Polish Journal of Medical Physics and Engineering 2016;22(1):1-4
doi: 10.1515/pjmpe-2016-0001

Scientific Paper

Effect of the thermoplastic masks on dose distribution in the build-up region for photon beams

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Abstract

The aim of the study was to investigate the influence of thermoplastic masks material (Klarity Medical&Equipment Co., Guangzhou, China) with different diameters of holes (ϕ 0.25 cm and ϕ 0.40 cm) on the dose distribution in the build-up region for photon beams. Measurements were made for external radiation beams produced by the linear accelerator (TrueBeam, Varian Medical Systems, Inc., Palo Alto, CA, USA) using the Markus parallel plane ionization chamber and the Unidos electrometer (both from PTW, Freiburg, Germany). Measurements were made in a solid water phantom for two photon energies 6 MV and 15 MV, at 90 cm source to skin distance, for four fields of 5 cm x 5 cm, 10 cm x 10 cm, 15 cm x 15 cm and 20 cm x 20 cm. Compared to the open field, the maximum dose with mask was closer to the surface of the phantom by about 1.4 mm and 1.2 mm for 6 MV and 15 MV X-Rays, respectively. The surface dose increase from 10% to 42% for 6 MV and from 5% to 28% for 15 MV X-Rays.

Key words: radiotherapy; thermoplastic mask; X-ray; percentage depth dose; AAPM TG 176.

Introduction

Thermoplastic masks are mainly used in the head&neck region to ensure the good reproducibility of the patients position during fractionated radiotherapy. In general the surface dose is considerably increased and the position of the maximum dose is reached at a shallower depth. From a clinical point of view these changes lead to the increase of radiation-induced skin reactions, which is the disadvantage of a masks implementation [1]. It's important that skin doses over about 25 Gy at 2 Gy per fraction produce clinically relevant skin reactions and greater than 45 Gy may produce dry desquamation [2]. However, in the certain situations masks play a role of the bolus, which may help in delivering the full dose to malignant tissue located very close to the skin surface. Regardless, the use of masks is beneficial or not, the knowledge of the influence is helpful in clinical practice. There are various commercially available thermoplastic masks produced by different manufactures. They have different thickness and holes diameters. In this study the purpose was to investigated the influence of two types of unstretched thermoplastic masks offered by the Klarity company (Klarity Medical&Equipment Co., Guangzhou, China) on the dose distribution for photon beams (6 MV and 15 MV) delivered through flattering filter.

Materials and Methods

The influence of masks on a dose distribution was investigated for two different unstretched samples with hole sizes of ϕ 0.25 cm and ϕ 0.40 cm diameters **(figure 1)**. Both samples had thickness of 2 mm. The percentage depth dose (PDD) for two x-rays photon beam (6 MV and 15 MV) delivered through flattering filter were measured respectively for setup with and without mask material. All measurements were performed on the TrueBeam accelerator (Varian Medical Systems, Inc., Palo Alto, CA, USA) in solid water equivalent phantom. The data was collected with the Markus parallel plate ionization chamber (ref. no. 23343, PTW, Freiburg, Germany) and the Unidos electrometer (PTW, Freiburg, Germany). **Figure 2** shows the measurement set-up used in this study.

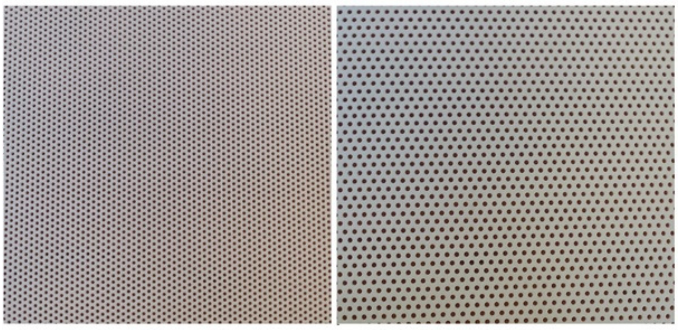

Figure 1. The sample masks with hole sizes of ϕ 0.25 cm (left) and ϕ 0.40 cm diameters (right).

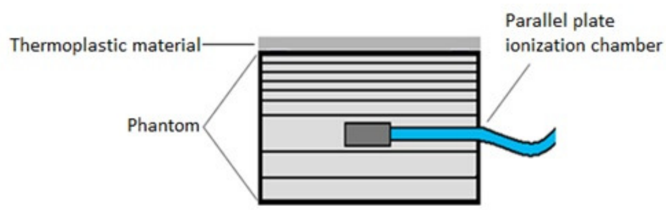

Figure 2. The measurement set-up.

