

# Study of Dosimetric Characteristics of Clinical Electron Beams Collimated by Square Applicators using Plane-Parallel Ionization Chambers

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## Abstract

**Introduction:** High-energy clinical electron beams are frequently used in external beam radiation therapy of superficial tumors. The present study aimed to assess the dosimetric characteristics of the electron beams of energies 4 – 15 MeV from Elekta Synergy platform linear accelerator incorporated by Elekta Medical Systems, Crawley, UK. In this study, the key parameters of central axis percent depth dose distribution and beam profile are measured and calibrated using national AERB, Mumbai, and International ICRP protocols.

**Materials and Methods:** The measurements were done for the square field applicators of sizes 6×6, 10×10, 14×14, 20×20 and, 25×25 cm<sup>2</sup> using a reference dosimetry system comprising a PTW-Freiburg parallel plate ionization chamber. The measurements are performed at a source to the surface distance (SSD) of 100 cm and dose rate of 100 MU/Second with the water phantom.

**Results:** The measurements performed are analyzed using a radiation field analyzer (RFA) under AERB Mumbai protocols. The results for the measurements for square field applicators are in good agreement with the reference values of PDD and beam profile measured with micro-silicon detectors and also within the stated uncertainties.

**Conclusions:** The results so obtained confirm the reliability of central axis PDD distribution and beam profile of the clinical electron beams collimated by square field applicators in the treatment of superficial tumors.

**Keywords:** Clinical electron beam, parallel-plate ionization chamber, central axis percent depth dose, beam profile.

## INTRODUCTION

The success of external beam radiation therapy depends on the preciseness and accuracy of the delivered dose to the tumor site. The rapid fall-off in the dose and sparing of the underlying normal healthy tissues from the radiation are the main characteristics of the beam data used in radiation treatment planning. High-energy clinical electron beams are frequently used in external beam radiation therapy of superficial tumors [1, 2].

The present study aims to assess the dosimetric characteristics of the electron beams of energies 4-15 MeV from the Elekta Synergy platform linear accelerator incorporated by Elekta Medical Systems, Crawley, the UK, installed and commissioned at the department of radiation oncology, Dr. Ram Manohar Lohia Institute of Medical Sciences, Lucknow, India [3].

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This system contributes three photon energies (6, 10, and 15 MV) and six electron energies in the 4 – 15 MeV range. A pair of chiseled diaphragms mounted orthogonally with a multi-leaf collimator (MLC) enables the maximum field applicator size of 40×40 cm<sup>2</sup> [4-6]. The dosimetric characterization and calibration of the medical accelerator is the essential requirement for clinical acceptance of a medical system.

The dosimetry of electron beams remains challenging due to multiple scattering and deflections in the applicators resulting in reduced output. The depth of the maximum dose is shifted toward the surface and the central axis depth dose distribution is decreased due to this fact. The dimensions of the applicator are of the order of the radius of the detector then the dose measurements are affected [7, 8]. The process of data commissioning is performed using a radiation field analyzer (RFA) system filled with water as recommended by national and international protocols used in the calibration of the absorbed dose in the medium. The Elekta synergy medical system was commissioned for an electron beam of energies in the range of 4 – 15 MeV with applicator sizes ranging from 6×6 cm<sup>2</sup> to 25×25 cm<sup>2</sup> at the SSD of 100 cm for the dose rate of 100 MU/second in the measurement of the percent depth dose (PDD) and beam profile [9].

## MATERIALS AND METHODS

The measurements for commissioning of the Elekta Synergy platform linear accelerator for electron beam were pursued using a reference dosimetry process comprising of PTW-Freiburg parallel plate ionization chamber. This ionization chamber is a parallel plate ionization chamber (waterproof with cap, Model TM 23343) with a sensitive volume of 0.055 cm<sup>3</sup> and a semi-flex chamber (waterproof with cap, Model TM 30010) with a sensitive volume of 0.125 cm<sup>3</sup> as a reference chamber both coupled with a digital electrometer (PTW-UNIDOSE) [10, 11].

The Percent depth dose (PDD) and beam profile (in-plane and cross-plane) were scanned in RFA of volume 48×48×41cm<sup>3</sup>. Data collection and processing were pursued following the protocols TRS-277, TRS-398, and recommendations of AAPM task group TG-106. A tolerance limit of 2 mm from the congruence of radiation and mechanical isocenter was recommended by TG-142 [12-14].

