THE CORRECTION OF ELECTRON OUTPUT AT EXTENDED SSD

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ABSTRACT

Correction of electron output at extended treatment distance in Mitsubishi ML-15 MIII Linear Accelerator that available with the solid closed-sided applicator was performed. Comparison of electron outputs from inverse square law (ISL) correction with the outputs from direct measurement in electron field 4x4 to 14x14 cm^2, 101-115 cm SSDs with energies at 8,10,12, and 15 MeV revealed that ,with a nominal SSD ,the ISL calculation will provide the corrected output that fitting within $\pm$ 3 % of the measured output if the field size is equal to or larger than 10x10 cm^2 in all gaps and all energies. While with the effective SSD, the calculated outputs were found to agree with all the measured doses in all field sizes, all SSDs, and all energies in the study.

INTRODUCTION

Due to the limitation of the electron applicator or cone and sites of treatment such as head and neck, groin and vulva, extended source to surface distance (SSD) electron beam treatments are occasionally performed. Corrections to dose rate or output at extended SSD do not follow the inverse square law (ISL) if the nominal value of SSD (usually 100 cm.) is used. Because the interactions of electron with the components of accelerator head and the applicator differ from the photon. Therefore, the electron point source does not exist at the accelerator window as in the case of photon.[1] It is desirable to represent the extended electron point source so that divergence correction formulae such as ISL can be applied. Two methods of characterizing electron point source are virtual point source[2-4] and effective point source.[5] Either method is considered acceptable for calculating output at extended treatment distance. Except that the use of virtual SSD to predict dose variation with distance requires another correction factor in addition to ISL relationship while the effective SSD does not.[6] Moreover, because the electron output are strongly affected by the scatter from the cones. Thus, in this study we would like to investigate that with the closed-sided electron applicators that are available in our linear accelerator, nominal or effective SSD will be suitable in correcting electron output at extended SSD treatment.

MATERIALS AND METHODS

Three solid closed-sided square and rectangular electron applicators were shaped into 4x4, 6x6, 8x8,10x10,12x12 and 14x14 cm^2 fields by inserting the lead cut-outs that have suitable thickness for electron energies at 8,10,12, and 15 MeV.

Then, the depth of dose maximum (d_{max}) in each electron field and beam energy will be determined from the film isodose measurements. Type of film using are Kodak X-OMAT TL Ready pack film. All films were processed by Kodak X-

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OMAT Auto Processor M-35 and the optical density was read by the X-Rite 301 black and white densitometer that the aperture is 1mm. in diameter.

After that, the measurements of output at d_{max} were undertaken in water phantom by Farmer Dosemeter Type 2571 ionization chamber and electrometer. The measurements were made in a given electron field and beam energy at various SSD values ranging from 100-115 cm. These electron outputs from direct measurements at various SSDs will be compared with the electron outputs from the ISL calculation that the equation was shown following

$$Dose_g = Dose_0 \{(SSD + d_{max})/(SSD + d_{max} + Gap)\}^2 \quad (1)$$

$Dose_g$ and $Dose_0$ are the outputs at gap g and at the standard nominal SSD 100 cm., d_{max} is the depth of dose maximum for a given electron field and energy.

The SSD value in an equation (1) could be either a nominal SSD 100 cm. (SSD_{NOM}) or effective SSD (SSD_{EFF}) as shown in equation (2) and (3) below.

$$Dose_g = Dose_0 \{(SSD_{NOM} + d_{max})/(SSD_{NOM} + d_{max} + Gap)\}^2 \quad (2)$$

and

$$Dose_g = Dose_0 \{(SSD_{EFF} + d_{max})/(SSD_{EFF} + d_{max} + Gap)\}^2 \quad (3)$$

The method to obtain the value of effective SSD was proposed by Khan et al (1978).[5] Q_0 is the ionization charge reading at d_{max} at the standard nominal SSD and Q_g is the charge reading at d_{max} at various gaps (in this study the gaps from applicator end to phantom surface, g =1,2,3, 6,9,12,and15 cm respectively). The value of effective SSD for a given electron field and energy then be determined from the value of the slope of the curve plotting between the ratio of $(Q_0/Q_g)^{1/2}$ and gap g as shown in an equation (4). Figure 1 is an example to determine the effective SSD in electron field 10x10 cm^2 , 10 MeV energy by this method.