The source skin distance (SSD) was 90 cm. The PDD measurements were performed for four square fields of 5 cm x 5 cm, 10 cm x 10 cm, 15 cm x 15 cm and 20 cm x 20 cm. The dose was measured with the resolution of 1 millimeter in depth range from 0 to 30 mm, and with a spacing of 5 mm at larger depths ranged from 30 to 60 mm. Each measurement was repeated three times. Percentage dose depth was determined by using the **equation 1** [3,4].

$$\mathrm{PDD}(\mathrm{d}, \mathrm{A}, \mathrm{SSD}, \mathrm{E}) = \frac{\mathrm{D(d)}}{\mathrm{D}(\mathrm{d}_{\max})} \times 100\% \qquad \text{Eq. 1}$$

where d - depth of measurement, A - radiation field size, SSD - Source Skin Distance, E - energy, D(d) - dose at depth d, $D(d_{max})$ - the maximum dose.

The inaccuracies in the measurement of dose in the buildup region when using Markus chamber are well known. Ideally extrapolation chamber or well-guarded fixed separation plane-parallel chamber should be used. The Markus chamber has narrow guard-ring causing perturbation of the electron fluence through the chamber side wall and significant overresponse in build-up region. Therefore, all results were corrected by the formula proposed by Gerbi and Khan **(equation 2)**. [5-7]:

$$\Delta\mathrm{PDD} = [27.19 - 32.59 \cdot \mathrm{TPR}^{20}_{10} + \mathrm{C} \cdot (-1.666 + 1.982 \cdot \mathrm{TPR}^{20}_{10})] \cdot \mathrm{L} \cdot \mathrm{e}^{\left(-5.5 \cdot \frac{\mathrm{d}}{\mathrm{d}_{\max}}\right)} \qquad \text{Eq. 2}$$

where TPR^{20}_{10} - parameter specifying the quality of the radiation beam, C - guard-ring width, L - the height of the air cavity, d - depth of measurement, d_{max} - the depth of maximum dose. In our case TPR^{20}_{10} for 6 MV was equal to 0.669 and for 15 MV was equal to 0.763. For Markus chamber (23343) C = 0.2 mm and L = 2 mm.

To correct PDD data points the four parameter function $D(D_0, \mu_1, \mu_2, d_0)$ was fitted using the least square method **(equation 3)**.

$$\mathrm{D} = \mathrm{D}_0 \cdot \mathrm{e}^{(-\mu_1 \cdot \mathrm{d})} \cdot \left(1 - \mathrm{e}^{(-\mu_2(\mathrm{d} + \sqrt{\mathrm{d}} - \mathrm{d}_0))}\right) \qquad \text{Eq. 3}$$

where D_0 - constant, describing the dose on the surface, μ_1 - parameter responsible for the PDD at depths larger than depth of maximum dose, μ_2 - parameter responsible for the PDD in the build-up region, d - depth, d_0 - constant.

Results

Figures 3 and 4 show the percentage depth dose measured for the square field size of 5 cm x 5 cm when the thermoplastic material with small and big holes (ϕ 0.25 cm and ϕ 0.40 cm) was placed on the phantom surface for energies 6 MV and 15 MV, respectively. The results indicate an unnoticeable influence of a hole diameter on the dose distribution for 6 MV and a very small difference for 15 MV at the depths from 0 mm to 10 mm.

Similar results were obtained for square field sizes of 10 cm x 10 cm, 15 cm x 15 cm and 20 cm x 20 cm. Non-significant differences between the results obtained for two kinds of masks. It allows us to further presentation the results obtained for one kind of mask.

Figure 5 and 6 show a comparison of percentage depth dose measured for a field size 5 cm x 5 cm, for masks with large holes (ϕ 0.40 cm) and without masks, for X-ray energy of 6 MV and 15 MV.

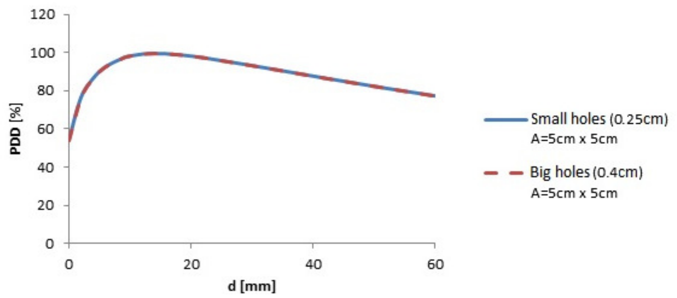

Figure 3. The PDD for the masks with hole diameters of ϕ 0.25 cm and ϕ 0.40 cm, for 6 MV. Results for square field of 5 cm x 5cm are presented.