The depth dose profile and percent depth dose (PDD) were measured with SSD of 100 cm for square field applicators of 6×6 cm<sup>2</sup>, 10×10 cm<sup>2</sup>, 14×14cm<sup>2</sup>, 20×20 cm<sup>2</sup>, and, 25×25 cm<sup>2</sup> following TRS-398 protocols [15]. All percent depth dose data were normalized to 100% and point-to-point comparisons were performed up to 30 cm maximum scanning depth. AERB recommended a maximum transmission of 2 % for multi-leaf collimators [16].

### Central Axis Percentage Depth Dose

The amount of energy deposited by the electrons along the

central axis of water or tissue-equivalent material is known as percent depth dose (PDD) [17, 18]. It depends upon depth in phantom material *d*, the source to surface distance (SSD) *f*, field size at phantom surface *A*, and effective energy of the beam *E*, and is expressed as-

$$PDD(d, f, A, E) = 100(D_Q / D_p) \quad (1)$$

### Relative Beam Flatness

Beam flatness is the indicator of the profile and may be denoted by the equation given below-

$$\text{Relative Flatness} = [(D_{\max} - D_{\min}) / (D_{\max} + D_{\min})] \times 100\% \quad (2)$$

Where *D*<sub>max</sub> = Maximum dose and *D*<sub>min</sub> = Minimum dose

Radiation field symmetry be defined by the maximum value of the ratio of doses at two symmetric points relative to the central axis of the radiation field [14, 19] and given by-

$$\text{Relative Symmetry} = [D_{(x,y)}] / [D_{(-x,-y)}] \times 100\% \quad (3)$$

## RESULTS AND DISCUSSIONS

The electron beams generated by medical linear accelerators for radiation therapy are nearly mono-energetic. Typically, the central axis depth dose curve of the electron beam exhibits a high surface dose compared to the megavoltage photon beam, and then the dose builds up to a maximum at a certain depth referred to as the depth of dose maximum at *Z*<sub>max</sub> of the electron beam. Beyond *Z*<sub>max</sub> dose drops off rapidly and approaches the minimum dose component referred to as the bremsstrahlung tail [20].

This rapid drop-off dose after *Z*<sub>max</sub> is attributed to the scattering and continuous energy loss of electrons. This characteristic of the electron beam enables it suitable for irradiating superficial tumors as well as tumors extending from the surface to a small depth [15].

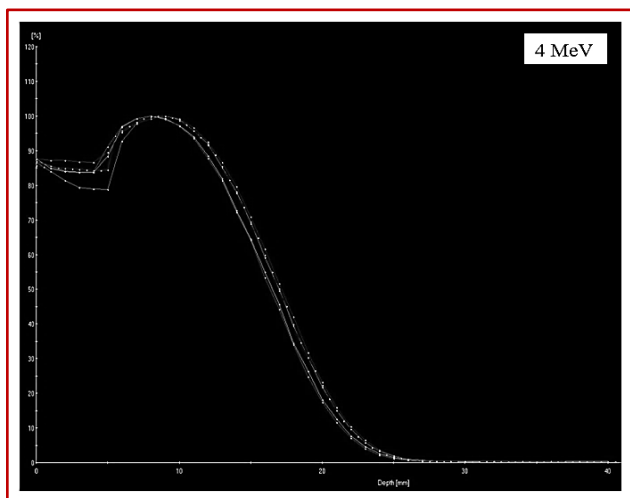
The long tail of the curve represents the dose from the x-rays which are usually termed as x-ray contamination of the electron beam [21]. Bremsstrahlung is produced as the electron beam passes through the accelerator exit window, scattering foils, monitor chambers, collimators, and air. The dose from x-ray contamination with electrons increases with energy and it is in the range of 0.5 to 5%. The magnitude of *Z*<sub>max</sub> depends on the accelerator design and the type of collimation system used with the electron beam [16].

### Central Axis Percent Depth Dose

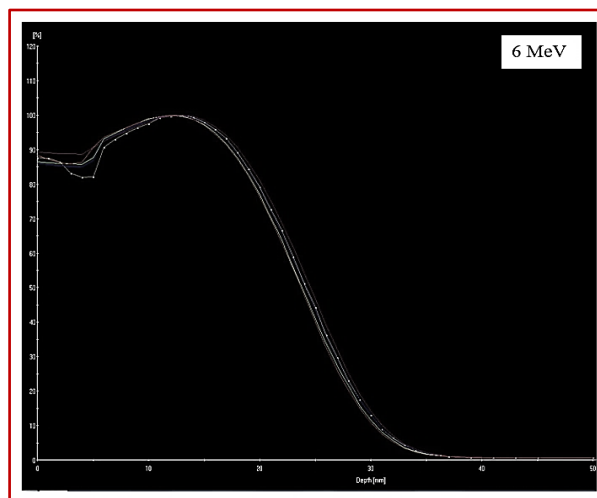
Electron beam percent depth dose (PDD) curves are plotted with the variation of depth in the phantom for different sizes

of field applicator. It is the inference that when the phantom is irradiated with a narrow beam of electrons, then most of the electrons are scattered by the narrow beam and the dose falls off rapidly with depth [22]. However, when the field size is increased, the scattering loss of electrons at the central axis decreases and results in a gradual increase of depth dose with the depth [23].