$$SSD_{EFF} = 1/slope - d_{max} \quad (4)$$

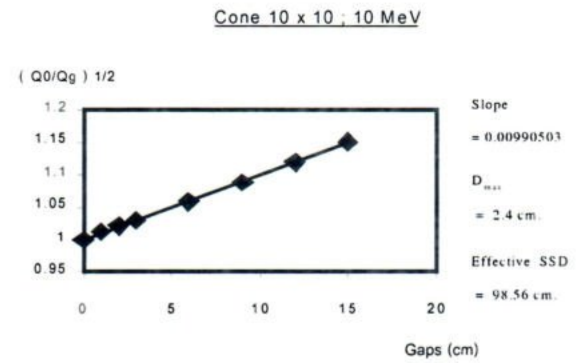

Fig.1 The curve plotting $(Q_0/Q_g)^{1/2}$ as a function of gaps in electron field 10x10 cm^2,10 MeV energy

Data will be analyzed by comparing the percentage of dose difference or variation between the calculated dose both with a nominal SSD and effective SSD in the ISL calculation to the dose from direct measurement.

$$\% \text{ Dose variation} = \frac{\text{Calculated dose} - \text{Measured dose}}{\text{Measured dose}} \times 100$$

RESULTS

The values of effective SSD in each electron field and beam energy that determined from a set of measurements are presented in Table 1.

Table 1. Effective SSD for various field sizes and beam energies

Field size	Effective SSD (cm)			
(cm^2)	8Mev	10MeV	12 MeV	15 MeV
4x4	59.14	65.88	69.66	75.18
6x6	66.83	73.94	78.69	86.48
8x8	84.98	90.46	98.25	93.36
10x10	91.28	98.56	95.48	100.65
12x12	96.44	102.53	100.91	102.85
14x14	98.93	101.50	103.39	95.87

The data in Table 1 clearly showed that the values of effective SSD in small fields prominently increased with the beam energy and also are much lower than the value of the nominal standard SSD. While in the large fields, the values are close to a nominal SSD and not depend on beam energy.

Comparisons of the output correction both with a nominal SSD and effective SSD in the ISL calculation with the output from direct measurement are simply presented by curves that plotting between the percentage of dose variation and gap distances as shown in Fig.2-Fig.7

