Original Article

Investigating the Dosimetric Leaf Gap Correction Factor of Mobius3D Dose Calculation for Volumetric-modulated Arc Radiotherapy Plans

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Abstract

Aims: The dosimetric leaf gap (DLG) is a parameter for correcting radiation transmission through the round leaf end of multileaf collimators. The purpose of this study was to determine and investigate the optimal DLG correction factor for 6 MV volumetric-modulated arc radiotherapy (VMAT) plan dose calculations in Mobius3D. **Materials and Methods:** Seventeen VMAT plans were selected for the DLG correction factor optimization process. The optimal DLG correction factor was defined as the minimum difference between the measured dose and the Mobius3D-calculated dose on the Mobius Verification Phantom™ with different DLG correction factors. Subsequently, the optimal DLG correction factor was applied for Mobius3D dose calculation, and accuracy was assessed by comparing the measured and calculated doses. For verification and validation, the 17 previous plans and 10 newly selected plans underwent Mobius3D calculations with the optimal DLG correction factor, and gamma analysis was performed to compare them to the treatment planning system (TPS). Gamma analysis was also performed between the electronic portal imaging device (EPID) and the TPS for cross-comparison between systems. **Results:** The DLG correction factor was optimized to −1.252, which reduced the average percentage differences between measured and Mobius3D-calculated doses from 2.23% ±1.21% to 0.03% ±1.82%. The cross-comparison between Mobius3D/TPS and EPID/TPS revealed a similar trend in gamma passing rate (>95%) in both the verification and validation plans. **Conclusion:** The DLG correction factor strongly influences the accuracy of Mobius3D-calculated doses. Applying the optimal DLG correction factor can increase dose agreement and gamma passing rate between calculation and delivered doses of VMAT plans, which emphasizes the importance of optimizing this factor during the commissioning process.

Keywords: Dosimetric leaf gap, Mobius3D, patient-specific quality assurance, secondary dose check

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INTRODUCTION

Volumetric-modulated arc radiotherapy (VMAT) has been utilized in numerous oncology centers. It provides a highly concave target dose distribution by modulation of gantry movement, multileaf collimator (MLC) movement, and dose rate.[1-3] The high degrees of modulation enhance the complexity of beam delivery for treatment. This results in a higher chance of error in the treatment process. Patient-specific quality assurance (QA) should therefore be performed before the treatment to ensure the deliverability of the treatment plan.[4] A measurement-based QA is often used as a dosimeter tool for patient-specific QA, such as film, detector arrays, and ionization chambers. A secondary dose check has also been introduced as part of the patient-specific QA process. It serves as an independent system that verifies the performance of the primary treatment planning system (TPS). This approach is an additional system that cooperates with measurement-based QA to increase the chance of error detection. It also fulfills some aspects of limitations in measurement-based QA, which delivers a dose on the homogeneous phantom, whereas the

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secondary dose check verifies the dose on actual patient geometry.[5,6]

The Mobius3D (Varian Medical Systems Inc., Palo Alto, CA, USA) was released as a commercial secondary dose check and was used in numerous institutions.[7-10] This software utilizes data from the primary TPS, which includes computed tomography (CT) data, radiotherapy (RT) plan, and RT structure, and operates with the Collapsed Cone Convolution Superposition algorithm to calculate the three-dimensional dose distribution on the patient geometry. The dose calculation result is automatically compared with the primary TPS dose calculation for verification using information including the mean target dose, dose-volume histogram, and gamma passing rate.[11]

Although the secondary dose check system is similar to the conventional TPS, the Mobius3D system still requires a beam model to collaborate with the algorithm for dose calculations. The beam model of the Mobius3D contains a set of default data that is provided by vendor-specific reference beam data.[12] The software allows the user to adjust the default data in the configuration which includes the dosimetric leaf gap (DLG) correction factor, output factor, off-axis-ratio (OAR), and percentage depth dose (PDD).[11] These parameters require suitable commissioning before the implementation of Mobius3D as the secondary dose check. All parameters can impact the reliability of the Mobius3D.[13,14]

The DLG correction factor is applied in the calculation process for correcting the transmission of radiation through the round leaf end of the MLC.[11] This parameter should be determined and modified by the user. Numerous studies have been conducted to explore the impact of optimizing this parameter. Kim *et al*.[13] adjusted the default DLG correction factor to an optimal value, which enhanced dose calculation accuracy by approximately 2%. In addition, McDonald *et al*.[10] and Shepard and Frigo[15] reported that optimizing this correction factor could result in the dose agreement between measurement and Mobius3D calculations approaching zero. These studies emphasize the importance of optimizing this parameter. Moreover, Kim *et al*.[14] conducted a study optimizing the DLG correction factor with various linac machines, which demonstrated that the optimal DLG correction factors varied across the machines. This raises concerns that the optimization of this parameter should be site specific, as incorrect settings may result in the misinterpretation of secondary dose calculation checks in clinical implementation. The purpose of this study was therefore to determine and investigate the applied optimal DLG correction factor for 6 MV energy in VMAT plan calculations, using the Mobius3D for secondary checks of the TPS calculations before clinical implementation.

