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Original research article

Measurement and comparison of head scatter factor for 7 MV unflattened (FFF) and 6 MV flattened photon beam using indigenously designed columnar mini phantom

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A B S T R A C T

Aim: To measure and compare the head scatter factor for 7 MV unflattened and 6 MV flattened photon beam using a home-made designed mini phantom.
Background: The head scatter factor (Sc) is one of the important parameters for MU calculation. There are multiple factors that influence the Sc values, like accelerator head, flattening filter, primary and secondary collimators.
Materials and methods: A columnar mini phantom was designed as recommended by AAPM Task Group 74 with high and low atomic number material for measurement of head scatter factors at 10 cm and d_{max} dose water equivalent thickness.
Results: The Sc values measured with high-Z are higher than the low-Z mini phantoms observed for both 6MV-FB and 7MV-UFB photon energies. Sc values of 7MV-UFB photon beams were smaller than those of the 6MV-FB photon beams (0.6–2.2% (Primus), 0.2–1.4% (Artiste) and 0.6–3.7% (Clinac iX (2300CD))) for field sizes ranging from 10 cm × 10 cm to 40 cm × 40 cm. The SSD had no influence on head scatter for both flattened and unflattened beams. The presence of wedge filters influences the Sc values. The collimator exchange effects showed that the opening of the upper jaw increases Sc irrespective of FF and FFF.
Conclusions: There were significant differences in Sc values measured for 6MV-FB and unflattened 7MV-UFB photon beams over the range of field sizes from 10 cm × 10 cm to 40 cm × 04 cm. Different results were obtained for measurements performed with low-Z and high-Z mini phantoms.

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1. Background

It is generally considered that the absorbed dose at the point within a phantom can be divided into two components[1–5]: a part due to primary radiation and a second part carried by photons scattered in the treatment head reaching the point of interest. Primary radiation is that photon radiation generated at the source that reaches the patient without any interactions. Scattered radiation (Sc) is that photon radiation with a history of interaction/scattering with the flattening filter, collimators or other structures in the treatment unit head. The direct radiation and scattered radiation comprise the output of radiation, which from the patient's point of view equals the incident radiation. The contribution to the absorbed dose from electrons released by photons scattered from elsewhere in the patient is called the phantom scatter (Sp) component. The basic method for separating scatter radiation (Sc) from Linac head and scatter radiation from phantom (Sp) involves the measurement of the total scatter factor in a phantom (St) and either the head scatter factor (Sc) or the phantom scatter factor (Sp) individually.[1,6,7] A direct measurement of Sp involves complex methods compared to Sc measurements.

The determination of the Sc is usually done by in-air measurements with sufficient material surrounding the detector to prevent contaminating secondary particles from reaching the detector volume and to provide enough charged particles for signal strength. Historically, Sc is measured at depth of maximum dose (d_{max}) with a water equivalent build-up cap and wall thickness equivalent to depth of maximum dose in water phantom. This method suffers from a number of problems, like detector response difference for electrons and photons,[8,9] absence of unique value of d_{max} for different field sizes and source-to-surface (SSD) distance.[10–12] To solve the above problem, AAPM therapy physics committee Task Group 74 (TG74)[13] recommends the build-up caps in cylindrical shapes along with long axis parallel with the beam central axis and the ion chamber placed at 10 g/cm^2 water equivalent depth for Sc measurements. These build-up caps are generally called columnar mini phantoms. The 10 g/cm^2 volume is sufficient to prevent contaminating electrons from reaching the detector.[14] In general, low-Z materials are recommended for mini phantoms. A high-Z mini phantom is used for small field Sc measurements.

In a conventional clinical accelerator, the flattening filter is placed in the photon beamline to compensate for the non-uniformity of photon fluence across the field. This, however, may not be necessary for certain types of treatments. In intensity modulated radiation therapy (IMRT), for example, additional beam modifying devices, such as multileaf collimators (MLCs), are used to modify actual fluence distributions to produce optimal fluence maps.[6,15–20] In principle, the flattening filter can then be removed, and the leaf sequences can be adjusted accordingly to produce fluence distributions similar to those of a beamline with a flattening filter. One of the cutting edge technologies introduced by linear accelerator manufacturers utilizes unflattened high dose rate beams (without flattening filter – up to 2400 MU/min) available for clinical treatment. The flattening filter is a major source of scatter radiation.[21–27] The variation in the characteristics of Sc due to the effect of contaminating electrons, collimator exchange effect, impact of beam modifying devices and the effect of source to detector distance have been extensively studied earlier using mini phantom and build up cap measurement for flattened beam.[5,28–32]

2. Aim

Aim of this study is to measure and compare Sc values of 6MV-FB (flattened) and 7MV-UFB (flattening filter free) photon beams which could be delivered by SIEMENS-ARTISTE linear accelerator (Siemens Medical Systems, USA). The home-made mini phantom was used to study and compare the Sc of three different LINACs, the effect of low and high-Z mini phantoms for various field sizes. Also Sc values were measured at different SSDs with and without beam modifying devices and the effect of collimator exchange of 6MV-FB and 7MV-UFB.