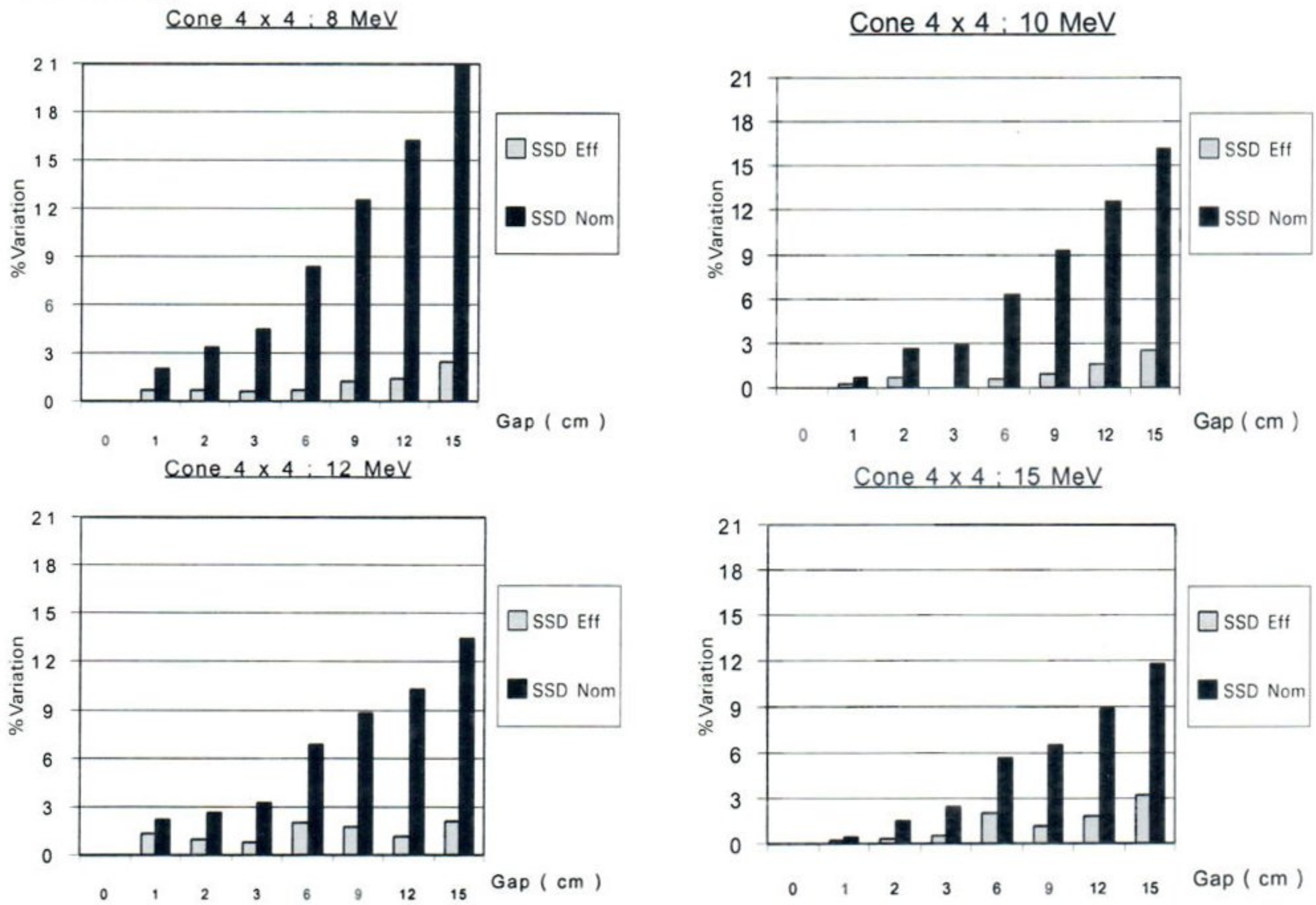

Fig. 2 Curve plotting the percentage of dose variation as a function of gaps in electron field 4x4 cm^2 at all energies