MATERIALS AND METHODS

Treatment planning system, linac machine, and Mobius3D

Eclipse version 16.1.0 (Varian Medical Systems, Palo Alto, CA, USA) was used as the primary TPS for creating patient VMAT plans and verification plans on a phantom. The TPS employed the analytical anisotropic algorithm (AAA) for dose calculations. This study utilized the TrueBeam linac (Varian Medical Systems, Palo Alto, USA) to deliver the beam, which was a Varian 120 Millennium MLC model.

The Mobius3D version 3.1 was installed, providing the vendor-specific beam model. The commissioning process was fully performed for the TrueBeam linac machine for a 6 MV energy by following the vendor guidelines.[11] Measurements of the output factors, OARs, and percentage depth doses (PDD) were compared to the provided beam model data, with tolerances of 1.5%, 2.0%, and 0.5% agreement, respectively. The stricter gamma evaluation criteria, such as 2%/2 mm or 3%/3 mm, could be applied for VMAT QA.

Dosimetric leaf gap correction factor optimization process

Another crucial procedure in the commissioning process is the optimization of the DLG correction factor. Initially, the vendor automatically determines an internal DLG value for each MLC, which cannot be modified in the Mobius3D. The DLG correction factor serves as an added parameter to combine with the internal DLG value to evaluate the MLC transmission of the rounded leaf end. The default value of this parameter was initially set to zero and can be manually adjusted in the configuration of each energy and machine. For the optimization process, the optimal DLG correction factor is determined as the minimum difference between the point dose measurement and the Mobius3D dose calculation. This minimization aims to reduce the difference in the DLG effect between the existing reality dosimetry and the inherent MLC modeling of the Mobius3D.

The Mobius Verification Phantom™ (MVP) was used as the verification phantom. It is a tissue-equivalent material phantom with an electron density of 1.03 g/cm^3 and dimensions of 23.0 cm × 26.0 cm × 10.0 cm. The MVP allows the placement of a CC13 ionization chamber (collecting volume = 0.13 cm^3; IBA Dosimetry, Germany) along seven positions, as shown in Figure 1. The MVP images were acquired by a CT simulator (Optima 580, GE Healthcare, Milwaukee, WI,

Figure 1: The Mobius Verification Phantom™ with seven slots for insertion of the ionization chamber (A to G location)

USA). The active region of CC13 (air) was overridden with a density of 1.0 g/cm^3 in the MVP images to reduce dose calculation errors due to air inhomogeneity. According to the manufacturer's specifications, the sensitivity of the CC13 is 3.8 nC/Gy, and the leakage current is $<\pm 4 \times 10^{-15}$ A.[16]

In total, 17 VMAT plans treated with the 6 MV TrueBeam linac were selected from various treatment sites for the DLG correction factor optimization process. The plan characteristics are shown in Table 1. These plans were calculated with original plan parameters on the MVP CT images in the Eclipse TPS and then exported to the Mobius3D. During the dose calculation process in the Mobius3D, each plan was calculated with DLG correction factors of +1, 0, and −1. In each plan, the mean dose within the active volume of the CC13 was recorded and used to compare with the measurement dose.

Subsequently, all of the plans were irradiated to the MVP, and the absolute doses were recorded. The ionization chamber was positioned in the low-dose gradient and high-dose region of each plan, selected from the seven available positions in the MVP. The percentage difference between the measured doses and the Mobius3D-calculated dose was defined using the following formula:

Percentage difference (%) = ([Calculated dose − Measured dose]/Measured dose ×100) (1)

A linear regression was fitted between the average percentage differences (on the y-axis) and the DLG correction factor (+1, 0, and −1) (on the x-axis). Subsequently, assuming a dose difference of 0 as the best-fit value between Mobius3D-calculated and measured doses, extrapolation was conducted to determine the x-intercept on the line where the dose difference equals 0. Through this extrapolation, the optimal DLG correction factor was determined at the x-intercept point.

Table 1: The selected volumetric-modulated arc radiotherapy plans for the Mobius3D dosimetric leaf gap optimization, along with each parameter's details

Plan number	Treatment site	Energy (MV)	Technique	MU	Number of arcs
1	Pelvis	6	VMAT	521	3
2	Pelvis	6	VMAT	465	3
3	Pelvis	6	VMAT	1385	3
4	Pelvis	6	VMAT	1519	3
5	Head and neck	6	VMAT	540	3
6	Head and neck	6	VMAT	421	3
7	Head and neck	6	VMAT	581	3
8	Head and neck	6	VMAT	411	2
9	Head and neck	6	VMAT	466	3
10	Head and neck	6	VMAT	584	3
11	Head and neck	6	VMAT	638	3
12	Head and neck	6	VMAT	619	3
13	Head and neck	6	VMAT	631	3
14	Head and neck	6	VMAT	542	3
15	Chest	6	VMAT	465	3
16	Chest	6	VMAT	418	4
17	Chest	6	VMAT	558	4