3. Materials and methods

The columnar mini phantoms used for Sc measurements were indigenously constructed using Poly Methyl Metha Acrylate (PMMA), which is a water equivalent polymer material. The chamber insert was 20.0 cm in total length and 3.5 cm in diameter (Fig. 1). The ion chamber was placed at 10 cm water

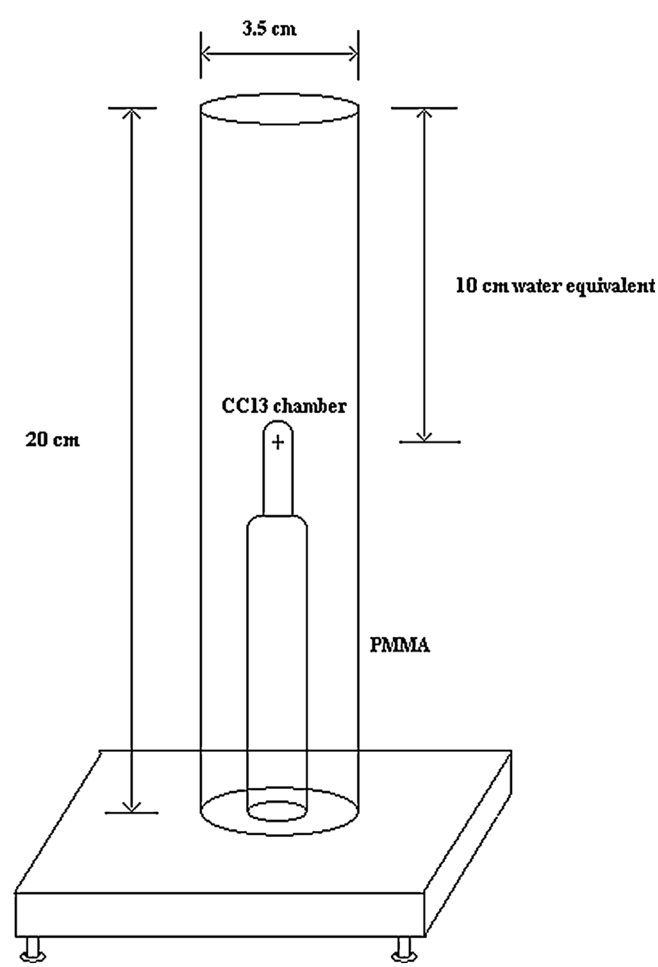

Fig. 1 – Block diagram of PMMA columnar mini phantom.

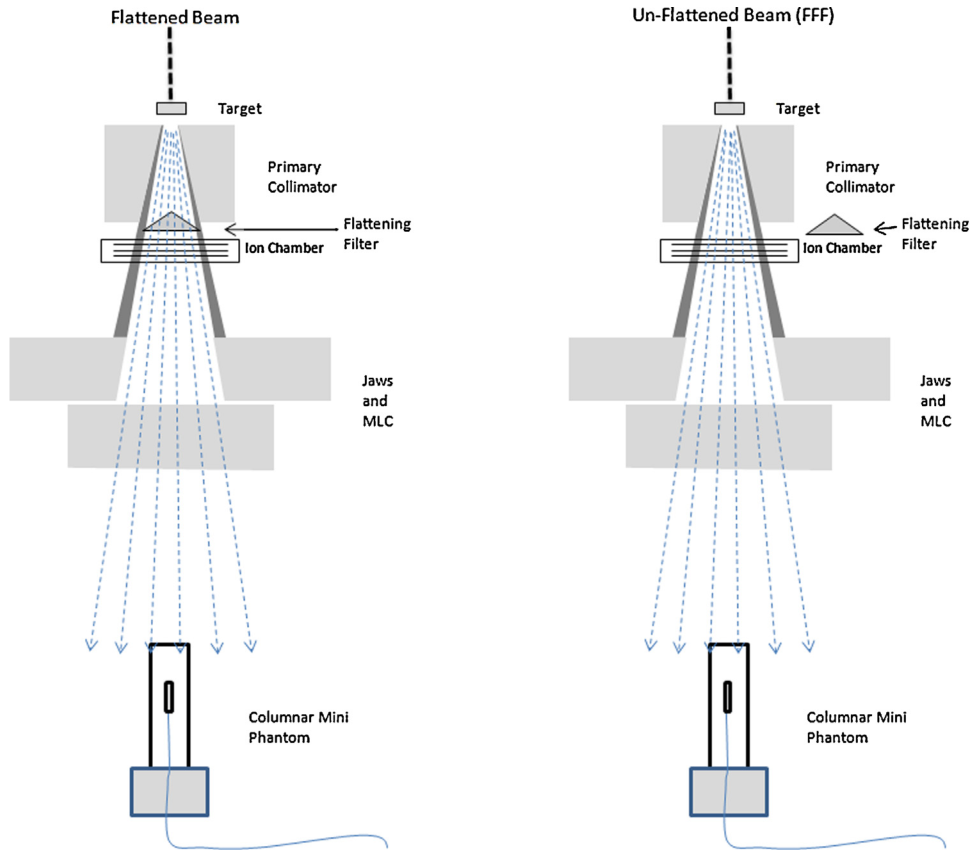

Fig. 2 – Schematic diagram of columnar mini phantom experimental setup in linear accelerator.

equivalent depth below the surface of the mini phantom. When the photon beam travelled through the long axis of the columnar mini phantom for 10 cm water equivalent depth or so, it was deep enough to stop all the contaminating electrons in the provided build-up depth. To measure the head scatter factor, the designed mini phantom was positioned as shown in Fig. 2. The brass build-up caps were constructed with wall thickness sufficient to give maximum dose build-up. These wall thicknesses corresponded to an areal density (thickness × mass density) of 1.7 g/cm^2 for 6MV-FB and 2.1 g/cm^2 for 7MV-UFB photon energy beams. The mini phantom was always placed to keep the ion chamber perpendicularly to the central axis of the beam.

