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Research Article

"STUDY OF CONSISTENCY AND STABILITY OF THE FLATTENING FILTER FREE BEAMS IN ELEKTA VERSA HD"

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A B S T R A C T

The purpose of the study was to evaluate the consistency and stability of the 6FFF, and 10FFF Flattening Filter Free (FFF) beams in terms of beam output, beam quality, symmetry, degree of unflatness and penumbra in Elekta Versa HD machine for a period of two years. Output constancy and beam quality index were measured using farmer type ion chamber in the water phantom in standard measurement conditions. To study the characteristics of the beam profiles, beam data measurements were performed in Radiation Field Analyser (RFA) using 0.125cc pinpoint chamber. All the scanned PDD and profile measurements were analysed using PTW's MEPHYSTO mc2 navigation software. Output constancy showed a mean difference of -0.35%±0.53SD and 0.46%±0.58SD for 6FFF and 10FFF respectively when compared with commissioning data. The maximum deviation was observed in the beam quality index were -1.35% for the 6FFF beam. Profile measurements showed that the Beam symmetry, degree of unflatness and penumbra were met the AERB task group recommendations. This study revealed that routine quality assurance has an excellent agreement with baseline data. Beam constancy and profile stability of the machine was very robust and well within the limit for two years.

INTRODUCTION

Traditionally, Medical linear accelerators (LINAC) are the most commonly used radiation beam delivery devices in the radiation oncology department for different types of cancer case-patients. In conventional LINAC machines, the flattening filter is placed in the path of the photon beams to obtain the uniform radiation intensity across the treatment field [1]. Which is more advantageous in 3 Dimensional Conformal Radiation Therapy (3DCRT). The presence of flattening filter (FF) in the path of raw beam leads to reduce the dose rate and further to increase the head scatter factor which is not included in the beam modelling in the treatment planning system. In the modern delivery techniques, the uniform fluence was modulated by the multileaf collimators (MLC) to create the more conformal dose distribution to the target volume which is called Intensity Modulated Radiation Therapy (IMRT). In such cases, the presence of FF becomes unnecessary in the beam path. The absence of the FF leads to an increase in the dose rate, which directly decreases the beam on time and reduced head scatter factor.

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When compare to the FF beam, FFF beam having the unique properties such as higher dose rate, lesser beam on time, beam profile patterns and head scatter properties [2]. The purpose of the study was to evaluate the constancy and stability of FFF beams over the two years data.

METHODS AND MATERIAL

Elekta Versa HD LINAC is capable of delivering flatten beams such as 6MV, 10MV and 15MV and Unflatten beams of 6FFF, 10FFF, as well as electron beams of 4, 6, 8, 10, 12, and 15 MeV. The dose rates can go up to 1400 MU/min for 6 MV FFF and 2400 MU/ min for 10 MV FFF beams. [5]. The 80 pairs of MLCs with interdigitating option have a leaf width of 5mm at the isocenter level. The thickness of the MLCs are 9cm, and there are no backup jaws. Agility MLC leaf speed of 3.5 cm/s and the carriage can travel up to 3 cm/s giving a maximum MLC speed of 6.5 cm/s. The Rubicon optical tracking system (Elekta) provides for accurate positioning of the leaves. The MLCs have a small tongue-and-groove interleaf gap, less than 0.1 mm, and are defocused from the source to minimize the interleaf leakage. The Agility collimator has a primary collimator speed of 9 cm/s and an isocenter clearance of 45 cm.

Initial Beam commissioning measurements were made using a PTW MP3-M water phantom (PTW, Freiburg, Germany) with a scanning range of 50 × 50 × 40 cm^3. PTW's TRUFIX system was used to place the chamber at the vertical level of the linac isocenter. All the measurements were taken at the gantry and collimator angle of 0° as per International Electrotechnical Commission (IEC) 1217 specifications [3][4]. Photon profiles and percentage depth dose (PDD) measurements were made using a PTW Semiflex 31010 chamber with a 0.125 cc active volume for both field and reference setup. All the scanned PDD and profile measurements were analysed using PTW's MEPHYSTO mc^2 navigation software (version 3.2.51). Beam profile measurements were made at 10cm depth using 20 cm^2 x 20 cm^2 collimator setting at 100cm SSD. The PDD data were smoothed by a least-squares algorithm, interpolated to 0.2 mm spacing and normalized to 100% by the values at a depth of maximum dose. A standard calibration protocol of IAEA TRS-398 used for absolute dose measurement. Output dose measurement was made using a Farmer-type ionization chamber with a 0.65cc active volume, and $TPR_{20/10}$ data were made using TPR (Tissue Phantom Ratio) phantom. The measured profile data was plotted in the Microsoft Excel sheet to analyze the data. To quantify the stability of the FFF beams, lateral distance from the central axis at 90%, 75% and 60% dose points on either side of the beam profile was recorded. The field size for FFF beams does not follow the standard definition [4]. The geometrical field size was defined by a collimator setting, and radiation field size was determined through the lateral separation between inflection points (IPs) along the central axis [7]. IP is a point, where the progression of dose deposition changes its direction geometrically from positive to negative or vice versa.