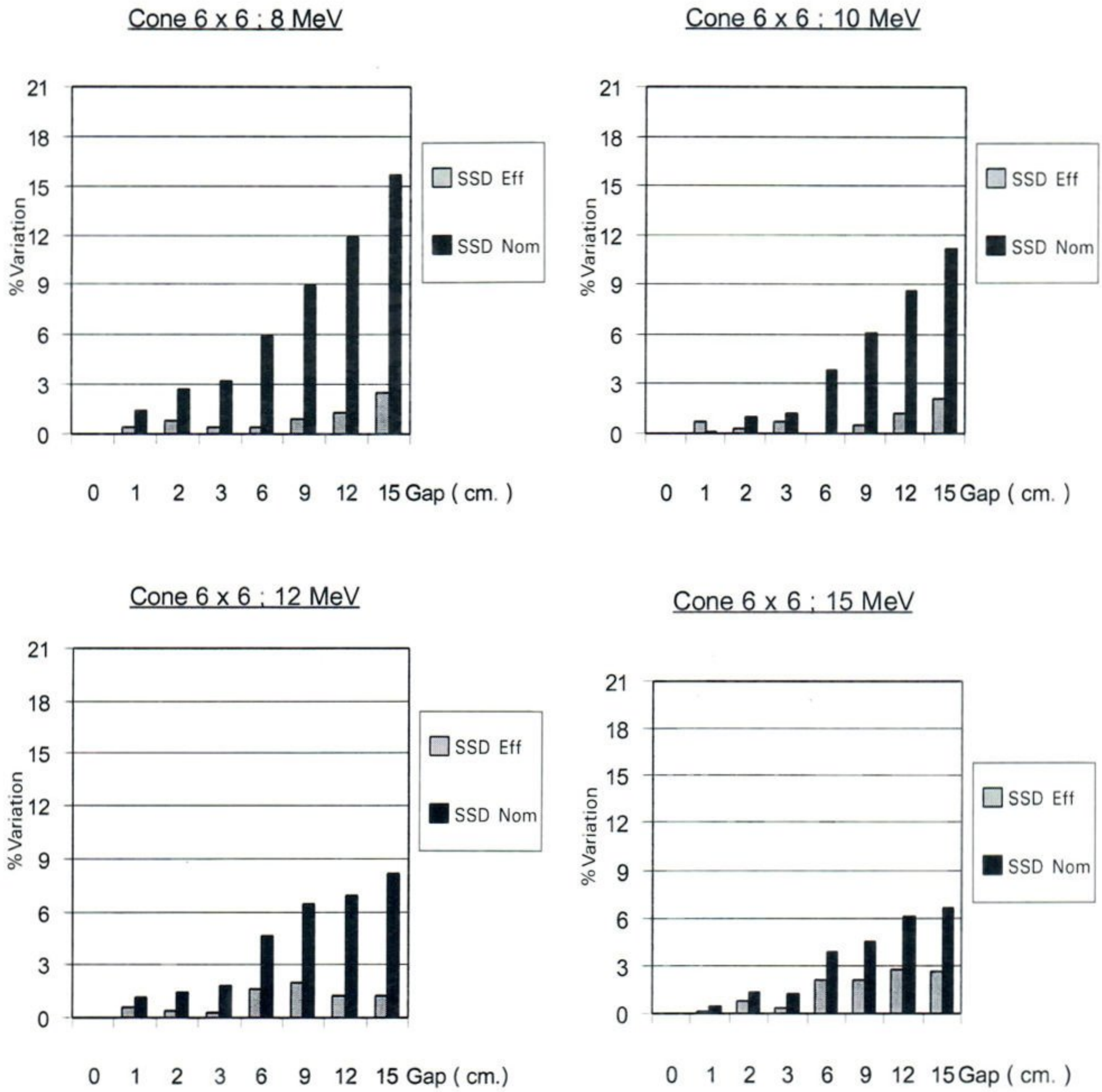

Fig. 3 Curve plotting the percentage of dose variation as a function of gaps in electron field 6x6 cm^2 at all energies