In this study, 6MV-FB beams of Primus, Artiste (Siemens Medical Systems, USA), Clinac iX (23100CD) (Varian Medical Systems, USA) and 7MV-UFB beams of Artiste (Siemens Medical Systems, USA) linear accelerator were used. The percentage depth dose (PDD) of 7MV-UFB and 6MV-FB at 10 cm depth is 69.1% and 66.9%, respectively, for the 10 cm × 10 cm field size at 100 cm SSD. The Sc measurement using PMMA mini phantom and brass build-up caps were performed with a CC13 ionization chamber with DOSE 1 (IBA, Germany) electrometer. The CC13 cylindrical chamber had a cavity length of 5.8 mm and the radius of the spherical part was 3.0 mm. The chamber had an air volume of 0.13 cm^3.

Sc measurements were measured with columnar mini phantom and brass build-up caps for various square and rectangular field sizes from 4 cm × 4 cm to 40 cm × 40 cm at various SSDs (80 cm, 100 cm, 120 cm) for Varian (Clinac iX (2300CD)) and Siemens (Artiste and Primus) linear accelerators for 6MV-FB and 7MV-UFB energy beams. The Sc measurements were also carried out for SSDs 80,100 and 120 cm for open and 30 degree wedged beams. All the readings were measured for 200 MU at the water equivalent depth of 10 cm columnar mini phantom unless otherwise stated. The measured values for different field sizes of open and 30° wedged beams were normalized to the output of the 10 cm × 10 cm open field size at 100 cm SSD.

4. Results

All the results of point dose measurements given below are mean values from at least five repeated measurements. The standard deviations were less than 0.20% and also partly cross-checked on different days and confirmed the initial results at least within ±0.30%.

Not much difference was observed in the values of Sc for small field sizes, though these three accelerators differed in the collimator design for 6MV-FB. The Sc for Varian (Clinac iX) was higher than the Siemens (Primus) in larger field sizes. This could be due to the additional scattering arising from tertiary collimator (MLC). The maximum deviation of Sc values for 6MV-FB was −0.7% (Artiste) and 1.4% (Clinac iX) for a larger field size with respect to Siemens (Primus) accelerator.

Table 1 – The measured Sc values at 10 cm depth for Siemens (Primus and Artiste) and Varian (Clinac iX) linear accelerators at 100 cm SSD.

Field size (cm^2)	6MV-FB Siemens (Primus)	6MV-FB Siemens (Artiste)	7MV-UFB Siemens (Artiste)	6MV-FB Varian (Clinac iX)
5	0.961	0.968	0.988	0.964
8	0.988	0.991	0.997	0.989
10	1.000	1.000	1.000	1.000
12	1.009	1.006	1.003	1.009
15	1.018	1.012	1.006	1.015
20	1.025	1.0200	1.007	1.025
25	1.028	1.023	1.009	1.032
30	1.032	1.025	1.009	1.037
35	1.033	1.026	1.010	1.042
40	1.033	1.025	1.010	1.048

The Sc for 6MV-FB was lesser than the 7MV-UFB in smaller field sizes, and a maximum deviation of Sc values was 2.7% in Artiste linear accelerator. The Sc for 6MV-FB was higher than the 7MV-UFB in larger field sizes and a maximum deviation of Sc values was 2.2% in Artiste linear accelerator. The Sc values of the three linear accelerators of 6MV-FB (Primus, Artiste and Clinac iX) and 7MV-UFB (Artiste) are shown in Table 1 and Fig. 8.

4.1. *Effect of low and high Z mini phantom on Sc measurements*

The details are given in Fig. 3. A maximum deviation of head scatter values ±0.51%, ±0.36% and ±0.40% were observed in various field sizes ranging from 5 cm × 5 cm to 40 cm × 40 cm for Siemens Primus 6MV-FB, Artiste 6MV-FB and Artiste 7MV-UFB, respectively, of mini phantom measured values compared to brass build-up cap measured values. The Sc was higher with brass build-up cap measured values than with mini phantom measured values irrespective of the beam energy and the machine for larger field size. Sc was higher with mini phantom measured values than with brass build-up cap measured values irrespective of the beam energy and the machine for field sizes smaller than 10 cm × 10 cm.

4.2. *Effect of Field Size on Sc*

Fig. 4 shows the head scatter factor measurements as a function of field size using a columnar mini phantom (100 cm SSD, 10 cm water equivalent depth). The Sc values ranged from 0.9682 to 1.0246 for 6MV-FB and 0.9882 to 1.0102 for 7MV-UFB for 5 cm × 5 cm to 40 cm × 40 cm field sizes. Sc values of 7MV-UFB were higher than 6MV-FB for field sizes of up to 10 cm × 10 cm. However, as the field size was increased above 10 cm × 10 cm, an increased amount of Sc values were observed in 6MV-FB than with 7MV-UFB. A significant reduction in Sc values was observed in 7MV-UFB compared to 6MV-FB, and a variation of only 2.2% was observed over the entire range of field sizes from 5 cm × 5 cm to 40 cm × 40 cm for 7MV-UFB compared to 5.8% for 6MV-FB.