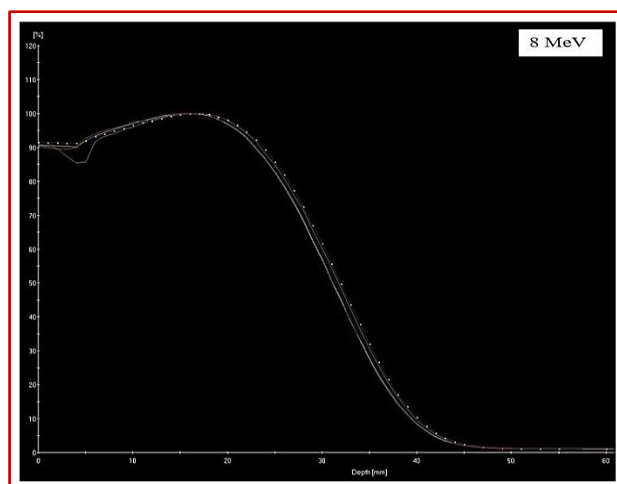
The measurements for the electron beam of 4 MeV are performed at the reference depths of measurement of 12.3, 12.0, 11.7, 12.4, and 11.6 mm respectively for the applicator sizes of 6×6, 10×10, 14×14, 20×20 and, 25×25 cm<sup>2</sup> as depicted in Figure 1(a). The measurements for the electron beam of 6 MeV are performed at the reference depths of measurement of 17.8, 17.7, 17.4, 18.2, and 17.3 mm respectively for the applicator sizes of 6×6, 10×10, 14×14, 20×20 and, 25×25 cm<sup>2</sup> as depicted in Figure 1(b). The measurements for the electron beam of 8 MeV are performed at the reference depths of measurement of 23.5, 23.3, 22.9, 23.8, and 22.8 mm respectively for the applicator sizes of 6×6, 10×10, 14×14, 20×20 and, 25×25 cm<sup>2</sup> as depicted in Figure 1(c). The measurements for the electron beam of 10 MeV are performed at the reference depths of measurement of 29.8, 29.3, 29.5, 31.2, and 29.4 mm respectively for the applicator sizes of 6×6, 10×10, 14×14, 20×20 and, 25×25 cm<sup>2</sup> as depicted in Figure 1(d).



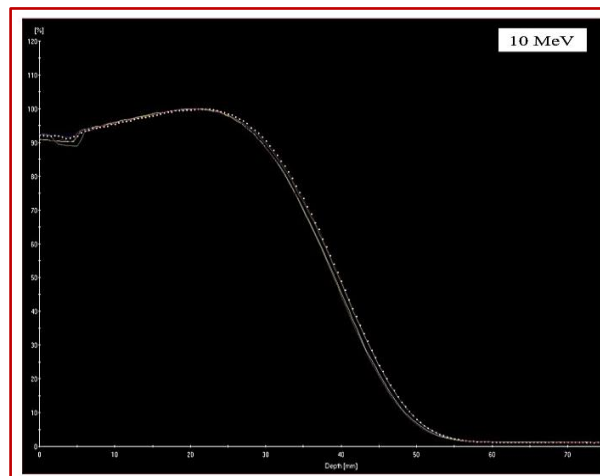
(a)



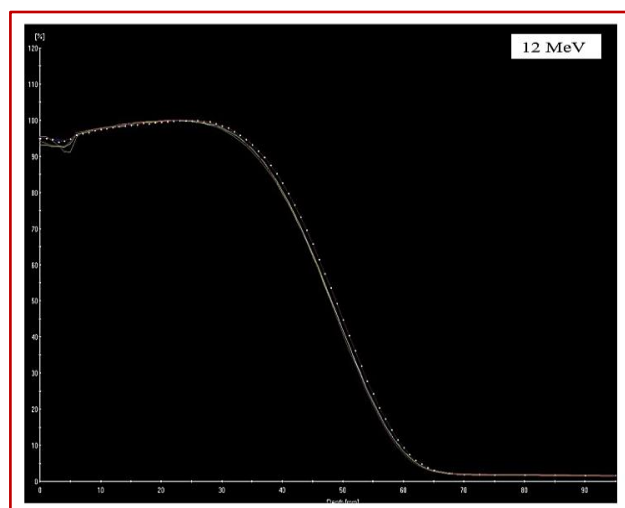
(b)