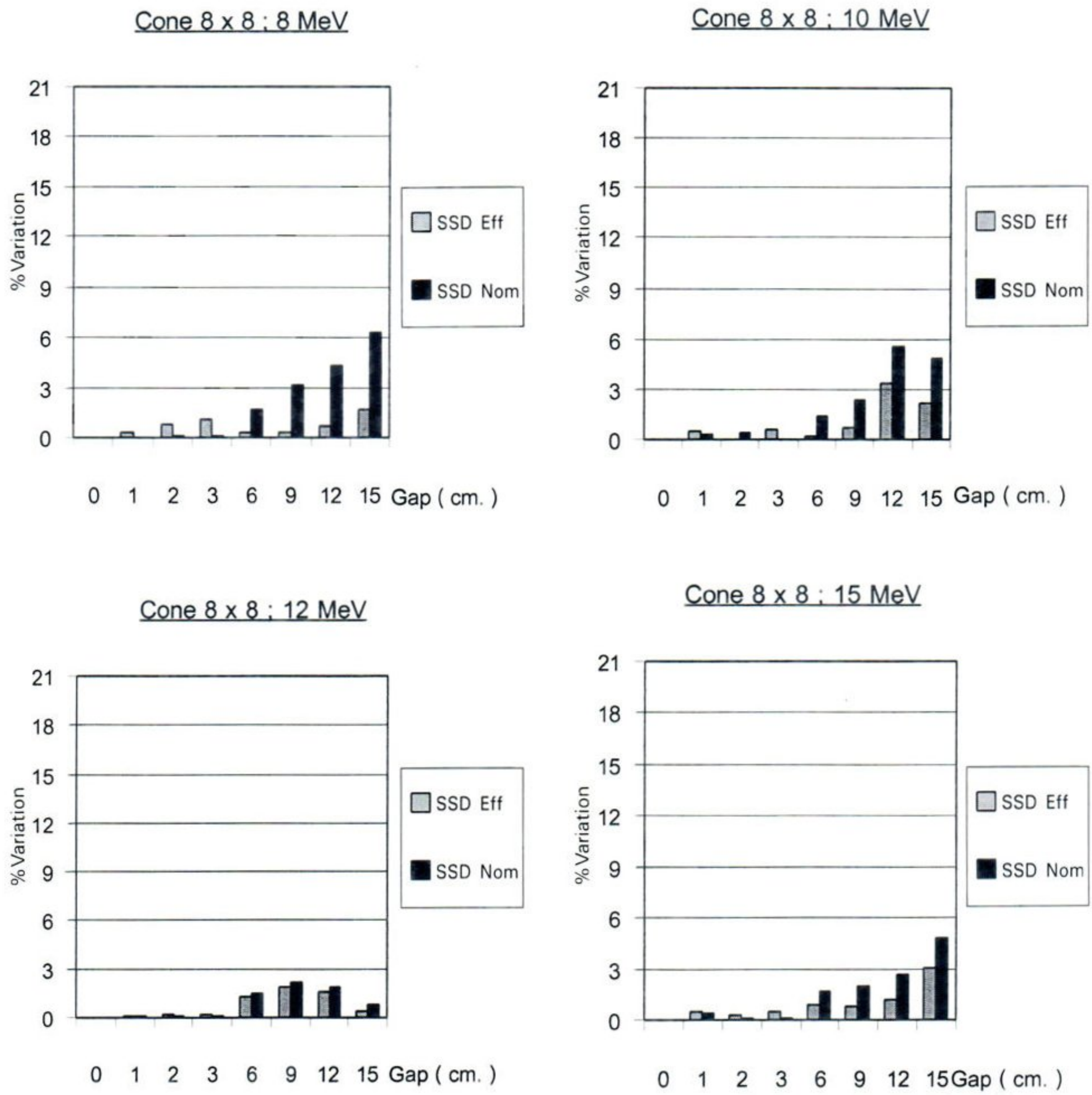

Fig. 4 Curve plotting the percentage of dose variation as a function of gaps in electron field 8x8 cm^2 at all energies

