Original Article

Assessment of the Dosimetric Performance of the Mobius3D against Portal Dose Measurements in Patient-specific Quality Assurance

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Abstract

Aim: The Mobius3D software addresses limitations lacking in measurement-based methods in patient-specific quality assurance (QA). The objective of this study was to validate its dosimetric performance against conventionally used portal dose measurements using gamma analysis and confidence limits. **Materials and Methods:** A total of 240 patient-specific QA plans for the Varian Halcyon linear accelerator were collected. The Mobius3D software was commissioned through beam data and plan verification. All plans underwent QA through the electronic portal imaging device, coupled with the Portal Dosimetry software, and the Mobius3D. Data were assessed using >95% gamma pass. Portal measurements were evaluated using 3%/2 mm and 3%/3 mm criteria, whereas Mobius3D was analyzed at 3%/3 mm and 5%/3 mm, at the 10% threshold. **Results:** Mobius 5%/3 mm mean gamma passes were 99.89% for volumetric-modulated arc therapy (VMAT) and 99.31% for intensity-modulated radiotherapy (IMRT), and correspondingly, the data for portal 3%/2 mm were 99.99% and 99.96%. The Mobius3D at 5%/3 mm can perform like Portal 3%/2 mm for VMAT plans at 0.1% difference, especially for head/neck and pelvic/abdominal cases. In IMRT-based treatments, at 0.7% difference in Mobius3D 5%/3 mm and Portal 3%/2 mm, the performance and error identification in IMRT plans should be applied more carefully due to the amount of failed plans, particularly the chest region. The confidence limits for VMAT plans for Portal 3%/2 mm and Mobius 5%/3 mm are 99.93% and 99.42%, respectively, while for IMRT plans are 99.69% and 97.43%, respectively. **Conclusions:** At a 5%/3 mm criterion, the Mobius3D may yield percentage gamma pass rates like measurements obtained by Portal Dosimetry 3%/3 mm and Portal Dosimetry 3%/2 mm. As the software is largely dependent on commissioned data, rigorous commissioning and a comprehensive QA program should be implemented.

Keywords: Electronic portal imaging device, intensity-modulated radiotherapy, Mobius3D, patient-specific quality assurance, volumetric-modulated arc therapy

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Introduction

Modern modes of external radiotherapy have evolved into conformal techniques that employ linear accelerators equipped with multileaf collimators (MLC), such as intensity-modulated radiotherapy (IMRT) and volumetric-modulated arc therapy (VMAT).[1-4] Furthermore, the addition of fractionation schemes and stereotactic procedures increases the complexity of these techniques.[1] As a result, the optimized modulated fields and intensities allow more precise sparing of critical structures, improving the overall prognosis of the patient.[1-4]

MLC-based treatments involve components that are absent in conventional three-dimensional conformal radiation therapy. These include nonuniform beam intensity, high-dose gradient, MLC movement and speed, gantry movement, and dose rate variation. Consequently, these factors may render the treatment session more likely to encounter errors or uncertainties.[3-5] Hence, the pretreatment verification of the calculated dose distributions from the treatment planning

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phase, or patient-specific quality assurance (QA), has become a necessary step in the radiotherapy workflow.

The current standard practice in patient-specific QA uses measurement-based methods, such as point dose measurements and planar dosimetry.[4-7] Examples of point dosimeters are cylindrical ionization chambers, which are characterized by desirable dosimetric properties such as dose and dose rate linearity, stability, directional independence, and energy independence, making them the preferable option for obtaining point-dose estimations. These detectors are, however, sensitive to positional errors and volume-averaging effects, especially in high-gradient regions.[4-5] Furthermore, common examples of planar methods include array detectors and portal imagers, which display results in two-dimensional (2D) dose distributions.[4-7] While array detectors are clinically accepted for its convenience and efficiency, the spatial resolution of isodose distributions is dependent on detector spacing.[4] On the other hand, the portal imager, or the electronic portal imaging device (EPID), yields fluence-based data in high resolution due to its amorphous silicon (a-Si) material composition. QA evaluations performed by EPID are acquired more efficiently as it is already mounted on the accelerator unit, making it less susceptible to positional errors. Furthermore, studies have characterized the EPID as an appropriate tool for evaluating QA plans in IMRT and VMAT due to its linear dose–response and high reproducibility.[6-7] It has also been shown to correspond well with ionization chamber response in terms of dose rate response and field size dependence.[8]