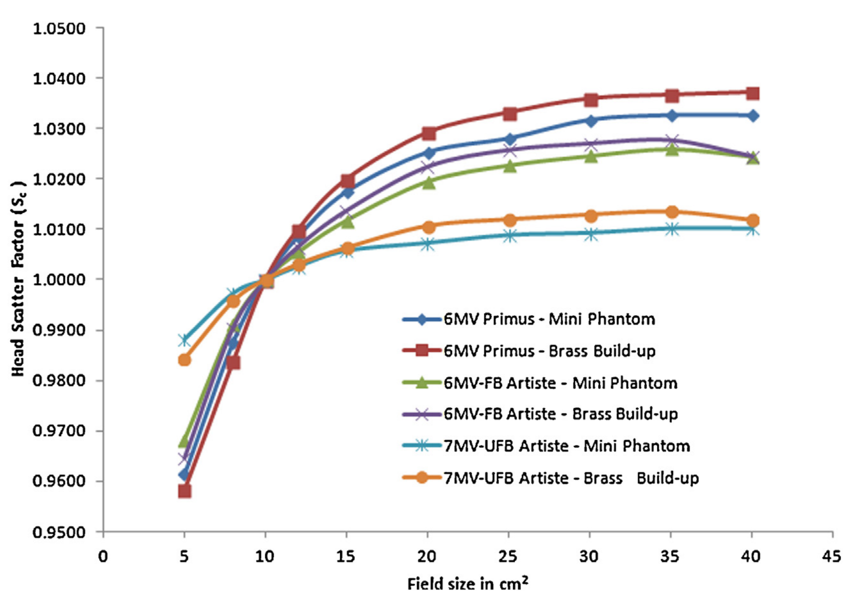

Fig. 3 – Variation of Sc with field size for with the mini phantom and brass bulid-up cap at 10.0 cm and 1.5 cm equivalent depth respectively in Simens Priums and Artiste machines for 6MV-FB and 7MV-UFB beams.

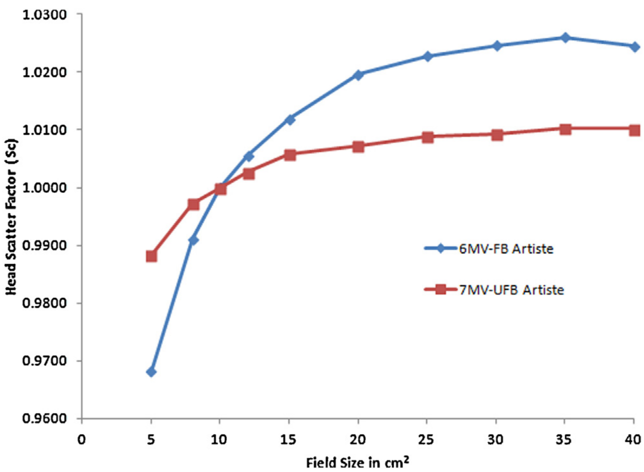

Fig. 4 – Variation of Sc with various field sizes for 6MV-FB and 7MV-UFB measured in Siemens Artiste.

4.3. *Effect of SSD on Sc*

Fig. 5 shows the variation in Sc for different field sizes with different SSD for the 6MV-FB and 7MV-UFB photon beam for 80,100 and 120 cm SSD in three different (Artiste and Primus) Siemens and (Clinac iX) Varian accelerators. There was no influence of the SSD on the Sc measurements for open field at 80 and 120 cm with respect to 100 cm SSD for all the linear accelerators and for both 6MV-FB and 7MV-UFB photon beams.

4.4. *Impact of beam modifying devices on Sc*

In the clinical work, the beam modifying device (high Z material) was used to alter the beam shape as per planning requirements. The Sc values for open and wedge fields were compared for 6MV-FB Siemens Primus linear accelerator and 6MV-FB and 7MV-UFB Siemens Artiste linear accelerator. It was observed that in the mini phantom the Sc reduced to maximum of 0.8% for 6MV-FB and 0.9% for 7MV-UFB in smaller fields and increased up to 4.9% for 6MV-FB and 2.9% for 7MV-UFB in larger field sizes (Fig. 6).

Fig. 7 shows the variation in Sc for different field sizes with wedge filter at different SSD, which was analyzed for the 6MV-FB and 7MV-UFB photon beams for 80,100 and 120 cm SSDs in two different (Artiste and Primus) linear accelerators. These data show a deviation of Sc values with wedge filters at SSDs 80 and 120 cm with respect to 100 cm SSD.

4.5. *Collimator exchange effect on Sc*

The Sc was measured for the rectangular field to check the collimator exchange effect. The readings for all three linear accelerators are shown in Figs. 9 and 10 and in Table 2. In this measurement Y jaw was always the upper collimator and X was always the lower collimator. Sc value was higher for small asymmetry fields (30 cm × 40 cm) and smaller in larger asymmetry fields (40 cm × 3 cm). Due to the collimator exchange (40 cm × 3 cm to 3 cm × 40 cm), Sc values differed from ±2.05% to ±0.5% (6MV-FB Clinac iX, Varian), ±1.6% to ±0.1% (6MV-FB Artiste, Siemens) and ±1.8% to ±0.01% (7MV-UFB Artiste, Siemens) with respect to smaller to larger asymmetry fields.

5. Discussion

The head scatter factor plays major a role in output measurements of megavoltage radiation beams as well as in beam modelling of treatment planning systems which are used for advanced treatment delivery techniques like IMRT, SRS, SRT, SBRT, etc. with summation of series of MLC shaped fields.[32–37] There are multiple factors that influence the Sc values: in particular, photons are scattered by structures in the accelerator head (primary collimator, flattening filter, the secondary collimator), tertiary collimators (MLCs and wedges), photons and electrons backscatter into the monitor chamber, and at very small field sizes, a portion of the X-ray source is obscured by the collimators. In recent times, linear accelerator manufacturers have made provisions to deliver radiation therapy treatments with the flattening filter removed from a traditional medical accelerator. The flattening filter scatters a large number of photons that contribute to the out-of-field dose[38] and the removal of flattening filter may also reduce the out-of-field dose during IMRT treatment delivery due to reduced head scatter.[39] The type of phantom and depth of measurement of Sc values are topics of interest, as has been reported by several authors.[4,7,9,14,29,32] The AAPM therapy physics committee Task Group 74 (TG-74)[13] recommends the build-up caps in cylindrical shapes along with long axis parallel with beam central axis and the ion chamber placed at 10 g/cm^2 water equivalent depth for head scatter factor measurements.

