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Exploring the Dosimetric Aspect of Physical & Enhanced Dynamic Wedges in the Varian Trilogy Linear Accelerator

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Abstract
The aim of radiotherapy is to deliver optimal dose to the tumour and a minimal dose to the normal tissues. So, in order to achieve homogenous dose distributions various devices are used among which wedge filters are the most common in external beam radiotherapy. Wedge can be classified into two types: Physical Wedge (PW) & Non-Physical Wedge (NPW). The Physical Wedge can be further divided into two types: individualized and universal wedge. On the other hand, NPW have been used on both Varian and Siemens' accelerators as the Varian Dynamic Wedge (DW) and Siemens Virtual Wedge (VW). Later, Varian introduced the Enhanced Dynamic Wedge (EDW) to add more functionality to this modality. Varian's Trilogy is equipped with two types of wedge filters: PW (i.e.,15^0, 30^0, 45^0 and 60^0) and EDW wedges (i.e.,10^0, 15^0, 20^0, 25^0, 30^0, 45^0 and 60^0). The PW can be inserted in the treatment head in four different orientations (Left, right, in and out) whereas in EDW, dose distributions can be achieved by the motion of collimating jaw in two directions (in and out). A dosimetric comparison between PW (15^0, 30^0, 45^0 and 60^0) and EDW wedges (15^0, 30^0, 45^0 and 60^0) for two different energies (6 MV & 15 MV) at 10cm water equivalent depth were studied. Beam profiles were obtained using MatriXX Evolution (IBA Dosimetry). Isodose curves & monitor units for both type of wedges was calculated using Eclipse Treatment Planning System. The result shows higher beam hardening effect for PW compared to EDW through the thick end of the wedge. Moreover, the number of MUs used to deliver a particular dose using a non-physical wedge field is less than that used for a physical wedge field. No differences were observed in isodose curves for both type of wedges.
Keywords: *Wedge, Physical Wedges, Enhanced Dynamic Wedge, Dosimetry, MatriXX Evolution.*

Introduction

The aim of radiotherapy is to deliver optimal dose to the tumor and a minimal dose to the normal tissues. So, in order to achieve homogenous dose distributions various devices are used among which wedge filters are the most common in external beam radiotherapy. Philip A. Flood et al reported the use of filters in short-distance low-voltage x-ray therapy for the first time. Subsequently F. Ellis et al first used the 'wedge technique' to obtain uniform dose distributions. Initially for several years the wedge filters consisted of wood, which now has evolved to a high-Z material consisting of steel, lead or brass. These wedges are physically inserted into the path of incident radiation, hence, also known as "physical wedge". The other type, known as "non-physical wedge" generates a spatial dose distribution similar to that produced by a physical wedge without a physical filter in the photon beam. Instead, an exponential fluence profile is produced via motion of one of the collimating jaws. The physical wedge can be divided into two types: individualised wedge and universal wedge. On the other hand, non-physical wedge has been implemented on both Varian and Siemens' accelerators as the Varian Dynamic Wedge (DW) and Siemens Virtual Wedge (VW). Later, Varian introduced the Enhanced Dynamic Wedge (EDW) to add more functionality to this modality.

In treatment planning wedge is used for two purposes: to alter the dose gradient in the patient to enable uniform dose distributions and to compensate for surface obliquity off-axis. Varian's Trilogy is equipped with two types of wedge filters: these are PW (i.e.,15^0, 30^0, 45^0 and 60^0) and EDW wedges (i.e.,10^0, 15^0, 20^0, 25^0, 30^0, 45^0 and 60^0). The PW can be inserted in the treatment head in four different orientations (Left, right, in and out) whereas in EDW, dose distributions can be achieved by the motion of collimating jaw in two directions (in and out).EDW is a technology breakthrough in conventional radiotherapy treatment planning developed by Varian. EDW replaces the manual procedure of mounting of PW on LINAC which is subjected to mechanical geometry error and time consumption for the placement of PW on LINAC. Hence, the use of EDW eliminates the operator handling of PW and provides the operator with more opportunity to focus on the patient, and reduces setup time between fields for the same patient and between patients. Despite EDW is more beneficial for daily radiotherapy work and clinicalapplications, it requires more extensive quality assurance (QA) and quality control(QC) as compared to PW because of computer controlled mechanism of jaw motion. Therefore, due to the differences in wedge effect generated by both types of wedges, it is important to take into account the differences in dosimetric characteristics for both PW and EDW, so that judicious use of either of the wedge can be used in any clinical scenarios.

