Flattening filter free (FFF) beams from TrueBeam and Versa HD units: evaluation of the parameters for quality assurance

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Introduction

Flattening filter free (FFF) beams generated by medical linear accelerators are today clinically used for stereotactical radiotherapy treatments, thanks to their very high dose rate (up to four times the dose rate of the common flattened beams). Such beams differ from the standard flattened beams (FF) in the profile shape, that is strongly peaked on the beam central axis. However, FFF beams are not standard in terms of the parameters describing the field characteristics. Definitions of new parameters as unflatness and slope for FFF beams have been proposed, based on a renormalization factor for FFF profiles. With those factors the FFF dose fall-off at the field edge is superimposed with the corresponding (in nominal energy) flattened profile commonly normalized to 100% at the beam central axis.

The present study aims to provide the renormalization factors for FFF beams of 6 and 10 MV generated by Varian TrueBeam and by Elekta Versa HD linear accelerators. Estimation of the values of the new parameters (unflatness and slope) for the two units are also given.

Material and Methods

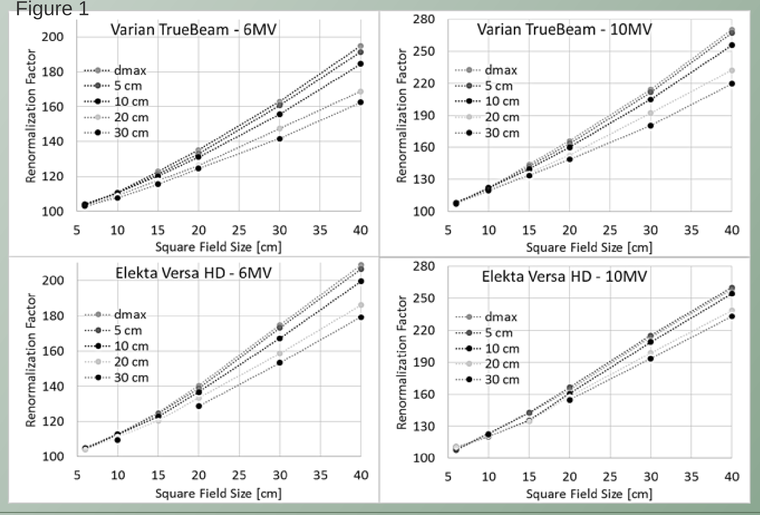
Dosimetric data from two Varian TrueBeam and two Elekta Versa HD linear accelerators, all with 6 and 10 MV nominal accelerating potentials, FF and FFF modes have been collected. Renormalization factors were estimated according to Fogliata et al. procedure (Med.Phys. 2012,39:6455) with the third derivative method (results here on the right), and parameters of:

$$RenormFactor = \frac{a+b\cdot FS+c\cdot depth}{1+d\cdot FS+e\cdot depth}$$

have been fitted for FFF beams of both units and energies.

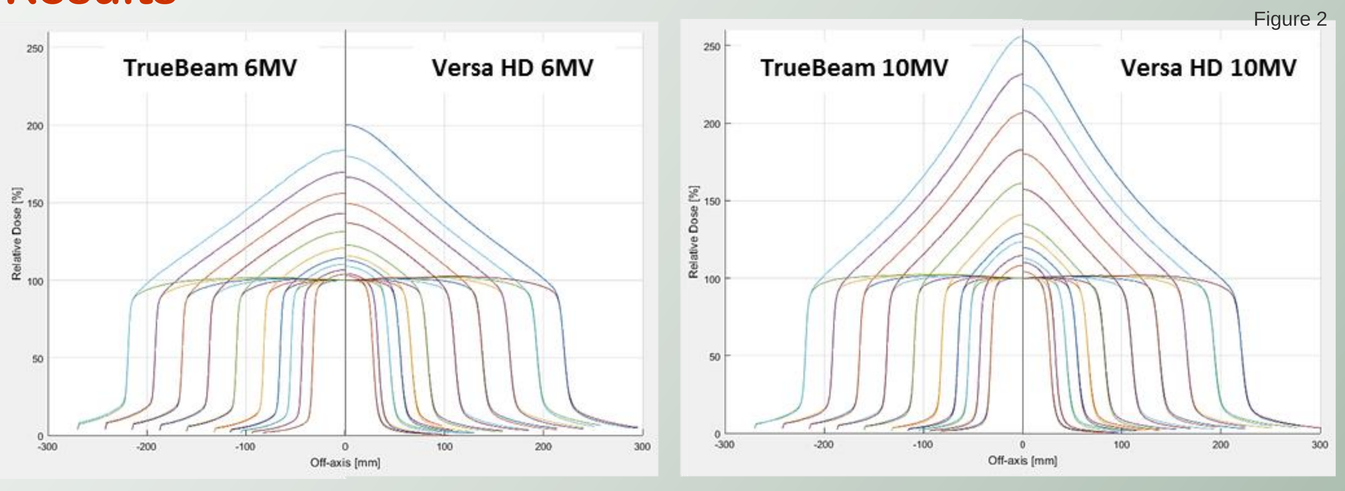
Unflatness and slope parameters from profile curves were computed. Dosimetric differences in terms of beam penetration and surface dose were also assessed.