VMAT: Volumetric-modulated arc radiotherapy, MU: Monitor unit

Investigating the accuracy of the optimal dosimetric leaf gap correction factor

The optimal DLG correction factor was applied in the Mobius3D for dose calculation. The 17 VMAT plans in the MVP were then recalculated using this factor. The percentage differences between the absolute dose and the Mobius3D-calculated dose with +1, 0, −1, and optimal DLG correction factors were recorded in each plan to observe the accuracy of applying these factors. In addition, a comparison was also made between the TPS-calculated and the measured doses. A paired *t*-test was conducted to compare the accuracy of dose calculation between the measurements of the TPS and the Mobius3D dose calculation using the default and the optimal DLG correction factors. The statistical analysis was conducted using SPSS statistical software version 18.0 (SPSS Inc., Chicago, IL, USA).

Investigation of preclinical implementation

To verify the application of the optimal DLG correction factor with patient geometry, the Mobius3D was used to compute VMAT plans for the previous 17 patients by applying both optimal and default DLG correction factors to each patient's CT image. The mean difference in target dose between Mobius3D and the TPS was used to assess agreement between the systems. The mean target doses were obtained through planning target volume (PTV) in each plan. In addition, the dose distribution agreement was evaluated through a global gamma analysis with criteria of 5%/3 mm, 3%/3 mm, and 3%/2 mm, using a low-dose threshold of 10%. The gamma analysis was adopted from the concept of Low *et al*.[17] A further set of 10 VMAT plans was also selected to validate the implementation of the optimal DLG correction factor to ensure its accuracy in other clinical plans.

In addition, to perform measurement-based QA against the Mobius3D for all of the VMAT plans, a Varian aSi 1200 electronic portal imaging device (EPID) was utilized. The 3%/2 mm gamma criterion with the low-dose threshold of 10% was applied to analyze the differences between the EPID-based verification and the Eclipse-calculated dose distribution, following the measurement-based QA guideline.[4] Although the dose distribution of the EPID-based QA could not be directly compared with that of the Mobius3D, the agreement of gamma passing rates was investigated through an indirect comparison of Mobius3D with the TPS and EPID-based measurements with the TPS. The overall workflow in this study is summarized in Figure 2.

RESULTS

Dosimetric leaf gap correction factor optimization

The average percentage differences between the measured dose from the CC13 ionization chamber and Mobius3D-calculated doses, with the +1, 0, and −1 DLG correction factors on the MVP, were 4.05% ± 1.00% (range of error: 1.98%–5.83%), 2.230% ± 1.21% (range of error: 0.11%–3.78%), and 0.458% ± 1.68% (range of error: −2.37%–3.08%), respectively. These differences were applied to create the linear regression model as illustrated in Figure 3. The R-squared value of fitting by the linear regression model was 0.9999. The lowest percentage difference (0%) between the measurement dose and the DLG correction factor of the Mobius3D was −1.252, which was extrapolated from the linear regression model. The optimal DLG correction factor was therefore defined as −1.252 for the 6 MV TrueBeam linac in our institution.

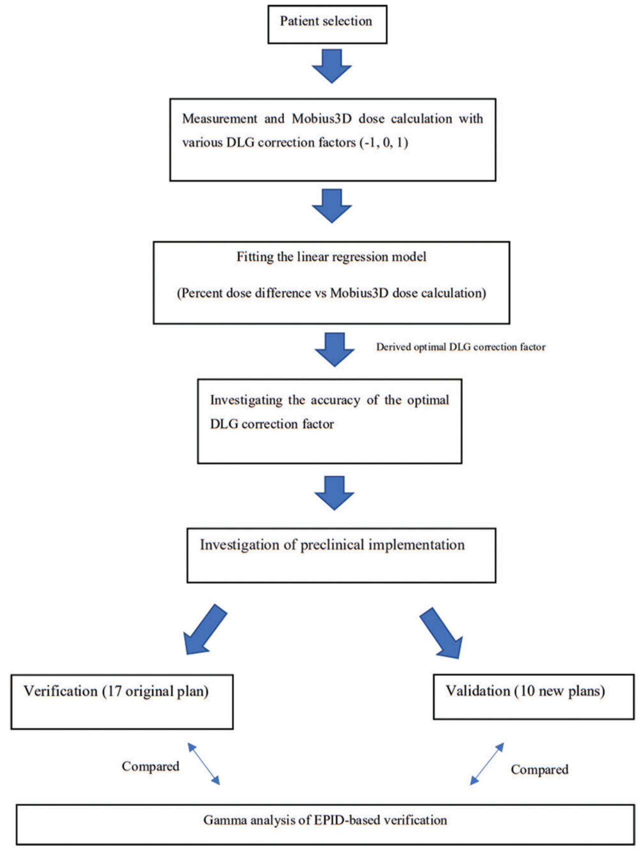

Figure 2: The summary workflow illustrates the methodological setup for investigating the dosimetric leaf gap correction factor of Mobius3D dose calculation for volumetric-modulated arc radiotherapy plans. DLG: Dosimetric leaf gap, EPID: Electronic portal imaging device

Investigating the accuracy of the optimal dosimetric leaf gap correction factor

Figure 4 graphically illustrates the percentage differences between the measured dose from the CC13 ionization chamber and the dose calculated by the Mobius3D, using various DLG correction factors (+1, 0, −1, and optimal [−1.252]). Almost all of the percentage differences between the Mobius3D and the measured dose tended to become close to zero when the DLG correction factor was adjusted from its default value of 0 to the optimal value of −1.252. The average percentage differences decreased from 2.23% ±1.21% (range: 0.11%–3.78%) to 0.03% ±1.82% (range: −3.01%–2.91%).