Aim

The main objective of the study is tocompare in-line& cross-line beam profile characteristics of PW and EDW for four angles 15°,30°, 45° and 60° at 10 cm water equivalent depth for a field size of 10 ×10 cm^2 for two different energies& alsoto investigate on the differences in MUs and isodose curves for PW and EDW for four different angles 15^o, 30°,45° and 60° measured for two different energies (6MV and15MV).

Materials and Method

MatriXX Evolution

MatriXX Evolution is a 2-dimensional array consists of 1020 ion chambers arranged in 32 × 32 grids except for the four corner positions. The active measurement area is 24.4cm × 24.4 cm. Distance between the chambers is 0.762 cm (centre to centre). The detector type is vented parallel plate ion chamber.

When irradiated, the air in the chambers is ionized. The released charge is separated by means of an electrical field between the bottom and the top electrodes. The current which is proportional to the dose rate, is measured and digitized by a non-multiplexed 1020 channels current sensitive analog to digital converter. Each chamber volume is 0.08 cm^3 with the height of 5 mm and diameter of 4.5 mm. The maximum dose rate detectable by the detectors is 12 Gy/min and minimum detectable dose rate is 0.02 Gy/min.The absorber material on top of the matrix is 3 mm ABS Tecaran (density 1.06 g/cm^3). The effective point of measurement is 3.5 mm below the surface, indicated by engraved markers on the housing sides. The matrix device can be directly connected to aPC via standard ethernet interface to acquire the measurement. The software integrated with the MatriXX is myQA.

Figure: MatriXX Evolution ionisation detector array and RW 3 Slab Phantom

Figure: myQA interface

Figure: Physical Wedges of 15◦, 30◦, 45◦ and 60◦

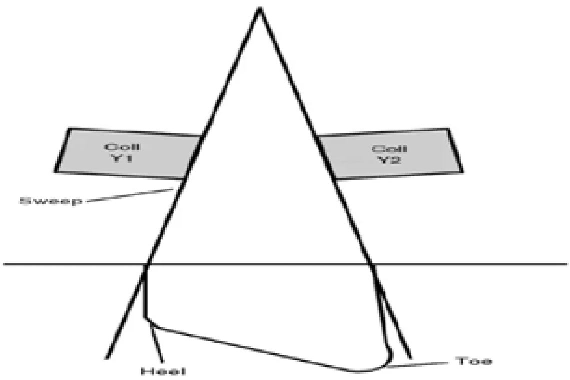


Figure: Wedge effect created by movement of jaw

Varian's Physical Wedge

The Physical wedge filters on the Varian Trilogy Accelerator have nominal wedge angles of 15◦, 30◦, 45◦ and 60◦ with four orientations (LEFT, RIGHT, IN, OUT). These filters are made of steel. and lead. The maximum field size for 15◦, 30◦, 45◦ wedges is 20 cm (in wedge direction) by 40 cm (in the non-wedge direction), and for 60◦ wedge is 15 cm × 40 cm. The base of the physical wedges is located 59.8 cm below the target. The physical wedge factor (PWF) is defined as a ratio of dose in water at a point on the central axis with and without the wedge for same number of monitor units.

Varian's Enhanced Dynamic Wedge

In Varian's EDW, wedge isodose profile is created by the integration of the dose deposited as the jaw sweeps the field from open to closed position. Computer control ensures that dose delivered versus jaw position follows the exact pre-calculated pattern that produces the prescribed dose distribution. In general, all EDW treatments start with some portion of the dose being delivered as an open field (a portion of the total dose is delivered before the jaw starts moving). After the appropriate fraction of total dose has been delivered, the jaw starts sweeping the field from open to closed position. The exact fraction of dose that is delivered as an open field is a function of the selected energy, field size, and wedge angle. Enhanced dynamic wedge (EDW) supports two wedge orientations: Y1-IN and Y2-OUT.The dose versus jaw position relationship that is followed during an EDW treatment is contained in a dose versus jaw position table referred to as Segmented Treatment Table (STTs).