The present study emphasizes the need for Sc measurements at 10 cm water equivalent depth with mini phantom for 6MV-FB photon beams. This is in agreement with the proposals of Venselar[13] who recommended to measure the Sc at 10 cm depth with mini phantom. For flattened beams, square field head scatter factors were compared with that of AAPM, TG-74[13] published data for both Siemens (Primus) and Varian (Clinac iX (2300CD)) accelerators (Table 3). The present data are in good agreement with published data in TG-74[13] reports.

The measured Sc values of three different linear accelerators, tabulated in Table 1 and Fig. 8, show significant differences between 6MV-FB and 7MV-UFB modes. This reveals the important contribution of the flattening filter to the scattered radiation observed by the detector. Sc values of 7MV-UFB photon beams are lesser (0.6–2.2% (Primus), 0.2–1.4% (Artiste) and 0.6–3.7% (Clinac iX (2300CD))) than those of the 6MV-UFB photon beams for field sizes ranging above 10 cm × 10 cm to 40 cm × 40 cm. This is in agreement with the findings of Ding[46] relating to the scattered dose contributions from the flattening filter at the isocenter which were about 0.9–3% for 6MV-FB photon beams.

The measurement with low atomic number (Z) mini phantom for flattened beams, square field head scatter factors are comparable with the previously published data for the same type of linac.[13] The atomic number of the material used in cylindrical build-up caps and field size (d_{max} shift) affect the measurement of Sc. This is due to the increase in contamination electrons with larger field sizes. In this work, Fig. 3 shows that Sc is slightly higher (0.5%) with brass build-up

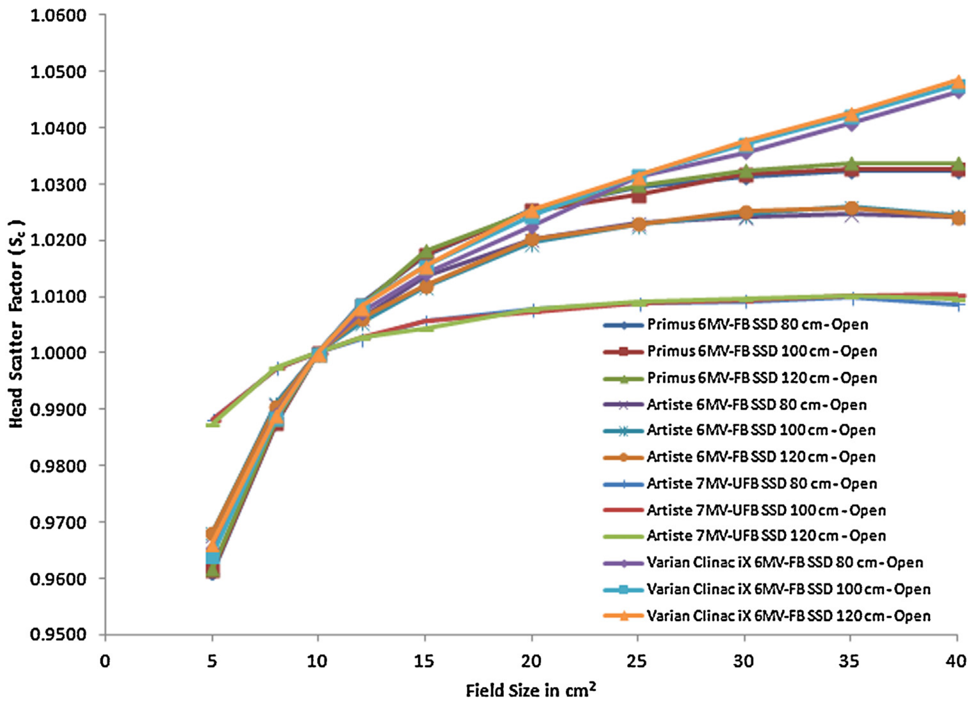

Fig. 5 – Variation of Sc with field size for different SSD for 6MV-FB and 7MV-UFB measured in Siemen (Artiste and Primus) and Varian (Clinac iX).

cap measured values than with low Z (PMMA) mini phantom measured values, irrespective of 6MV-FB and 7MV-UFB photon energy beams and different linear accelerator machine (different head design) for a larger field size. This agrees with the results obtained by Jursinic,[9] Weber[41] and Hounsell.[34] The result of the present study confirms that the build-up cap of high atomic number material causes much greater scatter of electrons[40] and maximum deviation, which was less than 0.5% compared to low Z mini phantoms for 6MV-FB and 7MV-UFB photon energies.

In Fig. 4 the Sc are presented for 6MV-FB and 7MV-UFB. The difference confirms that the flattening filter contributes significantly to the Sc. A variation of Sc values confirmed that only 2.2% was observed over the entire range of 5 cm × 5 cm to 40 cm × 40 cm field sizes for 7MV-UFB compared to 5.8% for 6MV-FB and corresponded to the findings of Zhu et al.[42] and