Figure 1



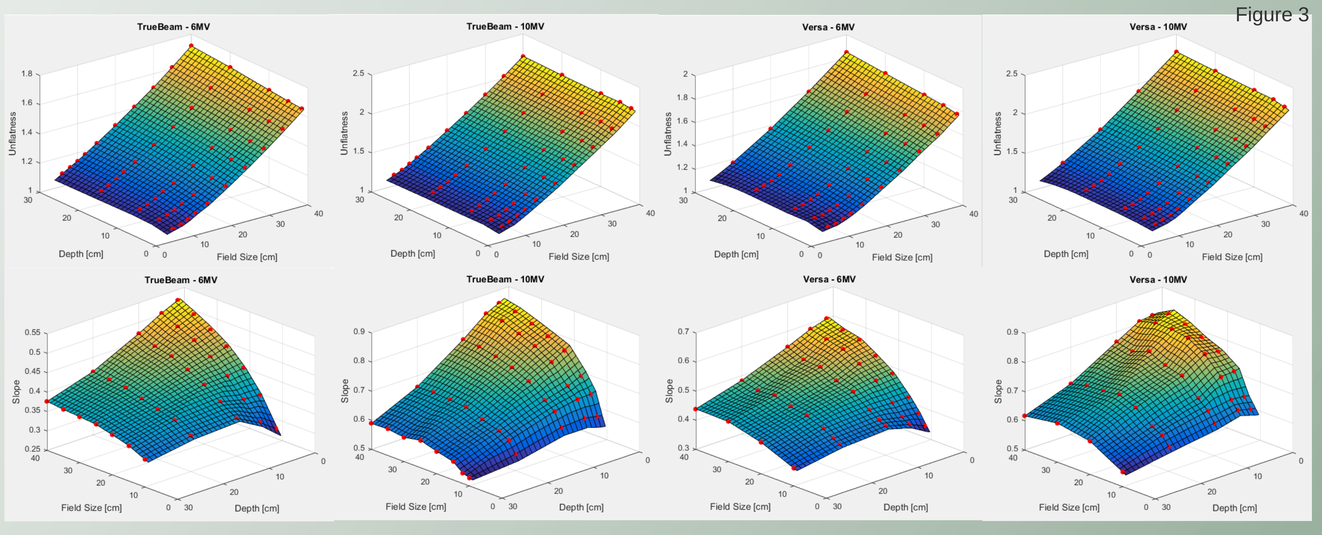
Results

Figure 2



Once the FFF profiles have been renormalized (profiles are shown in Figure 2, while the table presents the fit results), the unflatness and slope were computed. As an example of unflatness parameter, for a 20x20 cm^2 field, it was estimated in the range (from dmax to 30 cm depth) of 1.248-1.317, and 1.304-1.371 for the 6MV beams, TrueBeam and Versa HD, respectively. The same figure for the 10MV beams were 1.484-1.524, and 1.501-1.543. Comprehensive overview of the results is shown in Figure 3.