Slab Phantom

RW-3 slab phantom of density 1.045 g/cm^3 was used for the measurement. 10 cm water equivalent depth was used for the measurement.The density of slab phantom used in the study is in close approximation to water. They provide a convenient and reliable alternative for photon and electron beam dosimetry.

Measurement using MatriXX Evolution

CT scan with 3mm slice thickness of MatriXX Evolution detector along with slabs of 10 cm water equivalent depth were taken in a CT Simulator (Philips Brilliance Big Bore CT). The file is then exported in a DICOM format to the Eclipse Treatment Planning System.

Different plans were generated in Eclipse Treatment Planning System (Analytical Anisotropic Algorithm, Version 15.6.0) for Physical wedge & Enhanced Dynamic wedge of different wedge angles (15^0, 30^0, 45^0 and 60^0) and energies (6 MV and 15 MV) for a field size of 10cm×10cm on the CT images acquired. 100% dose was prescribed at the iso-centre (SAD=100 cm).Beam profiles of Physical wedge and Enhanced Dynamic wedge (15^0, 30^0, 45^0 and 60^0) at 10cm water equivalent depth were taken using MatriXX Evolution array detector along both inline and cross-line directions for both energies (6MV & 15MV).Profiles were then evaluated using myQA software.

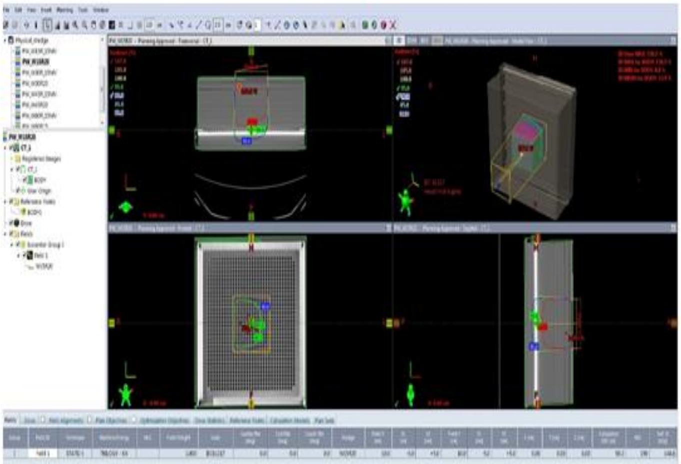


Figure: Plan generation in Eclipse TPS

Results

No notable variation in beam profiles along the wedge direction was observed between EDW & PW for 15^0 and 30^0 wedge angles. But differences in toe and heel end have been observed for 45^0 and 60^0 wedge, for both the energies. Moreover, differences in dose profile were observed in the penumbra region for both PW and EDW along the non-wedged direction. Large differences in MUs are observed between EDW and PW for both energy types (6 MV and 15 MV). With higher wedge angles, there was a sharp increase in treatment MUs for PW as compared to EDW. No notable differences in isodose curves were observed for both PW and EDW for both energy type.

Measurement of Beam Profiles

a) In-line profile:

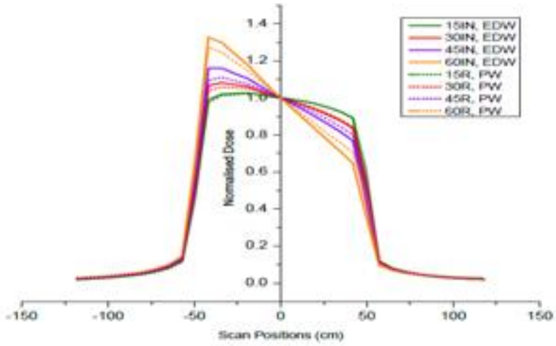


Figure: In-line beam profile for 6 MV

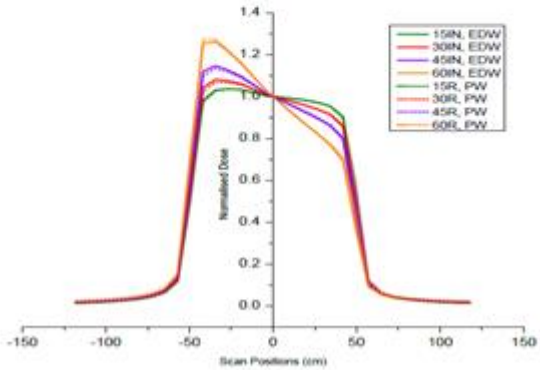


Figure: In-line beam profile for 15 MV

b) Cross-line Profile:

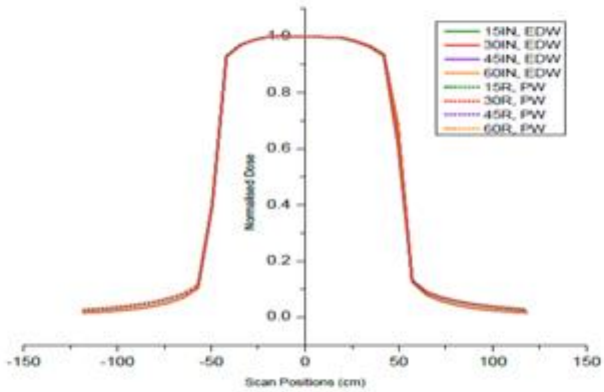


Figure: Cross-line beam profile for 6 MV

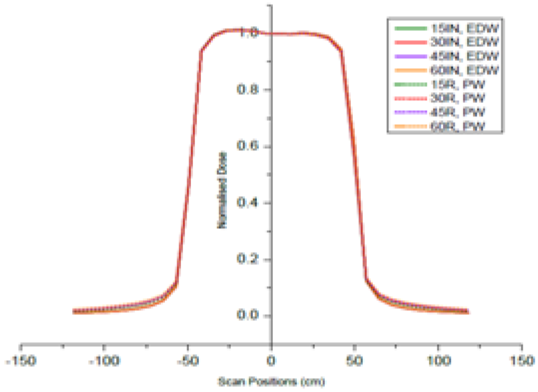
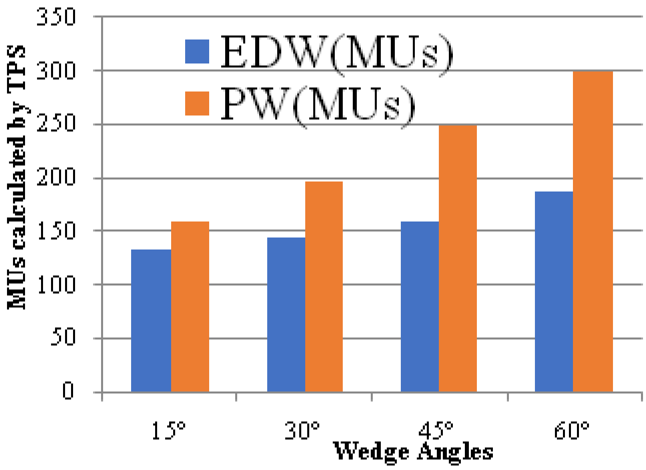