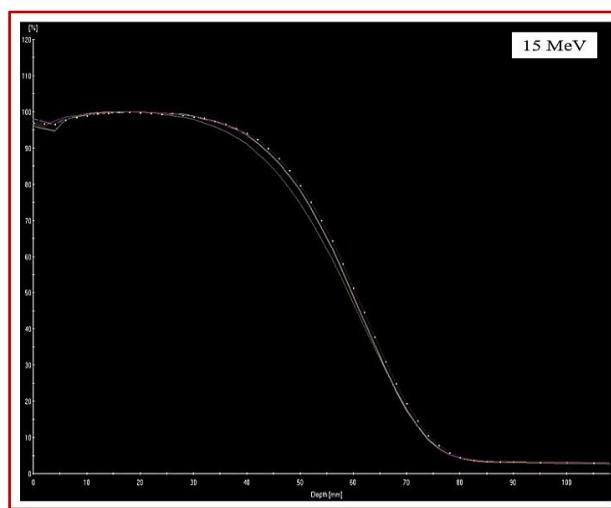
(c)



(d)



(e)



(f)

Figure 1. Experimental results for central axis percent depth dose (PDD) data for electron beam of energies (a) 4 MeV, (b) 6 MeV, (c) 8 MeV, (d) 10 MeV, (e) 12 MeV and (f) 15 MeV using square field applicators

The measurements for the electron beam of 12 MeV are performed at the reference depths of measurement of 35.7, 36.1, 36.0, 36.9, and 36.1 mm respectively for the applicator sizes of 6×6, 10×10, 14×14, 20×20, and 25×25 cm<sup>2</sup> as depicted in Figure 1(e). The measurements for the electron beam of 15 MeV are performed at the reference depths of measurement of 40.8, 41.6, 43.1, 44.0, and 43.6 mm respectively for the applicator sizes of 6×6, 10×10, 14×14, 20×20, and 25×25 cm<sup>2</sup> as depicted in Figure 1(f).

Table 1. Central axis percent depth dose (PDD) parameters for an electron beam of energies 4 MeV using square field applicators

S.N.	Field Size (cm <sup>2</sup> )	Applicator Size (cm <sup>2</sup> )	$R_{100}$ (mm)	$R_p$ (mm)	$R_{50}$ (mm)	$R_{90}$ (mm)	$R_q$ (mm)	$R_{30}$ (mm)	$R_{80}$ (mm)	$D_s$ (%)	$D_x$ (%)	$\bar{E}_{p0}$ (MeV)
1.	10x10	6x6	9.00	21.98	17.01	12.29	11.90	19.04	13.74	85.26	86.57	4.58
2.	10x10	10x10	8.98	21.92	16.96	12.29	12.00	19.04	13.71	85.36	85.75	4.57
3.	20x20	14x14	8.00	21.56	16.54	11.74	11.42	18.55	13.21	86.23	87.64	4.50
4.	25x25	20x20	9.00	22.23	17.18	12.43	12.09	19.21	13.95	87.42	87.62	4.63
5.	30x30	25x25	8.00	21.42	16.32	11.63	11.32	18.44	13.15	86.31	86.98	4.47

The values of the range of maximum dose , practical range of dose , range of 50% dose , ranges of 90% dose , range of

30% dose , range of 80% dose , and range for the electron beams of 4 – 15 MeV are listed in tables 1 – 6 respectively.

Table 2. Central axis percent depth dose (PDD) parameters for an electron beam of energies 6 MeV using square field applicators

S.N.	Field Size (cm <sup>2</sup> )	Applicator Size (cm <sup>2</sup> )	$R_{100}$ (mm)	$R_P$ (mm)	$R_{50}$ (mm)	$R_{90}$ (mm)	$R_q$ (mm)	$R_{30}$ (mm)	$R_{80}$ (mm)	$D_s$ (%)	$D_x$ (%)	$\bar{E}_{p0}$ (MeV)
1.	10x10	6x6	13.00	30.77	24.18	17.83	17.53	26.96	19.85	87.54	87.69	6.35
2.	10x10	10x10	13.98	30.76	24.14	17.69	17.38	26.85	19.72	85.89	86.01	6.35
3.	20x20	14x14	12.01	30.27	23.81	17.43	17.24	26.58	19.64	86.37	86.49	6.27
4.	25x25	20x20	13.00	31.05	24.56	18.16	17.97	27.29	20.19	89.15	89.24	6.38
5.	30x30	25x25	12.01	30.10	13.71	17.32	17.20	26.38	19.38	87.73	88.35	6.23