The percentage differences between the TPS-calculated and the measured doses are also plotted in Figure 4 for all plans, and these differences were also found to be close to zero. The average percentage difference was −0.60% ±1.31% (range: −2.64%–2.85%). To further investigate these results, a paired *t*-test was performed to statistically evaluate the percentage difference between the measurements of the TPS and the Mobius3D dose calculations with the default and the optimal DLG correction factor. A statistically significant percentage difference was observed ($P < 0.05$) between the TPS and the Mobius 3D with the default DLG. However, when applying the optimal DLG, there was no statistically significant difference between these systems ($P \geq 0.05$).

Investigation of preclinical implementation

Figure 5 shows the mean target dose differences, which were read from the PTV contour, between the TPS and Mobius3D

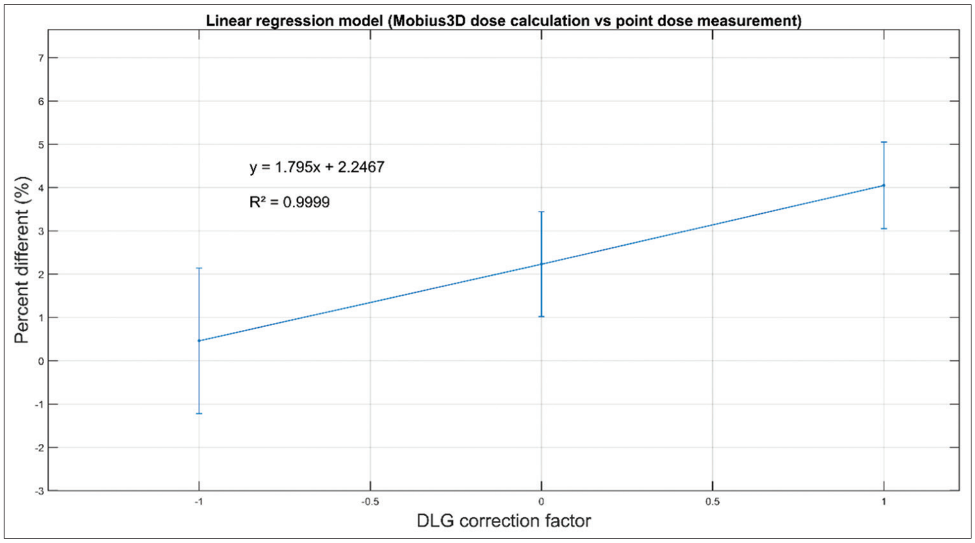

Figure 3: Linear regression modeling of the various dosimetric leaf gap correction factors and the percentage difference between the measured dose and Mobius3D-calculated dose. DLG: Dosimetric leaf gap

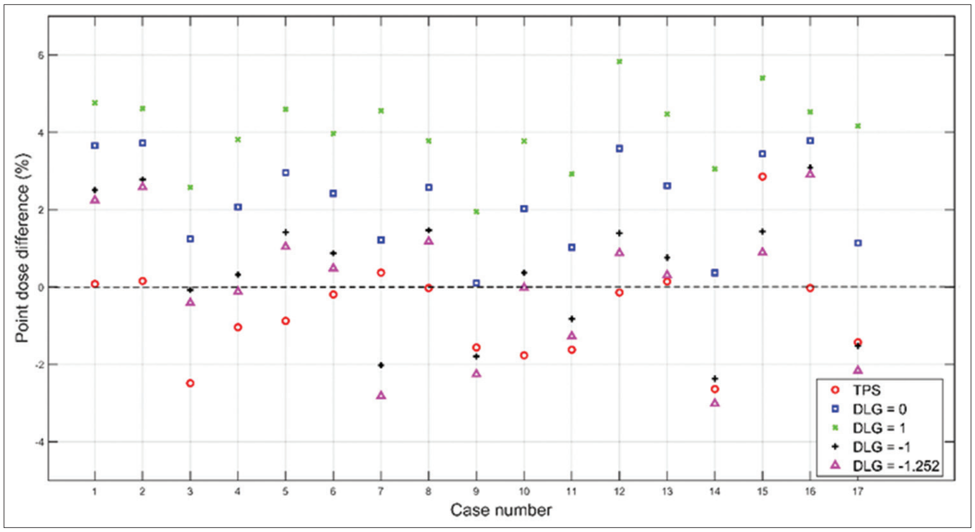

Figure 4: Comparison of the percentage differences between the measured dose (obtained using a CC13 ionization chamber) and the Mobius3D dose calculation, considering different dosimetric leaf gap correction factors and the treatment planning system on the Mobius Verification Phantom™ for 17 volumetric-modulated arc radiotherapy plans. DLG: Dosimetric leaf gap, TPS: Treatment planning system