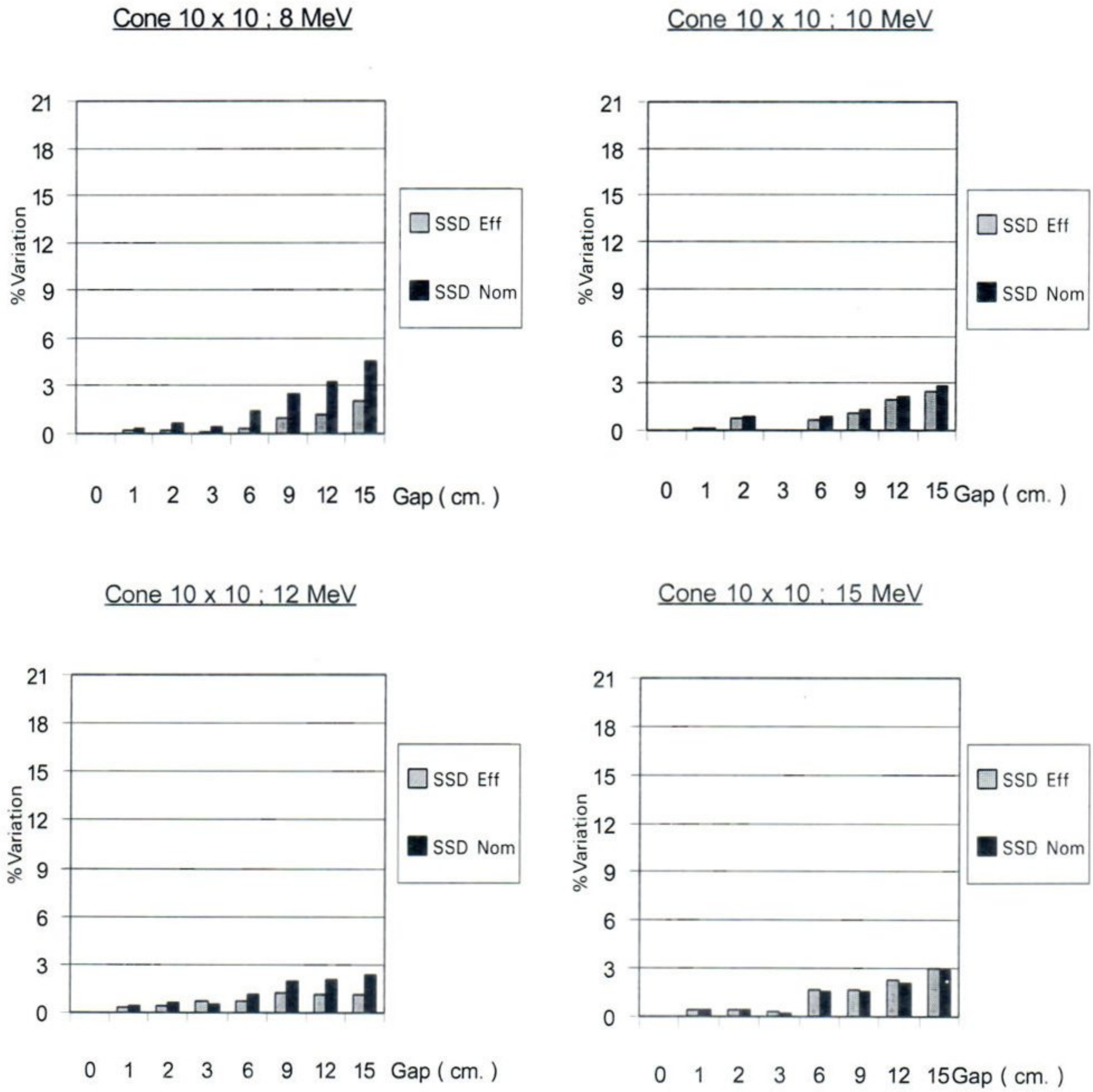

Fig. 5 Curve plotting the percentage of dose variation as a function of gaps in electron field 10x10 cm^2 at all energies