Table 3. Central axis percent depth dose (PDD) parameters for an electron beam of energies 8 MeV using square field applicators

S.N.	Field Size (cm <sup>2</sup> )	Applicator Size (cm <sup>2</sup> )	$R_{100}$ (mm)	$R_P$ (mm)	$R_{50}$ (mm)	$R_{90}$ (mm)	$R_q$ (mm)	$R_{30}$ (mm)	$R_{80}$ (mm)	$D_s$ (%)	$D_x$ (%)	$\bar{E}_{p0}$ (MeV)
1.	10x10	6x6	16.97	39.94	31.72	23.49	23.32	35.13	26.15	90.27	90.35	8.17
2.	10x10	10x10	16.00	39.63	31.47	23.24	23.08	34.96	25.87	90.90	90.93	8.10
3.	20x20	14x14	16.00	39.20	31.14	22.94	22.84	34.57	25.65	90.59	90.65	8.03
4.	25x25	20x20	16.01	40.13	31.98	23.76	23.57	35.35	26.41	91.54	91.54	8.23
5.	30x30	25x25	16.00	39.32	31.12	22.85	22.68	34.51	25.59	90.05	90.27	8.04

Table 4. Central axis percent depth dose (PDD) parameters for an electron beam of energies 10 MeV using square field applicators

S.N.	Field Size (cm <sup>2</sup> )	Applicator Size (cm <sup>2</sup> )	$R_{100}$ (mm)	$R_P$ (mm)	$R_{50}$ (mm)	$R_{90}$ (mm)	$R_q$ (mm)	$R_{30}$ (mm)	$R_{80}$ (mm)	$D_s$ (%)	$D_x$ (%)	$\bar{E}_{p0}$ (MeV)
1.	10x10	6x6	20.51	49.12	39.69	29.86	29.94	43.65	33.15	92.40	92.49	10.00
2.	10x10	10x10	20.00	48.81	39.15	29.34	29.18	43.20	32.65	92.24	92.43	9.94
3.	20x20	14x14	20.02	48.70	38.16	29.45	29.30	43.02	32.71	90.85	90.81	9.93
4.	25x25	20x20	21.49	49.14	39.82	30.19	30.15	43.74	33.36	92.16	92.22	10.01
5.	30x30	25x25	20.00	48.21	39.99	29.61	29.51	42.95	32.59	90.76	91.12	9.82

Table 5. Central axis percent depth dose (PDD) parameters for an electron beam of energies 12 MeV using square field applicators

S.N.	Field Size (cm <sup>2</sup> )	Applicator Size (cm <sup>2</sup> )	$R_{100}$ (mm)	$R_P$ (mm)	$R_{50}$ (mm)	$R_{90}$ (mm)	$R_q$ (mm)	$R_{30}$ (mm)	$R_{80}$ (mm)	$D_s$ (%)	$D_x$ (%)	$\bar{E}_{p0}$ (MeV)
1.	10x10	6x6	22.02	59.57	48.08	35.69	36.06	52.91	39.88	95.47	95.52	12.13
2.	10x10	10x10	23.95	59.55	48.19	36.10	36.05	52.96	40.18	95.13	95.23	12.11
3.	20x20	14x14	22.99	59.32	48.13	36.05	36.41	52.85	40.18	93.17	95.23	12.05

4.	25x25	20x20	24.00	60.08	48.95	36.87	36.99	53.50	40.92	95.04	95.10	12.20
5.	30x30	25x25	23.01	58.98	47.99	36.09	36.37	52.65	40.05	93.89	94.17	11.98

Table 6. Central axis percent depth dose (PDD) parameters for an electron beam of energies 15 MeV using square field applicators

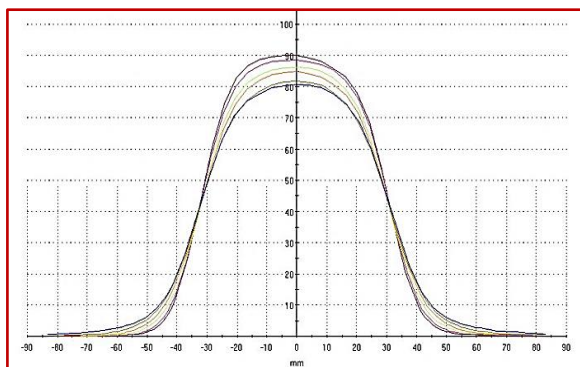
S.N.	Field Size (cm <sup>2</sup> )	Applicator Size (cm <sup>2</sup> )	$R_{100}$ (mm)	$R_p$ (mm)	$R_{50}$ (mm)	$R_{90}$ (mm)	$R_q$ (mm)	$R_{30}$ (mm)	$R_{80}$ (mm)	$D_s$ (%)	$D_x$ (%)	$\bar{E}_{p0}$ (MeV)
1.	10x10	6x6	17.71	74.18	59.08	40.84	42.76	65.53	47.40	97.84	98.04	15.05
2.	10x10	10x10	18.01	73.92	59.82	43.06	44.57	65.89	49.05	97.71	97.79	14.99
3.	20x20	14x14	19.78	73.56	59.77	43.14	44.89	65.71	49.20	95.89	96.07	14.93
4.	25x25	20x20	16.29	74.28	60.42	44.01	45.46	66.36	49.85	96.87	96.93	15.04
5.	30x30	25x25	19.51	73.38	59.64	43.09	44.82	65.61	49.10	96.55	96.12	14.89