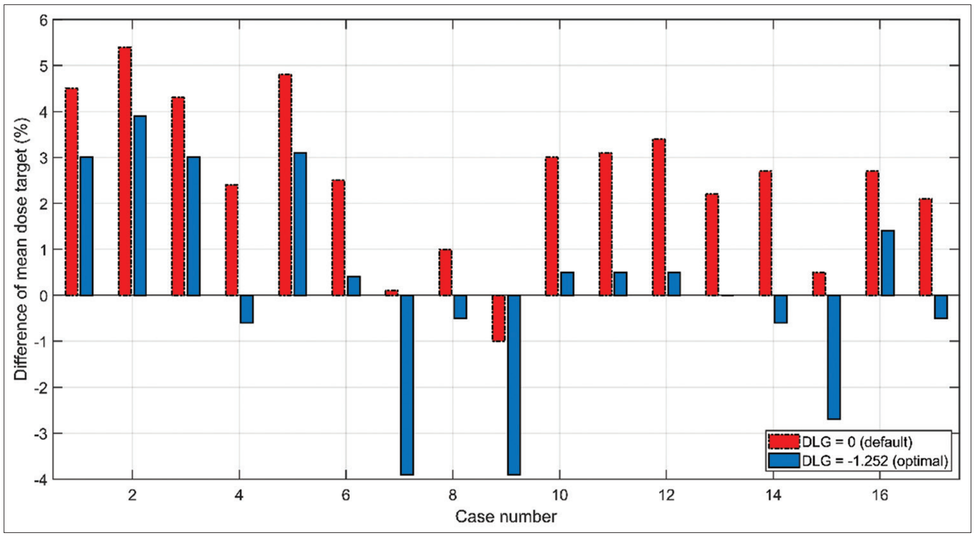

Figure 5: Mean target dose differences between the Mobuis3D-calculated dose (using the optimal and the default dosimetric leaf gap correction factors) and the Eclipse treatment planning system from the 17 verification patient plans. DLG: Dosimetric leaf gap

with the default DLG for the 17 plans. Notably, for 16 out of 17 VMAT plans, the mean target doses calculated by Mobius3D were consistently higher than the TPS. However, after applying the optimal DLG correction factor, the mean target doses tended to agree more closely between the TPS and Mobius3D.

Table 2 shows the global gamma passing rates obtained from comparing the dose distributions between the TPS and the Mobius3D, using the default and the optimal DLG correction factors.Applying the optimal DLG correction factor for the Mobius3D calculated dose resulted in higher gamma passing rates than using the default DLG correction factor in most of the plans. The average global gamma passing rates when using the 0 DLG correction factor (default) were 98.90% ± 1.76% (range: 93.5%–100%), 94.23% ±5.55% (81.8%–100%), and 92.16% ±6.87% (range: 78.5%–99.6%) for 5%/3 mm, 3%/3 mm, and 3%/2 mm, respectively. The average global gamma passing rate when applying the −1.252 DLG correction factor (optimum) was 99.75% ±0.35% (range: 98.7%–100%), 97.74% ± 2.80% (range: 91.9%–99.9%), and 95.68% ± 3.66% (range: 88.5%–99.9%) for 5%/3 mm, 3%/3 mm, and 3%/2 mm, respectively. The gamma passing rates obtained by comparing the TPS and EPID-based verification are also presented in Table 2, for which the average global gamma passing rate with 3%/2 mm was 98.72% ± 1.54% (range: 93.9%–100%).

The mean target dose differences between the TPS and Mobius3D for the 10 new plans are shown in Figure 6. The trend of differences was positive, indicating that the calculated target dose of Mobius3D was higher than the TPS. However, after using the optimal DLG correction factor, the mean target

Table 2: Comparison of gamma passing rates with various criteria between Mobius3D (optimal and default dosimetric leaf gap correction factor) and treatment planning system, as well as electronic portal imaging device and treatment planning system for 17 verification patient plans

Plan number	Gamma passing rate (%)						
	Mobius3D (default DLG) versus TPS			Mobius3D (optimal DLG) versus TPS			EPID versus TPS
	5%/3 mm	3%/3 mm	3%/2 mm	5%/3 mm	3%/3 mm	3%/2 mm	3%/2 mm
1	97.5	86.4	82.1	99.7	93.4	91.8	100
2	97.5	91.1	89.7	99.7	95.7	94.4	99.4
3	96.5	81.8	78.5	99.2	92.3	91.0	99.9
4	100	98.3	97.7	100	99.9	99.9	97.5
5	93.5	84.8	78.5	98.7	91.9	88.5	99.7
6	99.9	97.5	96.4	100	99.6	98.5	99.4
7	100	100	99.5	99.6	97.9	91.4	99.2
8	100	99.8	99.2	100	99.9	98.9	98.8
9	100	99.9	99.6	99.7	98.6	96.1	93.9
10	99.9	94.9	92.6	100	99.2	97.5	98.9
11	99.3	93.1	90.0	100	99.4	97.7	99.7
12	99.1	94.6	93.8	100	99.8	99.2	98.3
13	100	96.2	94.5	100	99.8	98.5	99.9
14	99.7	95.3	94.0	100	99.9	99.6	97.5
15	100	99.6	97.9	99.7	98.9	94.6	99.7
16	98.7	91.2	88.4	99.6	95.9	91.9	97.0
17	99.8	97.5	94.4	99.9	99.5	95.8	99.4
Average	98.90±1.76	94.23±5.55	92.16±6.87	99.75±0.35	97.74±2.80	95.68±3.66	98.72±1.54