Figure 3



Unit	TrueBeam	TrueBeam	Versa HD	Versa HD
Nominal Beam Quality	6MV	10MV	6MV	10MV
Parameter: a	91.3	84.4	91.0	81.8
b [cm^{-1}]	1.20	3.10	1.53	3.60
c [cm^{-1}]	1.38	1.37	1.15	0.89
d [cm^{-1}]	-0.0075	-0.0063	-0.0072	-0.0038
e [cm^{-1}]	0.014	0.013	0.011	0.008

Concerning beam penetration, TPR20,10 for 6 and 10 flattened and FFF TrueBeam beams were: 0.665, 0.629 (6MV) and 0.738, 0.703 (10MV), while for Versa HD beams are: 0.684, 0.678 (6MV) and 0.734, 0.721 (10MV). In Figure 4 the beam penetration as a function of field size.

Figure 4

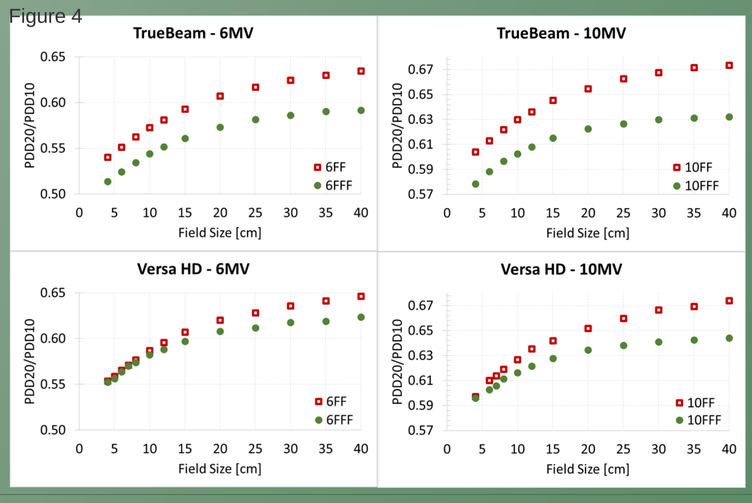
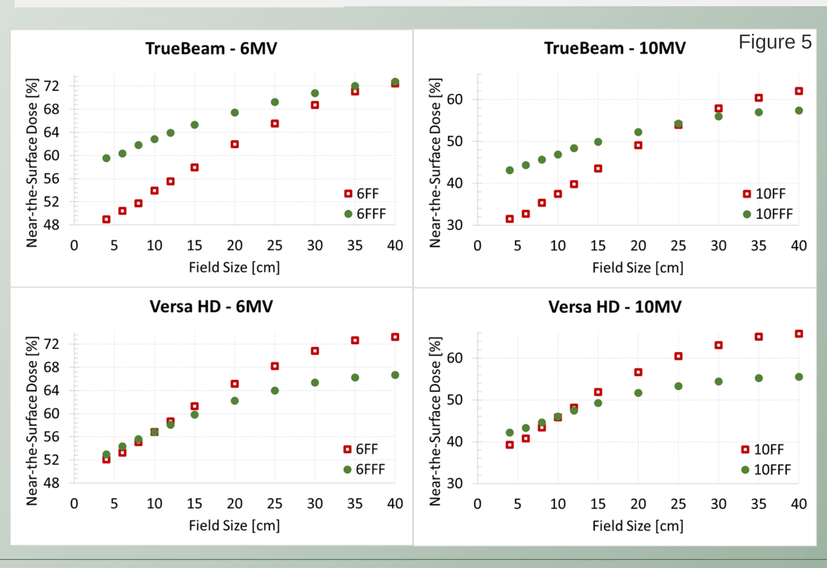


Figure 5



The TrueBeam FFF beam quality is significantly lower than the corresponding standard beam quality of the same nominal energy. Different is the pattern of Versa HD depth doses. The TPR20,10 for the 10x10 cm^2 field are similar for standard and FFF beams of the same nominal energy.

Near to surface doses are presented in Figure 5 showing the differences between units.

Conclusion

Renormalization factor and unflatness parameters proved to be efficient to describe the FFF beam characteristics. Renormalization factors here presented could be used for all TrueBeam and Versa HD beams, without the need of recalculate them for the site specific conditions.

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