Also, the variation of surface dose, dose at the given depth, and most probable energies of the beam are tabulated in tables 1 – 6 respectively. It is evident from tables 1 – 6 that the values of the output factors increase with increasing the beam energy and also with increasing the size of the applicator for a beam of a particular energy.

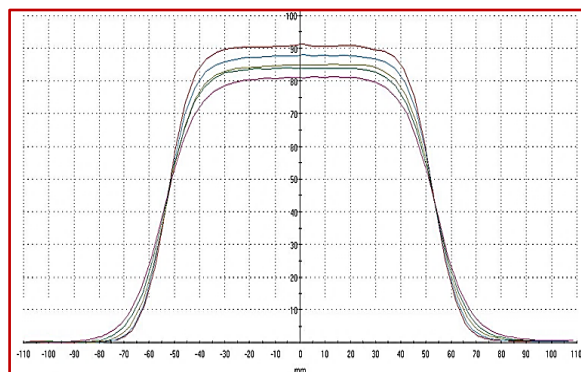
However, for the beams of all the energies of clinical use the values of the most probable energy are higher than the incident beam energy. This is due to the generation of secondary electrons due to scattering effects in the collimation tube of the linear accelerator and with the walls of applicators used.

Relative Depth Dose Profile

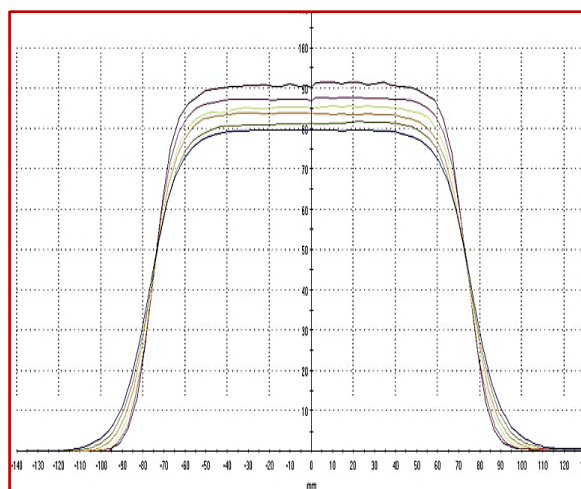
The depth profiles of the electron beam depend on the make and arrangement of the flattening system and the jaws of the beam collimation system (See Figure 3 (a-e)). The flatness of the beams of lower energy and smaller field size is smaller due to the scattering of electrons [16].



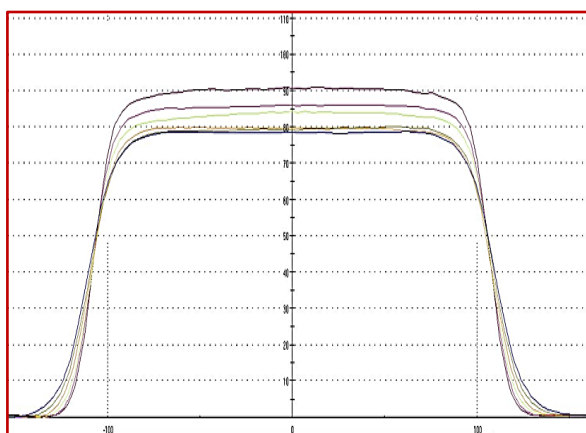
(a)



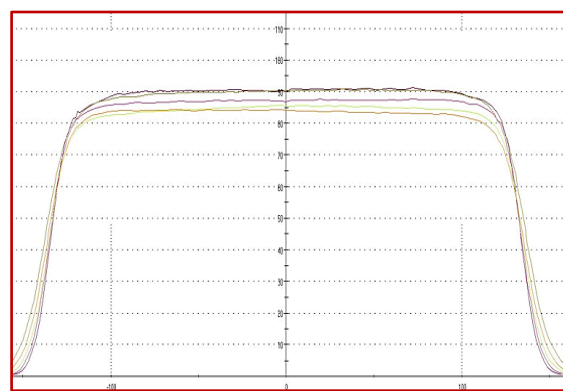
(b)