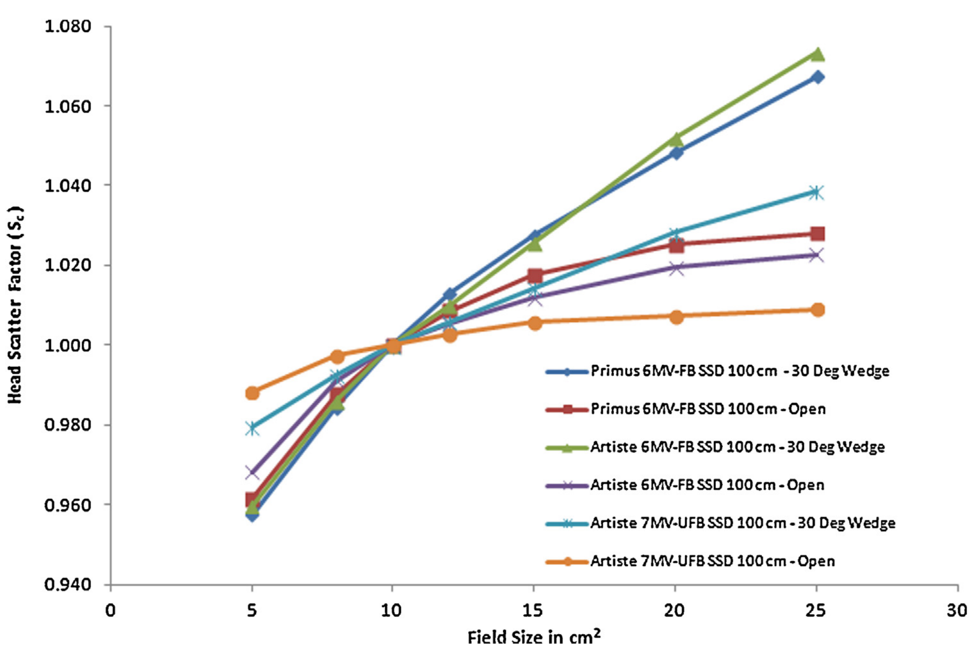

Fig. 6 – Variation of Sc with field size for wedge and open beams for 6MV-FB and 7MV-UFB measured in Siemens (Primus and Artiste).

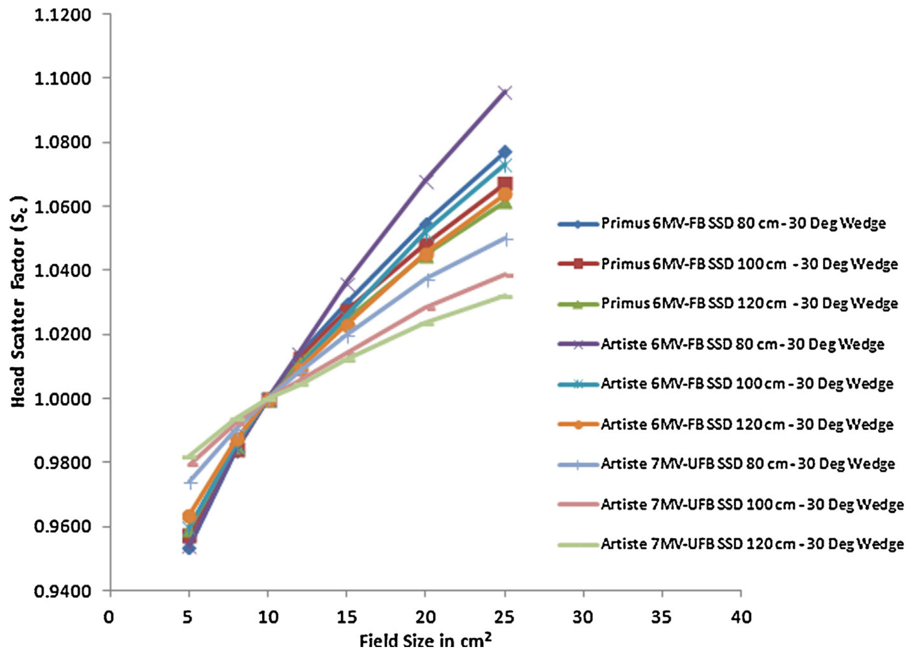

Fig. 7 – Variation of Sc for different field size with 30° wedge filter for different SSD for 6MV-FB and 7MV-UFB measured in Siemens (Artiste and Primus) accelerator.

Table 2 – Measured Sc values for rectangular collimator settings for open fields of 6MV-FB and 7MV-UFB of Varian and Siemens linear accelerators.

Collimator setting, X/Y	6MV-FB Clinac iX Varian 2300CD							
	4	5	10	15	20	25	30	40
4	0.9511	0.9563	0.9671	0.972	0.9739	0.9745	0.9751	0.9752
5	0.9587	0.961	0.9773	0.9796	0.9801	0.9805	0.9814	0.9823
10	0.973	0.9759	1	1.0049	1.0063	1.0077	1.0086	1.0091
15	0.9798	0.9796	1.0104	1.0163	1.0181	1.0208	1.0222	1.0231
20	0.9856	0.9891	1.0167	1.0222	1.0258	1.0267	1.0289	1.0308
25	0.9872	0.9909	1.0204	1.0267	1.0285	1.0308	1.0326	1.0344
30	0.9903	0.9932	1.0231	1.0289	1.0331	1.0344	1.0376	1.0394
40	0.9952	0.9955	1.0285	1.0358	1.0381	1.0426	1.0449	1.048
Collimator setting, X/Y	6MV-FB Artiste, Siemens							
	4	5	10	15	20	25	30	40
4	0.9494	0.9559	0.9649	0.9677	0.9695	0.9709	0.9722	0.9731
5	0.9581	0.9691	0.975	0.9754	0.9759	0.9773	0.9786	0.9795
10	0.9763	0.9795	1	1.0018	1.0045	1.0068	1.0086	1.0096
15	0.9845	0.9859	1.0114	1.0132	1.0164	1.0177	1.0191	1.02
20	0.9854	0.9891	1.015	1.0187	1.0214	1.0228	1.0237	1.0246
25	0.9868	0.9913	1.0159	1.0196	1.0232	1.0241	1.0246	1.025
30	0.9877	0.9936	1.0173	1.0205	1.0246	1.025	1.0255	1.0263
40	0.9891	0.9949	1.0187	1.0214	1.0255	1.0264	1.0273	1.0278
Collimator setting X/Y	7MV-UFB Artiste, Siemens							
	4	5	10	15	20	25	30	40
4	0.9658	0.9705	0.9734	0.9738	0.9749	0.9756	0.9758	0.9767
5	0.9798	0.9843	0.9894	0.9907	0.9916	0.9929	0.9939	0.9949
10	0.9886	0.99	1	1.002	1.0033	1.0044	1.0042	1.0062
15	0.9902	0.992	1.0028	1.0062	1.0078	1.008	1.0086	1.0098
20	0.9922	0.9938	1.0053	1.0798	1.0091	1.0104	1.0104	1.0115
25	0.9929	0.9949	1.006	1.0084	1.104	1.0111	1.0115	1.0129
30	0.9936	0.996	1.0067	1.0089	1.0111	1.0118	1.0126	1.013
40	0.9946	0.9969	1.0071	1.0098	1.0115	1.0126	1.0129	1.0138