Figure: Cross-line beam profile for 6 MV

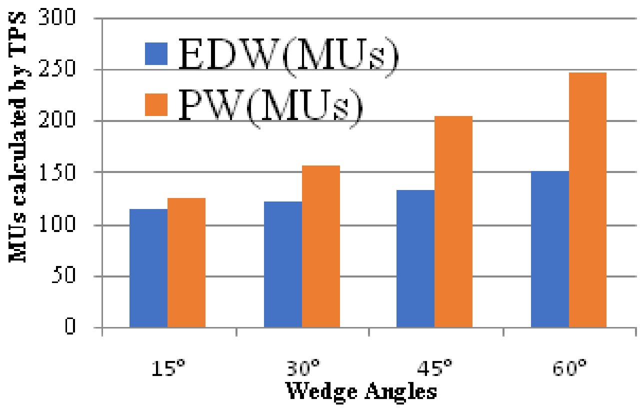
Measurement of Monitor Units

Energy	Wedge Angles	EDW(MUs)	PW(MUs)	% Difference
6MV	15°	133	159	19.55
	30°	144	196	36.11
	45°	160	248	55.00
	60°	187	300	60.43
15MV	15°	114	126	10.53
	30°	121	156	28.93
	45°	132	205	55.30
	60°	150	246	64.00