(c)



(d)



(e)

Figure 3. Experimental results for cross-plane depth profile at R90 for electron beam of energies 4 - 15 MeV using square field applicator of sizes (a) 6x6 cm<sup>2</sup>, (b) 10x10 cm<sup>2</sup>, (c) 14x14 cm<sup>2</sup>, (d) 20x20 cm<sup>2</sup> and (e) 25x25 cm<sup>2</sup>

The flatness of the beam from the central axis should not exceed ±3%. In external beam radiation therapy, the variation of dose over the target volume is limited, so that all points of the treated volume receive the prescribed dose within the tolerance limits [25].

Table 7. Cross-plane output factors for electron beam of energies 4 MeV - 15 MeV using square field applicator of the size of 6x6 cm<sup>2</sup>

Energy (MeV)	Depth (mm)	CAX Dev. (mm)	Field Size (cm <sup>2</sup> )	Pen. Left (mm)	Pen. Right (mm)	$D_{max}$ (%)	$D_{min}$ (%)	Flatness s ±(%)	Symmetry ±(%)	Field Size at SID (cm <sup>2</sup> )	$R_{80}$ (mm)	$R_{90}$ (mm)
4	12.3	-0.71	6.213	13.56	14.36	100.01	90.11	5.21	2.88	6.137	20.79	31.99
6	17.8	-0.68	6.219	14.28	15.16	100.03	89.88	5.35	1.78	6.110	20.77	32.09
8	23.5	-0.66	6.246	15.39	16.26	100.03	89.04	5.81	1.15	6.103	20.69	32.50
10	29.8	-0.62	6.293	16.76	17.60	100.03	87.87	6.47	1.17	6.111	20.51	32.97
12	35.7	-0.68	6.361	17.84	18.42	100.08	87.42	6.75	0.57	6.141	20.32	33.05
15	40.8	-0.61	6.441	17.58	18.08	100.06	88.54	6.11	0.61	6.189	19.82	32.17

Table 8. Cross-plane output factors for electron beam of energies 4 MeV - 15 MeV using a square field applicator of the size of 10x10 cm<sup>2</sup>

Energy (MeV)	Depth (mm)	CAX Dev. (mm)	Field Size (cm <sup>2</sup> )	Pen. Left (mm)	Pen. Right (mm)	$D_{max}$ (%)	$D_{min}$ (%)	Flatness s ±(%)	Symmetry ±(%)	Field Size at SID (cm <sup>2</sup> )	$R_{80}$ (mm)	$R_{90}$ (mm)
4	12.0	0.23	10.545	13.75	13.82	100.01	89.36	5.63	0.82	10.420	23.61	33.31
6	17.7	0.28	10.598	14.48	14.46	100.13	88.05	6.42	1.05	10.414	23.45	34.07
8	23.3	0.28	10.662	15.75	15.50	100.31	86.44	7.43	1.29	10.419	23.23	34.93
10	29.3	0.05	10.748	16.68	16.81	100.36	85.64	7.91	0.50	10.442	22.64	34.51
12	36.1	0.00	10.825	18.45	18.25	100.31	83.37	9.22	1.37	10.448	22.36	35.93
15	41.6	0.10	10.998	18.76	18.05	100.12	82.94	9.05	1.14	10.558	22.11	36.01

Table 9. Cross-plane output factors for electron beam of energies 4 MeV - 15 MeV using a square field applicator of the size of 14x14 cm<sup>2</sup>

Energy (MeV)	Depth (mm)	CAX Dev. (mm)	Field Size (cm <sup>2</sup> )	Pen. Left (mm)	Pen. Right (mm)	D <sub>max.</sub> (%)	D <sub>min</sub> (%)	Flatness s ±(%)	Symmetry ±(%)	Field Size at SID (cm <sup>2</sup> )	R <sub>80</sub> (mm)	R <sub>90</sub> (mm)
4	11.7	-0.32	14.859	13.71	13.70	101.43	94.61	3.48	1.29	14.687	27.12	36.68
6	17.4	-0.27	14.933	14.21	14.26	101.13	94.35	3.47	1.04	14.678	26.75	36.59
8	22.9	-0.27	14.976	15.58	15.75	100.09	92.29	4.05	1.02	14.641	26.64	38.13
10	29.5	-0.33	15.068	16.75	17.36	100.03	91.68	4.35	0.78	14.636	26.37	38.92
12	36.0	-0.28	15.183	18.54	18.49	100.32	89.97	5.44	1.09	14.655	25.82	39.06
15	43.1	-0.32	15.308	19.36	19.65	100.09	89.67	5.49	0.45	14.676	25.31	39.24