TPS: Treatment planning system, EPID: Electronic portal imaging device, DLG: Dosimetric leaf gap

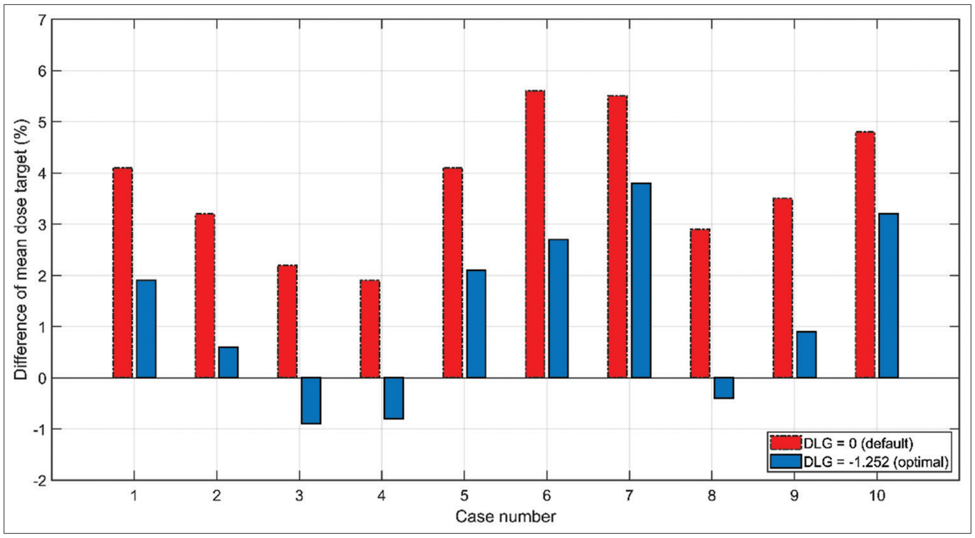

Figure 6: Mean target dose differences between Mobuis3D dose calculation (the optimal and the default dosimetric leaf gap correction factor) and the Eclipse treatment planning system from the new 10 validation patient plans. DLG: Dosimetric leaf gap

dose tended to match better between the TPS and Mobius3D doses.

The gamma passing rates obtained from the comparison between the TPS and the Mobius3D with the optimal and the default are shown in Table 3 for the 10 plans. The average global gamma passing rates when using the default DLG correction factor of 0 were 98.33% ± 1.75% (range: 94.4%–99.9%), 95.27% ± 3.30% (88.5%–99.3%), and 92.73% ± 4.67% (range: 83.1%–98.5%) for 5%/3 mm, 3%/3 mm, and 3%/2 mm, respectively. The mean global gamma passing rate when applying the optimal DLG correction factor of −1.252 was 99.87% ± 0.15% (range: 99.6%–100%), 98.38% ± 1.54% (range: 94.5%–99.7%), and 96.28% ± 1.96% (range: 92.6%–98.5%) for 5%/3 mm, 3%/3 mm, and 3%/2 mm, respectively. The gamma passing rates obtained by comparing the TPS and EPID-based verification are also presented in Table 3, and the average global gamma passing rate with 3%/2 mm was 99.14% ±0.84% (range: 97.3%–99.9%).

DISCUSSION

The Mobius3D dose calculations demonstrated a high degree of agreement with the ionization chamber measurements after the optimal DLG correction factor (−1.252) was applied. The average difference between the Mobius3D-calculated dose with the optimal DLG correction factor and the measured dose was almost zero (0.03 ± 1.82, range of error: −3.01–2.91), indicating that the DLG optimization process could enhance the accuracy of the Mobius3D dose calculation. The results of the paired *t*-test showed no significant difference in accuracy between the Mobius3D dose calculation with the optimal DLG correction factor and the Eclipse TPS. The average percentage difference also agreed very well with results of previous studies from McDonald *et al*.,[10] Kim *et al*.,[13] and Shepard and Frigo[15] [Table 4]. In the Shepard and Frigo study, the average point dose difference between the measured dose and the Mobius3D-calculated dose with the optimal DLG correction factor closely matched our findings, with an average percent difference of −0.1 ± 2.0 (range of error: −6.1–2.6).[15] The study was also conducted with Varian TrueBeam with the Millennium MLC in various energies. The optimal DLG correction factors were adjusted for 6, 10, 15, 6FFF, and 10FFF MV as −0.02, 0.89, −0.46, −0.71, and 0.07, respectively. Kim *et al*.[13] conducted the study with 6 MV but with a different MLC model and linac machine (Elekta Versa HD with Agility MLC), where the optimal DLG correction factor was defined as 1.0. The average percentage difference was 0.6 ± 1.9 (−1.9–3.2), which also agreed well with our study results. These findings emphasize the uniqueness of the optimal DLG correction factor, even under seemingly identical conditions. Different optimal values were determined even though the linac machine and MLC model were similar to our study. This might be due to the different cases used for optimizing the DLG correction factor, which reflect the different degrees of modulation levels from this study. In addition, the utilization of various energies also demonstrates various ranges of optimal DLG correction factors. We therefore suggest that this factor should be individually adjusted at each site, as it may depend on several