RESULTS

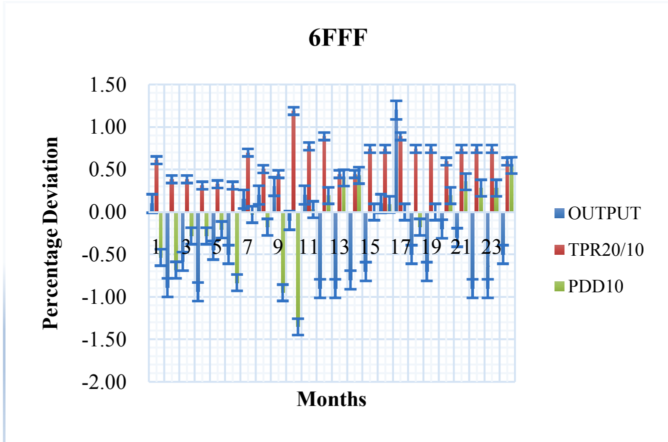
For this study, two years measurements total of 24 months data were taken. Initial beam commissioning data were chosen as a baseline. Output constancy showed a mean percentage deviation of -0.35%±0.53SD and 0.46%±0.58SD for 6FFF and 10FFF respectively. Beam quality was analysed using $TPR_{20/10}$ and PDD_{10} measurements. The maximum variation of -1.19% for 6FFF and 1.12% for 10FFF was observed for $TPR_{20/10}$ measurements [9]. The maximum variation of -1.35% for 6FFF and 0.62% for 10FFF was observed in PDD_{10} measurements. The maximum variation tabulated below (Table-1) and Observed measurements readings were shown in below graph (Graph1 and 2).

Table 1 Beam Characteristics of 6FFF and 10FFF Beams Maximum Deviation Observed when compare with Baseline Value

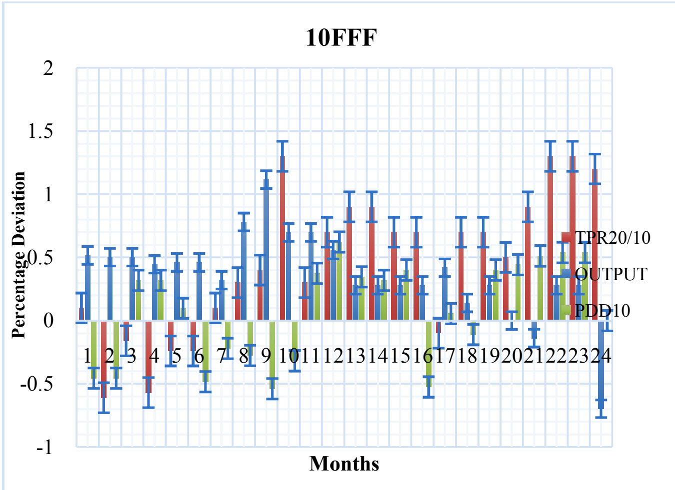
Energy	D_{max} in mm	$TPR_{20/10}$	PDD_{10}
6FFF	1	0.681	66.45%
10FFF	2	0.725	72.78%

*6FFF baseline were: Dmax (1.7cm); TPR20/10(0.673); PDD10 (67.36%)
*10FFF baseline were: Dmax (2.3cm); TPR20/10(0.717); PDD10 (72.33%)

The symmetry of 6FFF and 10FFF beams was measured for a field size of 20 cm × 20 cm at 100 cm SSD, 10 cm depths for the flattened region of 80% intensity level. The maximum variation in symmetry was -0.75%±0.42SD in Cross-Plane and 0.57%±0.29SD in In-Plane for 6FFF. 10FFF had a Cross-Plane symmetry of 0.18%±0.37SD and In-Plane symmetry of 0.24%±0.25SD over two years. The measurement readings were tabulated below (Table-2).



Graph 1



Graph 2

Table 2 Symmetry for FFF Beams

Profiles	Base Line in %	Percentage Deviation
6FFF - In Plane	100.62	0.57%±0.29SD
6FFF - Cross Plane	102.2	-0.75%±0.42SD
10FFF -In Plane	100.6	0.24%±0.25SD
10FFF - Cross Plane	100.3	0.18%±0.37SD

The stability of FFF for both the In-Plane and Cross-Plane profiles was measured for the 20cm^2 × 20 cm^2 field size at 100 cm SSD and 10 cm depth. The lateral distance from the central axis at 90% ($X_{90\%}$), 75% ($X_{75\%}$) and 60% ($X_{60\%}$) dose points on either side of the beam profile was measured for 6FFF and 10FFF beam energies. The measurement readings were tabulated below (Table-3 and 4).