Table 3 – Comparisons of measured head scatter factor with that of TG-74 published data at 10 cm water equivalent depth in mini phantoms.

Field size (cm^2)	6MV-FB Siemens (Primus)	TG-74	% of deviation	6MV-FB Varian (Clinac iX)	TG-74	% of deviation
5	0.9614	0.9610	0.04	0.9642	0.9680	−0.40
10	1.0000	1.0000	0.00	1.0000	1.0000	0.00
15	1.0175	1.0170	0.05	1.0154	1.0160	−0.06
20	1.0253	1.0270	−0.17	1.0245	1.0260	−0.15
30	1.0317	1.0320	−0.03	1.0372	1.0410	−0.37
40	1.0326	1.0320	0.06	1.0476	1.0510	−0.32

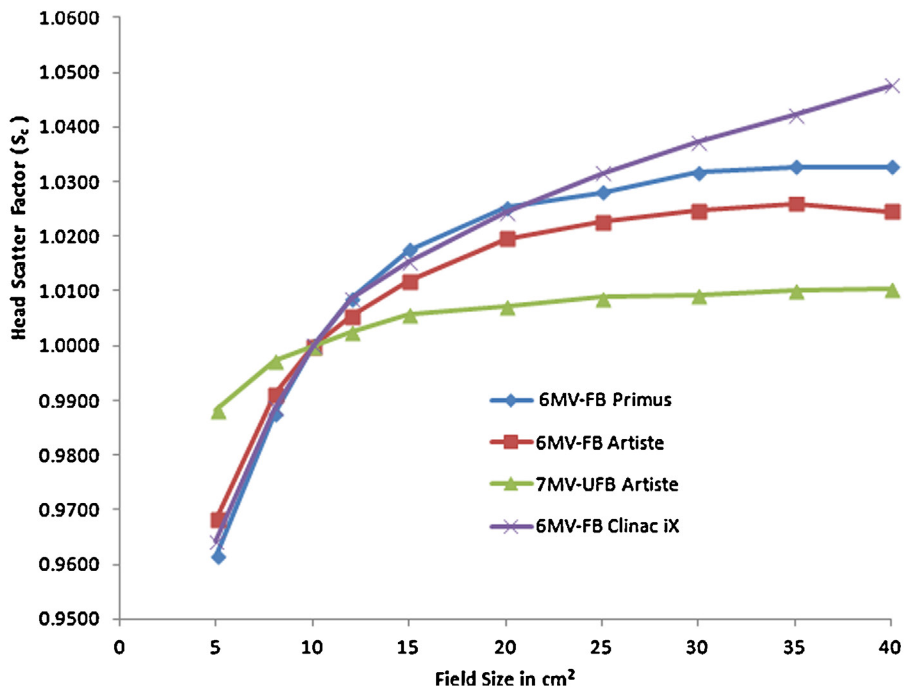

Fig. 8 – Sc values for three different linear accelerators with different field sizes for 6MV-FB and 7MV-UFB.

Cashmore.[43] Removal of flattening filter (7MV-UF) leads to a decrease in head scatter and reduces the whole body dose to the patient (reducing the risk of secondary cancers).

The role of SSD on the Sc was evaluated by measuring the Sc at different SSD (80, 100, 120 cm) with low Z mini phantom at 10 cm water equivalent depth for 6MV-FB and 7MV-UFB photon beams as shown in Fig. 5. The results suggest that the SSD had no influence on head scatter for both flattened and unflattened beams and irrespective of head design of the different linear accelerators. This is an agreement with the results of Rickard et al.[44]

Figs. 6 and 7 show the variation Sc for wedge filters positioned in the beam path. This was studied for the designed mini phantom of 6MV-FB and 7MV-UFB photon beams at different SSDs. The measurement compared with that of open and wedge fields for both Primus (6MV-FB) and Artiste (6MV-FB and 7MV-UFB) Siemens linear accelerators. A discrepancy was observed in Sc values with wedge and open fields for both energies. The maximum deviation is found to be 4.9% for larger fields of 6MV-FB and the corresponding value of 7MV-UFB is 2.9%. These findings indicate that the wedge filters produce new scattered electrons with increased fluence at shortest SSDs (80 cm) and decreased electron contamination at SSDs (120.0 cm) larger than normal treatment SSD (Fig. 7) for both flattened and unflattened photon beams. 7MV-UFB beams produce lesser scatter electrons compared to the 6MV-FB flattened beams with wedge filters placed in the beam path. These results are similar to those found by Henkelom et al.,[45] Zhu et al.,[13] Ling and Biggs.[28,29]