Table 3: Comparison of gamma passing rates with various criteria between Mobius3D (optimal and default dosimetric leaf gap correction factor) and treatment planning system, as well as electronic portal imaging device and treatment planning system for 10 validation patient plans

Plan number	Gamma passing rate (%)						
	Mobius3D (default DLG) versus TPS			Mobius3D (optimal DLG) versus TPS			EPID versus TPS
	5%/3 mm	3%/3 mm	3%/2 mm	5%/3 mm	3%/3 mm	3%/2 mm	3%/2 mm
1	97.3	88.5	83.1	99.8	97.5	95.4	99.7
2	98.9	99.3	98.5	100	99.3	98.5	99.1
3	99.9	98.8	98.2	100	99.7	97.7	99.5
4	99.9	97.1	95.6	100	99.4	98.4	98.3
5	98.5	95.9	94.2	99.8	98.3	95.6	99.9
6	96.6	92.8	91.9	100	98.5	97.4	99.8
7	94.4	92.0	90.4	99.6	94.5	92.6	98.6
8	99.2	95.4	90.9	99.8	98.6	94.3	99.7
9	99.5	96.8	95.4	100	99.7	97.7	99.5
10	99.1	96.1	89.1	99.7	98.3	95.2	97.3
Average	98.33±1.75	95.27±3.3	92.73±4.67	99.87±0.15	98.38±1.54	96.28±1.96	99.14±0.84

TPS: Treatment planning system, EPID: Electronic portal imaging device, DLG: Dosimetric leaf gap

Table 4: Comparing the average point dose difference between the measured dose and the Mobius3D-calculated dose with the optimal dosimetric leaf gap correction factor to those of other publications

References	Linac machine	Plan technique	Number of plans	Energy (MV)	Phantom	Range of percent difference (%)	Average±SD of percent difference (%)
McDonald *et al*.[10]	Varian TrueBeam	VMAT	9	6, 10	MVP	−3.3–2.1	0.2±1.3
		IMRT	8	6, 10	MVP	−3.1–1.8	−0.7±1.0
Shepard and Frigo[15]	Varian TrueBeam	VMAT	7 (for each energy)	6, 10, 15, 6 FFF, 10 FFF	Cheese phantom	−6.1–2.6	−0.1±2.0
	Varian TrueBeamSTx	VMAT	7 (for each energy)	6, 10, 6 FFF, 10 FFF	Cheese phantom	−4.0–2.2	0.0±1.5
Kim *et al*.[13]	Elekta VersaHD	VMAT	13	6	ArcCHECK phantom	−1.9–3.2	0.6±1.9
This study	Varian TrueBeam	VMAT	17	6	MVP	−3.01–2.91	0.03±1.82

VMAT: Volumetric-modulated arc radiotherapy, FFF: Flattening-filter-free, IMRT: Intensity-modulated radiation therapy, MVP: Mobius verification phantom, SD: Standard deviation factors such as energy, local plan characteristics, number of cases for optimization, machine, and MLC model.

For the investigation of preclinical implementation, the mean target doses of the PTV contour in the 17 plans showed that the dose calculated by the Mobius3D using the default DLG correction factor tended to be higher than that of the Eclipse TPS. It is worth noting that our Eclipse TPS had already accounted for the DLG effect during the commissioning process. This may imply that the default DLG correction factor was not appropriate for the Mobius3D dose calculation. We also observed that the Mobius3D dose calculation with the default DLG correction factor tended to be greater than that of the Eclipse TPS in the additional set of 10 plans. However, after applying the optimal DLG correction factor, the mean target doses were observed to be closer to the TPS doses in the 17 plans and the newly selected 10 plans [Figures 5 and 6]. The largest difference in the gamma passing rate when the DLG correction factor was adjusted from the default value to the optimal value was observed in plan number 3 (from the 17 previous plans): it increased from 78.5% to 91.0% for 3%/2 mm, as shown in Figure 7.

The average gamma passing rates for the 17 plans, obtained by comparing the TPS and Mobius3D with the optimal DLG correction factor, closely match those reported by Fontenot,[18] Jolly *et al*.,[8] and McDonald *et al*.,[10] [Table 5]. However, our study found that the range of gamma passing rates was different from those studies, possibly due to differences in algorithms and the number of plans in each study.

