge angle for the Elekta 60° motorized wedge filter is much closer to the calculated angle which is around 56°. If the wedge angle is 60°, the curve plotted should be parallel to the X-axis of the graph as the chamber was moving on an isodose line. However, the measured data show that the 55.6° line is more parallel to the X-axis of the graph. This shows the actual wedge angle of the 60° wedge filter is much closer to the calculated angle than 60° (Figure 6). The above Figure 6 also verifies the accuracy of the method used in this study to calculate wedge angles. Because it shows the calculated value is more suitable for the wedge angle for the 60° wedge filter.

5. CONCLUSIONS

This study aims to determine the accuracy of wedge angles of virtual wedge filters produced by the 60° motorized wedge of the Elekta Synergy Platform LINAC machine. The calculated wedge angles were obtained for the field sizes 10×10 cm² at 10 cm depth which will be helpful, to manual treatment planning (without Computed Tomography (CT) images) during CT simulation machine failure or in an emergency radiotherapy treatment to the patient. The difference between the applied (manufacturer's) wedge angle and the calculated wedge angle was increased for higher wedge angles. The difference is around 3° for wedge angles up to 25° for 10×10 cm² field size. Therefore, it shows a good approximation with the uncertainty value for the wedge angle $\pm 2^\circ$ given in IEC Report 977. But for wedge angles higher than 25° the difference increased up to 5°. Figure 6 also confirmed that the actual wedge angle for Elekta 60° motorized wedge is much closer to the calculated angle which is around 56° than 60°. Therefore, it is better to use calculated wedge angles for manual radiotherapy treatment planning to achieve an approximate uniform dose distribution inside the tumor and to avoid hotspots within the target area. The actual wedge angles for the 15 MV energy photon beam of LINAC were not measured in this study. Since the 15 MV energy was not permitted to be used without a special lead door for the linear accelerator facility, during that period of research work. It is better to conduct this as an extension of this study in the future.

6. REFERENCES

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