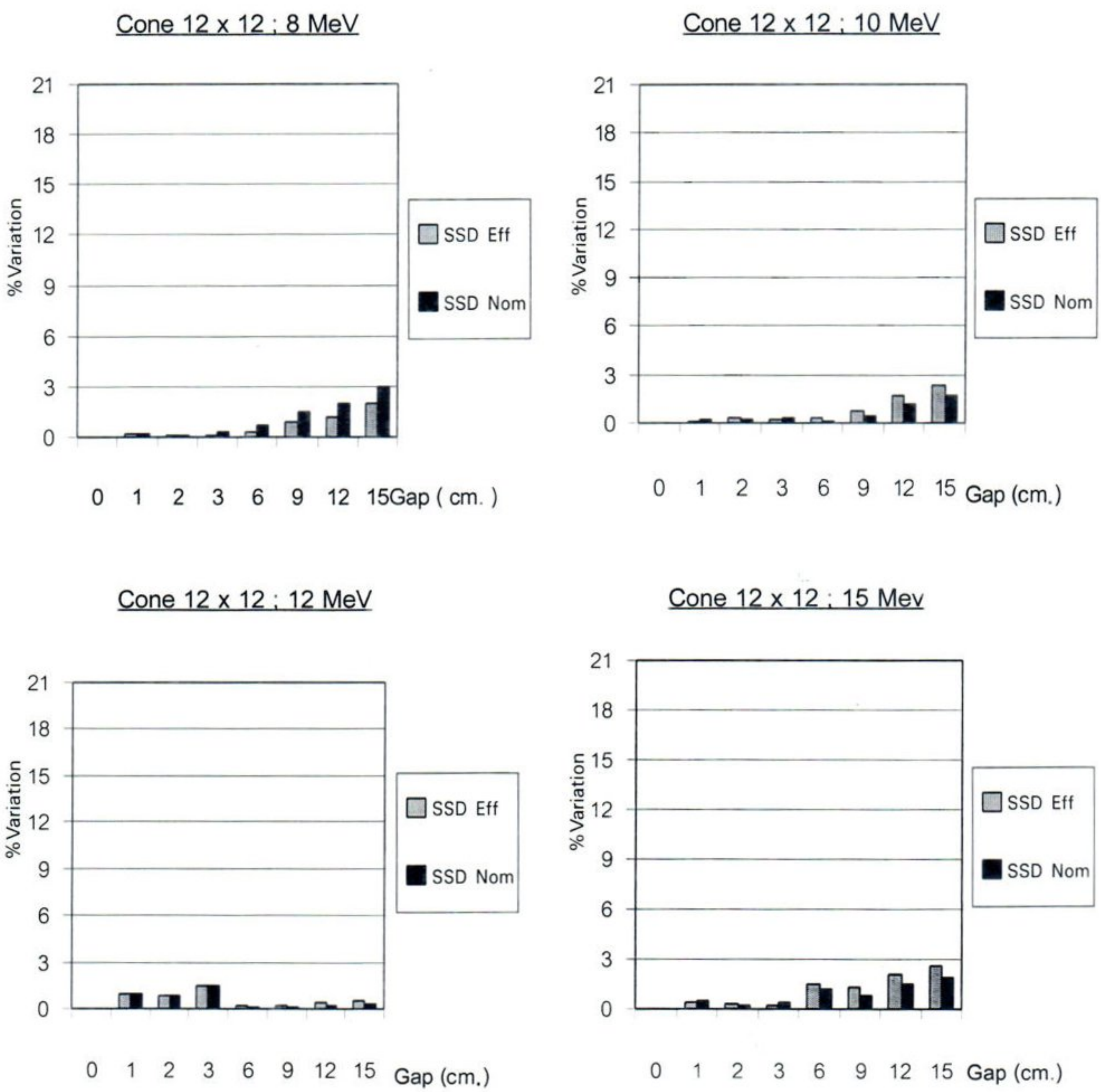

Fig. 6 Curve plotting the percentage of dose variation as a function of gaps in electron field 12x12 cm^2 at all energies