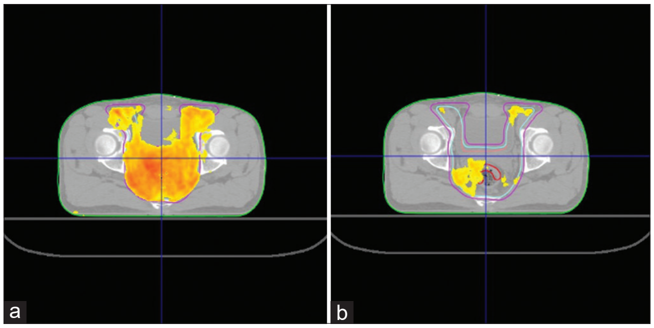

Figure 7: (a) Plan number 3 with the default dosimetric leaf gap (DLG) correction factor (0) shows differences between the calculated dose and the treatment planning system dose, indicated by the orange color, (b) Plan number 3 with the optimal DLG correction factor (−1.252) shows a notable reduction in dose difference within the target

The gamma passing rates from cross-comparison between the EPID-based verification/TPS system and the Mobius3D/TPS system, considering both the optimal and default DLG correction factors, are shown in Tables 2 and 3. There was a higher level of agreement between EPID-based verification and Mobius3D when using the optimal DLG correction factors compared to the default DLG correction factor for the verification and validation of VMAT plans (17 and 10 plans) across all criteria. Particularly, with the gamma criterion of 5%/3 mm applying for Mobius3D as a secondary dose calculation,[15,19] the gamma passing rates of Mobius3D with optimal DLG correction factors were higher than 95%. This demonstrates a similar trend in EPID-based verification with the 3%/2 mm criterion. Our findings also agreed with a recent study, indicating that Mobius3D at 5%/3 mm can achieve performance comparable to that of EPID-based verification at 3%/2 mm.[20]

A limitation of this study is that we determined the DLG correction factor for the Mobius3D using only the 6 MV energy of the TrueBeam linac with the Millennium MLC. Differences in machines, MLC models, and energies can lead to varying DLG values, so applying the optimal value from this study to other linacs may not be appropriate. In addition, Li and Price[21] suggested that the DLG correction factor may need to be separately defined for stereotactic body RT (SBRT) and non-SBRT. Kim *et al*.[14] indicated that small field cases should be excluded from the optimization of the DLG correction factor to prevent overestimation. Moreover, the other aspects of MLC parameters, such as interleaf and intraleaf leakage, may impact dose calculation accuracy.[13] The influence of MLC modeling, including not only DLG but also interleaf and intraleaf leakage, should also be investigated to understand the reliability of the Mobius3D calculations. Concerns related to dose calculation should also be considered. This study only utilized the AAA algorithm for conducting the research. However, further studies should investigate other dose calculation algorithms.

Table 5: Comparison of gamma passing rates on patient plans obtained by Mobius3D calculation with the optimal dosimetric leaf gap correction factor compared with treatment planning system in this study and other publications

Reference	TPS	Algorithm	Technique	Total number of plans	Gamma criteria	Range of gamma passing rate (%)	Average±SD of gamma passing rate (%)
Fontenot[18]	Pinnacle	CCCS	VMAT	30	5%/3 mm	93.2–100	99.44±1.25[a]
Jolly *et al*.[8]	Eclipse	AAA	IMRT	246	3%/3 mm	87.3–100	98.40±1.80
McDonald *et al*.[10]	Eclipse	AcurosXB	IMRT and VMAT	17	3%/2 mm	87.9–99.9	94.40±3.30
This study	Eclipse	AAA	VMAT	17	5%/3 mm	98.7–100	99.75±0.35
-	-	-	-	-	3%/3 mm	91.9–99.9	97.74±2.80
-	-	-	-	-	3%/2 mm	88.5–99.9	95.68±3.66

[a]Calculated from the available gamma passing rates reported by Fontenot *et al*. VMAT: Volumetric-modulated arc radiotherapy, IMRT: Intensity-modulated radiation therapy, SD: Standard deviation, CCCS: Collapsed cone convolution superposition, AAA: Analytical anisotropic algorithm, TPS: Treatment planning system

CONCLUSION

The DLG correction factor strongly influenced the accuracy of the Mobius3D-calculated dose distribution for the VMAT. Applying the optimal DLG correction factor can increase dose agreement and gamma passing rate between calculations and delivered doses of VMAT plans, which emphasizes the importance of optimizing this factor during the commissioning process. The optimal DLG correction factor should therefore be investigated and applied to enhance the accuracy of the Mobius3D dose calculation before clinical implementation. This correction factor should be specifically optimized for each site, considering several factors such as energy, machine, and plan characteristics. The verification and validation need to be performed comprehensively. In addition, further investigation may be conducted under small field conditions such as those in stereotactic radiosurgery plans, as well as regarding the effects of different dose calculation algorithms and other MLC aspect parameters.

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Conflicts of interest

There are no conflicts of interest.

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