Table 3 Degree of 6FFF beam compared with baseline value

Parameters	6FFF In Line		6FFF Cross Line	
	Baseline	Maximum Deviation observed	Baseline	Maximum Deviation observed
Lateral Width at 90% dose level ($X_{90\%}$) in cm	8.8	0.2	8.7	0.2
Lateral Width at 75% dose level ($X_{75\%}$) in cm	16.3	-0.3	16.1	0.2
Lateral Width at 60% dose level ($X_{60\%}$) in cm	19.4	-0.2	19.3	0.1
Separation between IP_L and IP_R in mm	200	1	200	2

*IP – Inflection Point Right and Left

Table 4 Degree of 10FFF beam compared with baseline value

Parameters	10FFF In Line		10FFF Cross Line	
	Baseline	Maximum Deviation observed	Baseline	Maximum Deviation observed
Lateral Width at 90% dose level ($X_{90\%}$) in cm	6.6	-0.2	8.7	-0.2
Lateral Width at 75% dose level ($X_{75\%}$) in cm	12.6	-0.2	16.1	-0.3
Lateral Width at 60% dose level ($X_{60\%}$) in cm	18.4	-0.2	19.3	0.1
Separation between IP_L and IP_R in mm	200	1	200	2

The maximum variation observed for X90%, X75%, X60% with 6FFF and 10FFF were 0.2 cm, 0.2 cm, 0.1 cm (Cross-Plane), 0.2 cm, -0.3 cm, -0.2 cm (In-Plane) and -0.2 cm, -0.3 cm, 0.1 cm (Cross-Plane), -0.2 cm, -0.2 cm, 0.2 cm (In-Plane), respectively. Maximum variation observed with 6FFF and 10FFF was 0.02 cm (Cross-Plane), −0.03 cm (In-Plane) and −0.03 cm (Cross-Plane), −0.02 cm (In-Plane), respectively.

To find the penumbra, the separation between Pa and Pb (shown in Fig-1) on either side of the profile was determined from the approximation method using excel sheet. The penumbra was indicated along the central axis for 6FFF and 10FFF beam energies. For the set collimator field size of 20 $cm^2 \times 20\ cm^2$ at 100 cm SSD at 10 cm depth, the right side penumbra and left side penumbra was measured and values are presented in the table-5.

DISCUSSION

The measured beam physics characteristics such as absolute dose measurements, the dose at maximum depth (D_{max}), tissue phantom ratio and percentage depth dose of the 6FFF and 10FFF were good in agreement with the baseline data. When compared with the baseline data the maximum deviation for depth dose maximum of 1mm, 2mm was observed for 6FFF and 10FFF respectively. The maximum deviation was found in the beam quality index were -1.35% for the 6FFF beam. Output constancy showed a mean difference of -0.35%±0.53SD and 0.46%±0.58SD for 6FFF and 10FFF respectively; it showed that the beam output variation over the period was good agreement with the baseline. For profile measurements data analysis, the data was taken into graph paper using PTW-TBA scan process. To avoid the manual error, two independent physicists were analysed the readings. The symmetry of the beam was evaluated for both the In-Plane and Cross-Plane, and the results agreed within the ±1.5%. The result value was reflecting the reproducibility over a more extended period.

To quantify the stability of unflattness beam, the lateral distance from the central axis at 90%, 75% and 60% dose points on either side of the beam profile are recorded along significant axes for all available beam energies. The maximum variation observed with the baseline value was -3mm for the lateral width at 75% dose level ($X_{75\%}$) for 10FFF mean cross line.

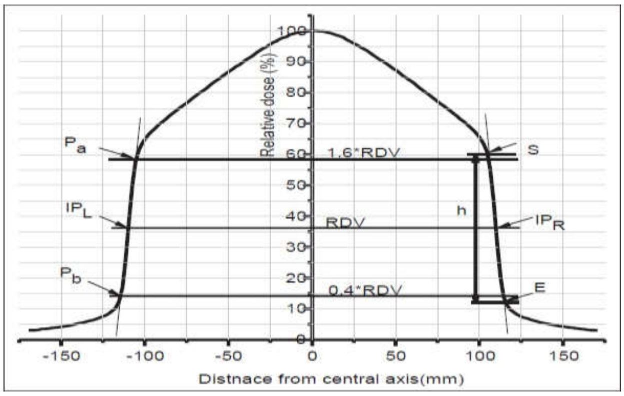


Figure 1 Diagram for determination of inflection point and penumbra

Table 5 Penumbra for FFF Beams Base Line in mm

Profiles	Left	Right	Maximum variation in mm
6FFF - In Plane	10	10	2
6FFF - Cross Plane	11	11	-2
10FFF - In Plane	9	9	2
10FFF - Cross Plane	10	10	2

In order to measure the Right and left side penumbra, a reference dose value (RDV) was calculated at IP. Points Pa and Pb, which are located at 1.6 (Pa) and 0.4 (Pb) times of RDV, respectively (Figure-1), were identified on either side of the profile to provide the measure of the penumbra. The results of penumbra were found to be within ±2 mm for the 20 cm × 20 cm field size, and the variation in their measurements was shown for In-Plane and Cross-Planes in the table (Table-5). The approximation method used to determine the field size for FFF beam and the maximum variation was observed less than ±1mm in both the energies.

CONCLUSION

This study revealed that routine quality assurance has a very good agreement with baseline data. The constancy and stability of absolute dose measurement, beam quality index, symmetry, degree of unflatness and penumbra of machine were very robust and well within the tolerance limit for a period of two years. A beam stability is maintained for FFF beams as similar to flattened beam.

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