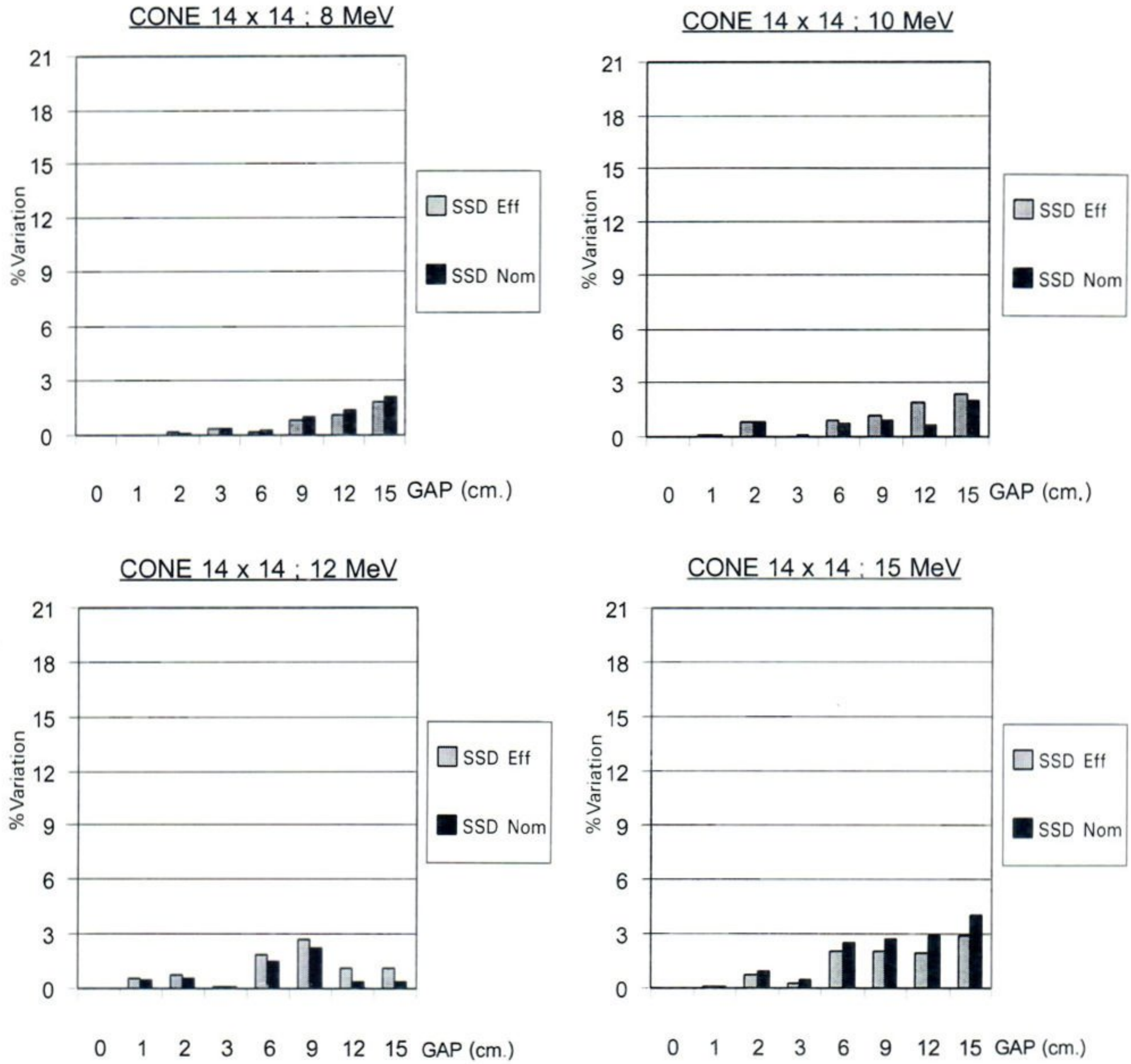

Fig. 7 Curve plotting the percentage of dose variation as a function of gaps in electron field 14x14 cm^2 at all energies

Based on Figure 2 to Figure 7, it could be seen that if the effective SSD is in the ISL calculation, the corrected dose will be fitted within ±3% of the measured dose in all field sizes, all SSD distances and all energies in the study. In contrast with the nominal SSD, the percentage of dose difference will be significantly high in small fields such as 4x4 and 6x6 cm^2 and in large gaps. But it will decreased rapidly with the beam size.As it was seen in 10x10 cm^2 field ,at almost energies, that the dose variation were in ±3% of the measured dose at all gaps. However, nominal SSD in the ISL dose correction are also found to be valid in small fields with in some small gaps. We summarized the maximum gap available for dose correction when a nominal SSD is in the ISL calculation as presented in Table 2.

Table.2 Maximum gap available when a nominal SSD is in the ISL dose correction at extended SSD

Field size (cm^2)	8 MeV	Energy (MeV) 10 MeV	12 MeV	15MeV
4x4	2	3	3	3
6x6	3	3	3	3
8x8	9	9	15	12
10x10	12	15	15	15
12x12	15	15	15	15
14x14	15	15	15	15

DISCUSSION AND CONCLUSION

In this study, we characterize the extended electron point source with the effective SSD method because of its advantages over the method of virtual point source. The effective SSD is measured under more realistic conditions of collimation and phantom scatter. Moreover, it is independent from depth, so the effective SSD that normally determined at d_{max} would be adequate for correcting dose at all depths.[5]

Effective SSD is known to vary with field sizes and strongly depend on the accelerator characteristics. For a given energy, the effective SSD depends strongly on the collimator opening and for a given collimator opening, the effective SSD depends on the energy of the beam.[5,7-9] This investigation, with the difference in electron applicator design, the results agreed with the previous studies in small fields only. In large electron fields (≥ 8x8 cm^2), it showed that the effective SSD were independent from both field size and beam energy.

It can be concluded from this study that, with the effective SSD, the inverse square law correction agreed for all field sizes, all SSDs and all energies. With the nominal SSD , the corrected dose will agree in all gaps, all energies in the study if the field size is equal to or larger than 10x10 cm^2. However, in small fields such as 4x4 and 6x6 cm^2, if the gap in the treatment is not too large, the nominal SSD are found to be valid in dose correction also. Use of the effective SSD or nominal SSD in correcting electron output at extended SSD treatment depends on clinical situation.

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