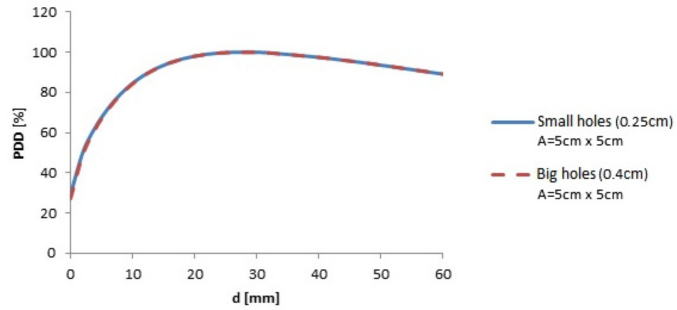

Figure 4. The PDD for the masks with hole diameters of ϕ 0.25 cm and ϕ 0.40 cm, for 15 MV. Results for square field of 5 cm x 5 cm are presented.

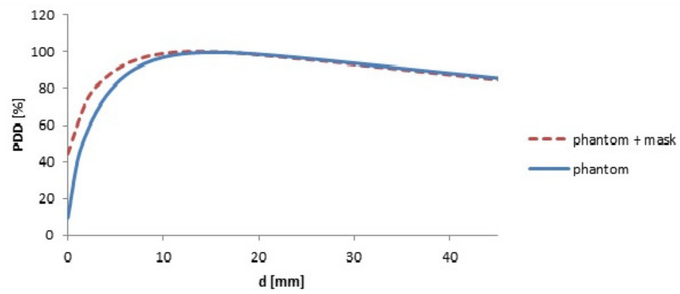

Figure 5. The comparison of PDD measured with a mask (ϕ = 0.40 cm) and without a mask for 6MV photon beam.

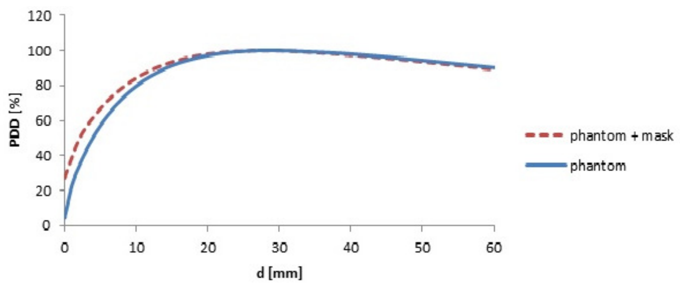

Figure 6. The comparison of PDD measured with a mask (ϕ = 0.40 cm) and without a mask for 15MV photon beam.

Table 1. The surface dose.

Set-up	Energy [MV]	Dose on the surface [%] for field A [cm^2]			
		A=5x5	A=10x10	A=15x15	A=20x20
Phantom	6MV	10	17	20	26
Phantom + Mask	6MV	42	48	52	58
Phantom	15MV	5	12	20	28
Phantom + Mask	15MV	28	34	41	52

Table 2. The depths of 70%, 90% and depths of maximum dose.

Set-up	Energy [MV]	PDD [%]	Depth of PDD [mm] for field A [cm^2]			
			A=5x5	A=10x10	A=15x15	A=20x20
Phantom	6MV	70%	3.5	3.0	2.5	2.0
		90%	7.0	6.5	6.0	5.5
		100%	15.2	14.9	14.5	13.9
Phantom + Mask	6MV	70%	2.0	1.5	1.0	0.5
		90%	5.5	5.0	4.5	4.0
		100%	13.6	13.5	13.1	12.9
Phantom	15MV	70%	8.0	6.5	5.5	4.5
		90%	14	12	11	9.5
		100%	29.2	27.2	25.1	23.1
Phantom + Mask	15MV	70%	7.0	5.5	4.5	3.5
		90%	13	11	10	8.5
		100%	27.9	26.4	23.9	22.1

In **table 1** the surface doses for fields with a mask and without a mask for all square fields and for 6 MV and 15 MV are given. In **table 2**, the depths of 70%, 90% and the depth of d_{max} measured with and without a mask for all fields and both energies are given. Measurement uncertainties shifts are respectively 0.5 mm.