The collimator exchange effect was studied for both 6MV-FB and 7MV-UFB photon beams produced in Varian (Clinac iX (2300CD)) and Siemens (Artiste) as shown in Figs. 9 and 10 and Table 2. The collimator was exchanged from 4 cm × 40 cm to 40 cm × 4 cm field sizes. The maximum deviation observed was 2.5% for Varian and 1.6% for Siemens linear accelerator suggesting that the collimator exchange effect was lower in Siemens linear accelerator compared to Varian accelerator. This could be due to the difference of linear accelerator head construction and beam collimating devices of Varian machine. The collimator exchange effect might be due to the back scatter from the dose monitor chambers. The back scatter from the beam monitor chamber contributed up to 2% (6MV-FB) for Varian, 1.6% (6MV-FB) and 1.8% (7MV-UFB) for Siemens accelerator due to the collimator exchange effect for various rectangular field sizes as seen in Fig. 9. Thus, the results are

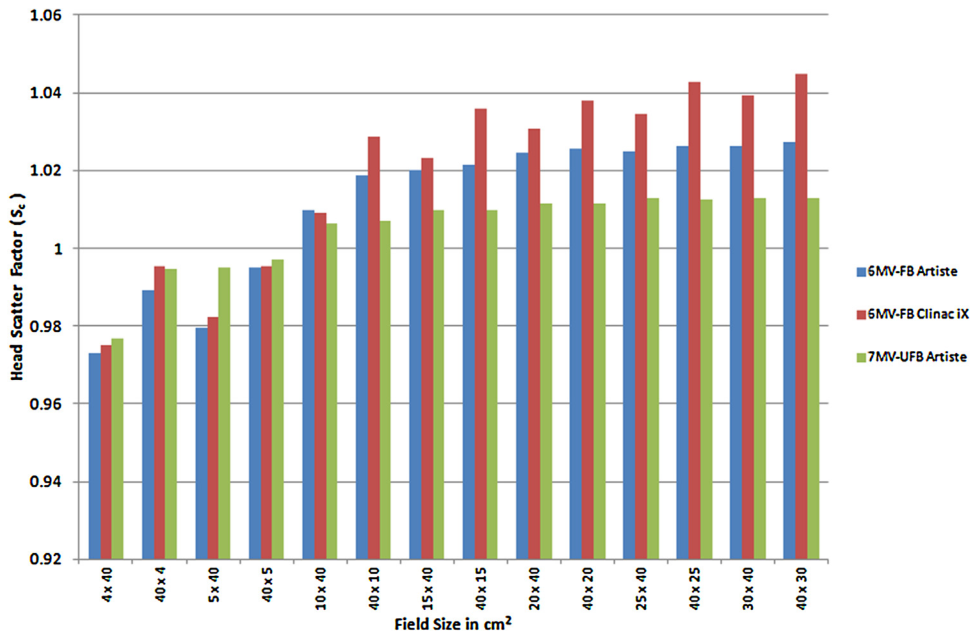

Fig. 9 – Variation of Sc for rectangular fields with *X* and *Y* jaws exchanged in Siemens (Artiste) and Varian (Clinac iX) linear accelerators.

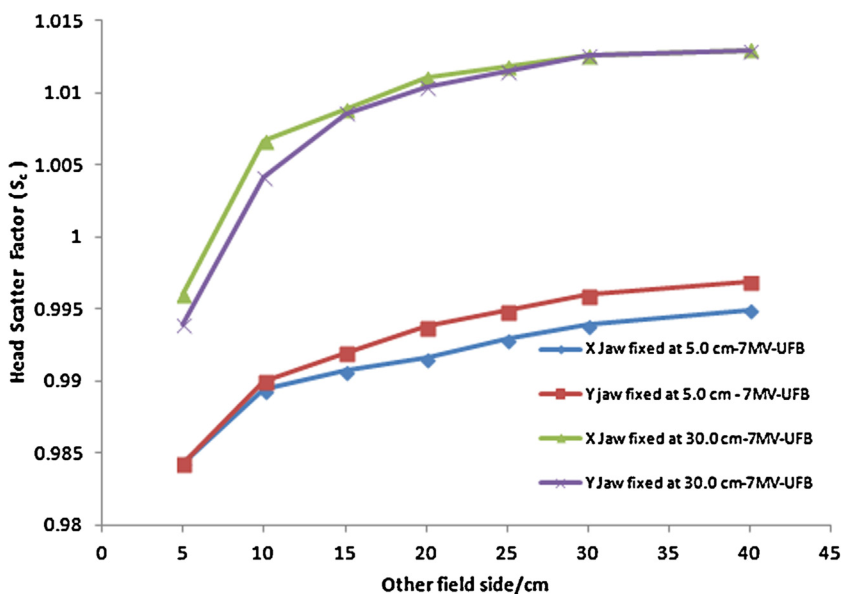

Fig. 10 – The collimator exchange effect in 7MV-UFB for larger and smaller asymmetric fields. The measured Sc factors are plotted as a function of the one field side, keeping either the *X*-lower or the *Y*-(upper) jawas fixed at 5.0 cm.

consistent with the measured data reported by Ding[46] for both flattened and unflattened photon beams.

6. Conclusions

The head scatter of 6MV-FB square field is measured with a indigenously designed low and high Z mini phantoms and validated by comparing the measured data with those of AAPM, TG-74 published data for both Siemens (Primus) and Varian (Clinac iX) accelerators. Further, the effect of Sc values with respect to low and high Z mini phantoms, SSD, beam modifying devices and due to collimator exchange of both 7MV-UFB and 6MV-FB photon beams were studied and the results are comparable with previously published data. For both flattened and unflattened beams Sc values were independent of SSDs. Also we found that the effect of collimator exchange on Sc is lesser in an unflattened beam. Our result clearly shows that a considerable amount of scattered radiation arises from the flattening filter in the linear accelerator head.

Conflict of interest

None declared.

Financial disclosure

None declared.

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