Table 10. Cross-plane output factors for electron beam of energies 4 MeV - 15 MeV using a square field applicator of the size of 20x20 cm<sup>2</sup>

Energy (MeV)	Depth (mm)	CAX Dev. (mm)	Field Size (cm <sup>2</sup> )	Pen. Left (mm)	Pen. Right (mm)	D <sub>max.</sub> (%)	D <sub>min</sub> (%)	Flatness s ±(%)	Symmetry ±(%)	Field Size at SID (cm <sup>2</sup> )	R <sub>80</sub> (mm)	R <sub>90</sub> (mm)
4	12.4	-0.12	21.368	14.17	14.26	100.13	95.85	2.18	1.11	21.107	19.39	30.33
6	18.2	-0.13	21.490	14.92	15.96	100.31	96.39	2.00	0.93	21.106	18.85	30.07
8	23.8	-0.13	21.568	16.53	16.38	100.01	94.55	2.81	1.51	21.055	18.59	31.47
10	31.2	-0.29	21.723	17.66	18.26	100.49	95.37	2.61	1.34	21.066	18.09	32.00
12	36.9	-0.15	21.878	19.00	18.90	100.11	95.00	3.11	1.59	21.100	17.25	31.23
15	44.0	-0.26	22.051	19.72	20.05	100.48	95.09	2.76	0.30	21.122	16.56	31.09

The depth beam profile [Figure 2(a) to 2(e)] of the electron beam of energies 4 MeV – 15 MeV is plotted with square field applicators of sizes 6x6 cm<sup>2</sup> to 25x25 cm<sup>2</sup> at R90 showing that beam symmetry is higher for smaller field applicators and decreases with increasing the applicator size

[26]. The output factors CAX. Deviation, allowed field sizes by the linear accelerator, left and right side beam penumbra, maximum and minimum dose delivered to the phantom, relative flatness, and symmetry of the beam, field sizes at SID, and the ranges of 80% and 90% doses R80 and R90 are measured and tabulated from table 7- 11.

Table 11. Cross-plane output factors for electron beam of energies 4 MeV - 15 MeV using a square field applicator of the size of 25x25 cm<sup>2</sup>

Energy (MeV)	Depth (mm)	CAX Dev. (mm)	Field Size (cm <sup>2</sup> )	Pen. Left (mm)	Pen. Right (mm)	D <sub>max.</sub> (%)	D <sub>min</sub> (%)	Flatness s ±(%)	Symmetry ±(%)	Field Size at SID (cm <sup>2</sup> )	R <sub>80</sub> (mm)	R <sub>90</sub> (mm)
4	11.6	-0.16	26.749	13.78	14.44	100.29	96.31	2.52	1.50	26.443	7.53	3.32
6	17.3	-0.30	26.898	14.36	14.04	100.95	97.71	1.63	1.34	26.441	8.07	2.49
8	22.8	-0.21	26.988	16.01	15.78	100.35	95.62	2.42	1.79	26.378	8.49	4.29
10	29.4	-0.39	27.180	16.92	17.97	100.26	96.35	1.99	2.02	26.404	9.13	5.05
12	36.1	-0.20	27.346	19.25	19.00	100.63	95.32	2.71	1.82	26.393	10.06	5.03
15	43.6	-0.35	27.142	19.14	19.25	100.23	95.21	2.96	1.93	26.384	10.23	5.13

The field size of the linear accelerator and field size at SID

increases with increasing the applicator size. However, the

values of R80 and R90 decrease with increasing the applicator sizes for all the electron energies.

## CONCLUSION

Electron beams of all energies delivered by the Elekta Synergy platform linear accelerator show that the surface dose is generally higher for the smaller field applicator and the depth of the dose maximum shifted towards the surface in comparison to other conventional methods [3]. The change in percent depth dose affects the clinically relevant portion of the electron beam. In this study distinguishing between large and small field sizes is depend on electron range, the field is considered small if the cross-section is small compared to the electron range in the medium [27]. The depth of maximum dose with 10×10 cm<sup>2</sup> field size applicators increases with energy and analogous results were derived for photon beams. The values of R100, RP, R50, R90, Rq, R30, R80, Ds, Dx, and Ep0 are in good agreement with the recommendations of AAPM TG-142 [14]. The results from the measurements for square field applicators are in good agreement with the reference values of PDD and beam profile measured by micro-silicon detectors and also within the stated uncertainties. The results so obtained confirm the reliability of central axis percent depth dose distribution and beam profile of the clinical electron beams collimated by square field applicators in the treatment of superficial tumors.

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