Discussion

The purpose of this study was to investigate the effect of thermoplastic masks on the dose distribution in the build-up region of photon beams. As we show, the usage of thermoplastic masks slightly increases the therapeutic area located directly below the surface of the body. Due to the increase of the dose in the build-up region, the use of thermoplastic masks will result in increased radiation skin reactions. These reactions are uncontrolled when the mask is not included during the planning process. The planned doses in the skin area are inaccurate and significantly differ from the doses delivered during radiation therapy.

Our study was targeted on the specific product developed by Klarity Company. Therefore, the surface dose for Klarity masks increases respectively for 6 MV from 10% to 42% and for 15 MV from 5% to 28%, irrespective of the field size. Moreover, the maximum of the percentage depth dose occurs closer to the surface, in case of using thermoplastic material. For 6 MV, the average value by which the dose has been shifted (in the entire area of the build-up region) towards the surface was 1.4 mm, in turn for the energy of 15 MV it amounted to 1.2 mm. This shifting effect could be used positively for simple radiotherapy techniques (e.g. two opposite beams) when mask is included during planning process. For example, the 90% (PDD) isodose is reached at a depth of about 1 mm shallower, compared to the situation without mask. This may help in delivering the full-prescribed dose for targets located very superficially, however this dose increase may not always be sufficient.

Other important observation is, that 2 mm thickness of mask delivered by Klarity Company does not change the shape of the percentage depth curves. The dose increases rapidly and then slowly decreases. Our study shows that different hole diameters (e.g. ϕ 0.25cm and ϕ 0.40 cm) of thermoplastic material, have a very small influence on the characteristics of the percentage depth dose curve. Therefore we recommend the masks with a smaller diameter of the hole due to the increased stiffness and thus, better immobilization properties.

Conclusions

The use of a thermoplastic mask slightly increases the therapeutic area located directly below the surface of the body. The surface dose for Klarity masks increases respectively for 6 MV from 10% to 42% and for 15 MV from 5% to 28%, irrespective of the field size. The smaller (ϕ 0.25 cm) and larger holes (ϕ 0.40 cm) in investigated masks material affect the depth dose distribution in a comparable way.

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Appendix

Table 3. Provides a summary of four fitting parameters with errors, to the equation 3.

Set-up	Energy [MV] | File size [cm^2]	D_0	ΔD_0	μ_1	$\Delta\mu_1$	μ_2	$\Delta\mu_2$	d_0	Δx_0
Phantom	6MV A=5x5	113.0	0.2	0.00618	0.00005	0.179	0.001	-0.49	0.02
	6MV A=10x10	111.1	0.2	0.00545	0.00005	0.187	0.002	-0.78	0.02
	6MV A=15x15	110.0	0.2	0.00504	0.00005	0.197	0.002	-1.06	0.03
	6MV A=20x20	109.1	0.2	0.00479	0.00005	0.204	0.002	-1.34	0.03
Phantom + Mask	6MV A=5x5	112.8	0.8	0.0064	0.0002	0.169	0.005	-2.97	0.09
	6MV A=10x10	110.7	0.7	0.0056	0.0002	0.178	0.005	-3.24	0.10
	6MV A=15x15	109.6	0.7	0.0052	0.0002	0.183	0.006	-3.56	0.11
	6MV A=20x20	108.3	0.5	0.0048	0.0002	0.196	0.005	-3.73	0.10
Phantom	15MV A=5x5	121.8	0.7	0.00495	0.00009	0.086	0.001	-0.46	0.04
	15MV A=10x10	118.8	0.6	0.00462	0.00010	0.092	0.001	-1.23	0.05
	15MV A=15x15	116.2	0.5	0.00439	0.00008	0.101	0.001	-1.88	0.05
	15MV A=20x20	114.3	0.4	0.00425	0.00008	0.111	0.001	-2.45	0.06
Phantom + Mask	15MV A=5x5	122.9	1.1	0.0053	0.0001	0.078	0.002	-3.22	0.11
	15MV A=10x10	118.8	1.0	0.0047	0.0001	0.086	0.002	-3.97	0.14
	15MV A=15x15	115.9	0.7	0.0045	0.0001	0.096	0.002	-4.62	0.14
	15MV A=20x20	114.9	0.7	0.0045	0.0001	0.096	0.002	-6.22	0.14