Figure: Monitor unit comparison of PW & EDW for 6 MV and 15 MV

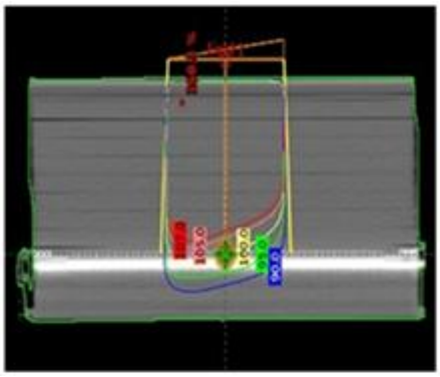


Wedge Angle Vs Monitor units for 6 MV

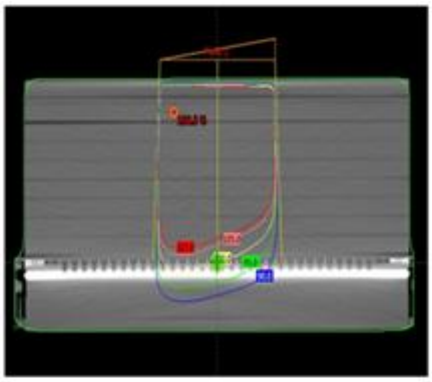


Wedge Angle Vs Monitor units for 15 MV

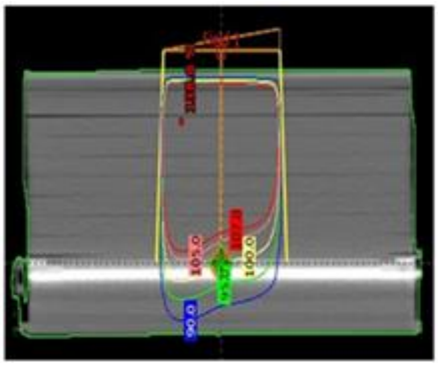
Measurement of Isodose Curves



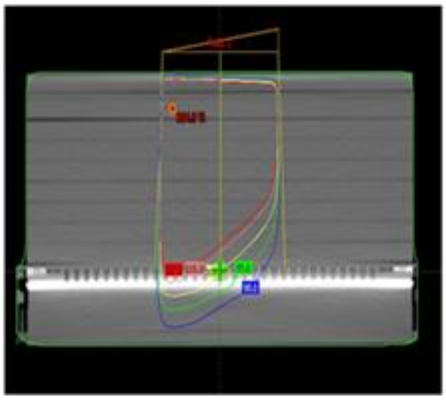
EDW 15^0, 6MV energy



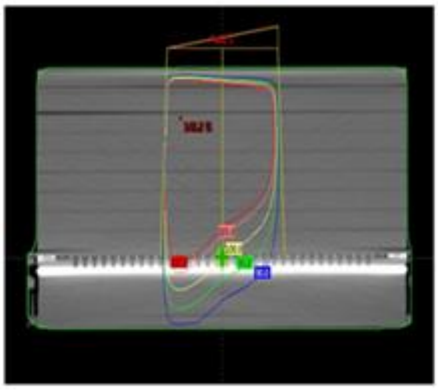
PW 15^0, 6MV energy



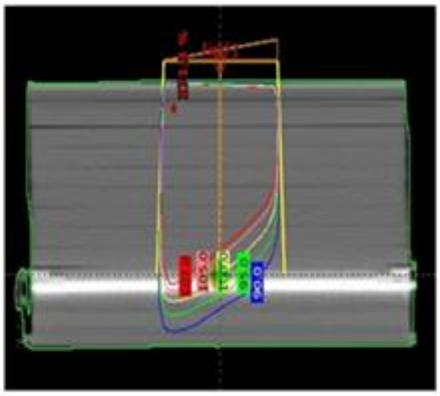
EDW 15^0, 15 MV energy



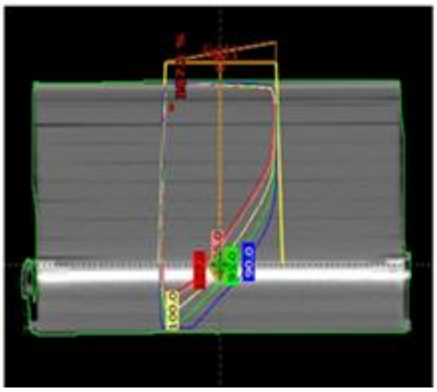
PW 15^0, 15 MV energy



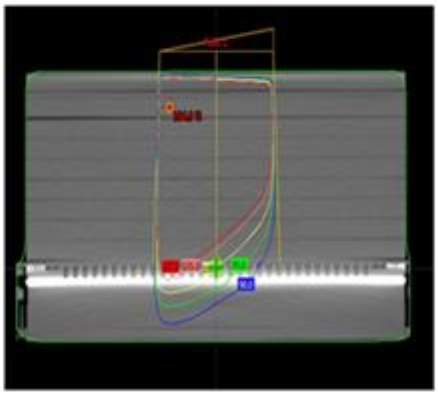
PW 30^0, 15 MV energy



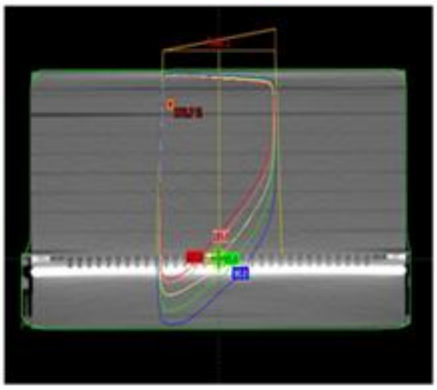
EDW 30^0, 6 MV energy



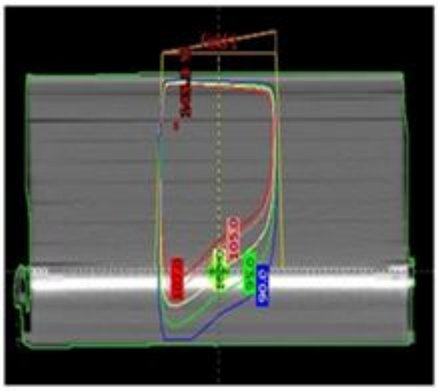
EDW 45^0, 6 MV Energy



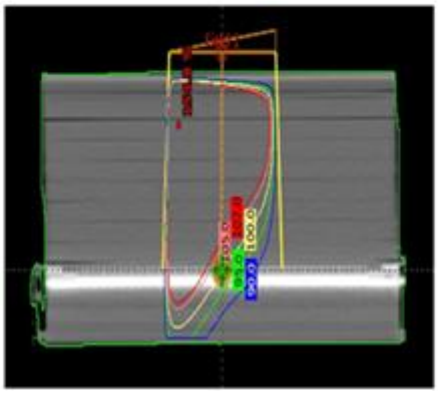
PW 30^0, 6 MV energy



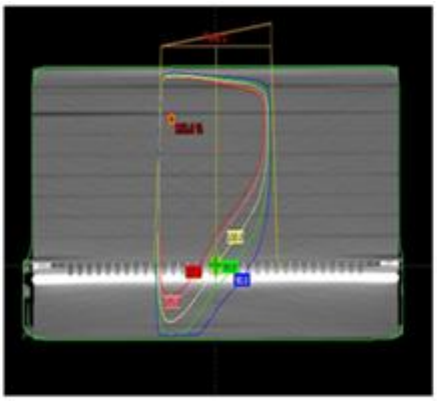
PW 45^0, 6 MV Energy



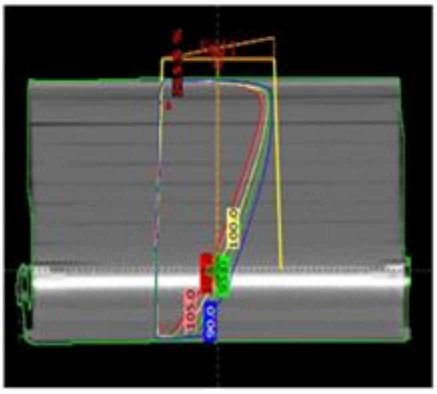
EDW 30^0, 15 MV energy



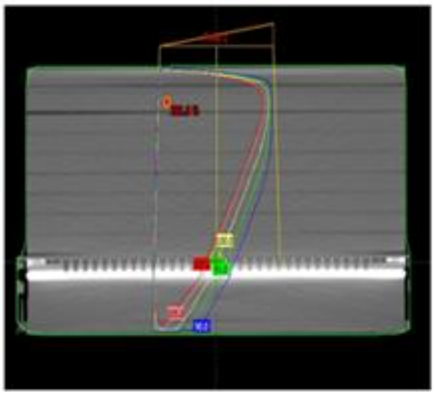
EDW 45^0, 15 MV Energy



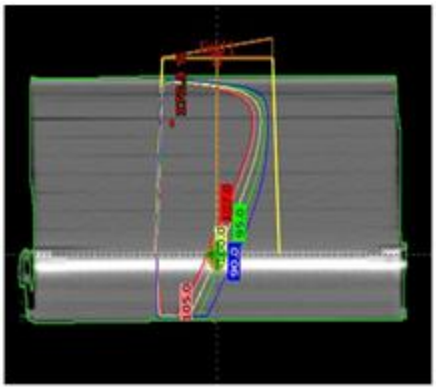
PW 45^0, 15 MV Energy



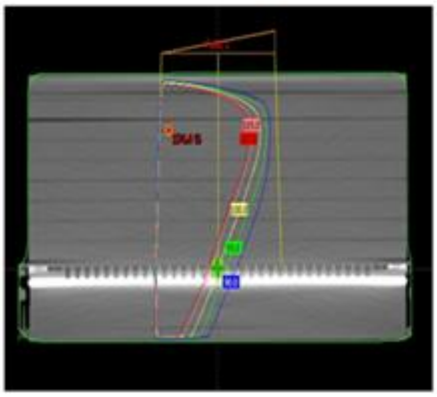
EDW 60^0, 6 MV Energy



PW 60^0, 6 MV Energy



EDW 60^0, 15 MV Energy



PW 60^0, 15 MV Energy

Figures: Isodose curves for PW & EDW for 15^o, 30^o, 45^o& 60^o wedge angles at two different energies (6 & 15 MV)

Conclusions

The number of monitor units to deliver a particular dose with an EDW field is lower than that of PW field, due to the change in wedge factor. Enhanced dynamic wedges eliminate the beam hardening effect, which is common in physical wedges. The dosimetric characteristics, like profile and isodose of enhanced dynamic wedge, closely match with those of the physical wedge except for the higher wedge angles. Differences in profile near the penumbra region for non-wedged direction indicates difference in scattered radiation for both PW & EDW.

The use of EDW, eliminates the operator handling of PW and provides the operator with more opportunity to focus on the patient, and reduce setup time between fields for the same patient and between patients. Also, the dose and jaw position control accuracy statistics are displayed on the screen and saved to dynalog files after each clinical EDW treatment. These statistics confirm the precision of treatment delivery.

Each of the two wedge types, physical and nonphysical, has several characteristics that produce both advantages and disadvantages under specific conditions. Clinicians should choose between physical and nonphysical wedges with careful consideration to tumour motion, the effect of secondary radiation, and the performance status of the patient.

Acknowledgement

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