Absolute dose determination is the advantage of measurement-based methods.[3,9] However, these methods have limitations in accounting for patient heterogeneities, are prone to human errors, and have slower acquisition times.[9-12] Thus, in recent years, these setbacks are being addressed using independent software. The Mobius3D (Varian Medical Systems, Palo Alto, CA, USA) uses commissioned beam data to make QA plan calculations based on the patients' computerized tomography (CT) images within minutes. The system performs dose recalculation, error identification, and gamma evaluation using a collapsed cone convolution (CCC) algorithm as a heterogeneity corrector.[13,14] This type of algorithm is also known as a superposition algorithm, similar to those employed in TPS software. It models the output fluence coming from the treatment head, accounting for the primary beam, scattered photons, and electron contamination, which is why the acquisition of output factors is an essential step in software commissioning. The dose deposited is then calculated using energy kernels. The Mobius3D system supports VMAT, IMRT, and tomotherapy plans. However, superposition algorithms tended to have limitations in locations that are highly heterogenous, like in the chest region where densities varied between air and tissue.[11] At present, the Mobius3D is mainly used as a secondary QA verification tool in a comprehensive patient-specific QA program.[9,15]

A widely used verification metric in patient-specific QA is the gamma index, which accounts for the dose difference (DD), the difference between the evaluated dose and the reference dose at the same point, and the distance-to-agreement (DTA), the distance between two dose distributions.[5] Reporting confidence limits also serves as useful information in determining baselines for interinstitutional comparisons.[3] Thus, the objective of this study was to validate the dosimetric performance of the independent software, Mobius3D, against portal dose measurements using gamma analysis and to determine the confidence limits in both methods.

Materials and Methods

Treatment plan acquisition

This research was a retrospective study involving 120 IMRT plans and 120 VMAT plans of the head–neck, chest, and pelvic/abdominal regions delivered from May 2022 to September 2022 using the Varian Halcyon™ (Varian Medical Systems, Palo Alto, CA, USA) accelerator unit. Table 1 displays the scope of the treatment characteristics in this study. Treatment plans and dose calculations were created, verified, optimized, and exported with the Eclipse™ 16.1 Treatment Planning System (Varian Medical Systems, Palo Alto, CA, USA) using the analytical anisotropic algorithm. Delivery parameters, including field size and shape, treatment time, gantry angle, collimator settings, and dose, are defined in the treatment plan.

Electronic portal imaging device

The a-Si-based EPID (a-Si 1200, Varian Medical Systems, Palo Alto, CA, USA) was used to acquire electronic data for dose validation in the 2D plane. It has a maximum active image area of 43 cm × 43 cm and a total pixel matrix of 1280 × 1280. It offers a high spatial resolution with a 0.336 mm pixel size.[8] The device is attached to the gantry of the linear accelerator and works in conjunction with the Portal Dosimetry software (Varian Medical Systems, Palo Alto, CA, USA), which evaluated the gamma index of composite images of the measured portal dose and the predicted dose.

Before performing QA measurements, the EPID was calibrated to create a homogenous space with minimal background noise for obtaining images. This was done through the acquisition of dark-field and flood-field (FF) images using an open field under 6-MV flattening filter-free photon energy at a source-to-detector distance of 154 cm and 800 MU/min dose rate. The system used the information from these two images to correct for differences in pixel sensitivities in subsequent images.[7,8]

Table 1: Summary of treatment characteristics

Treatment region	Number of cases (%)	
	IMRT	VMAT
Head and neck	37 (31.7)	29 (24.2)
Chest	43 (35.0)	46 (38.3)
Pelvic/abdominal	40 (33.3)	45 (37.5)
Total	120	120

IMRT: Intensity-modulated radiotherapy, VMAT: Volumetric-modulated arc therapy

Mobius3D software

The Mobius3D version 4.0 (Varian Medical Systems, Palo Alto, CA, USA) was used to perform comprehensive, model-based patient-specific QA using the CCC algorithm to recalculate doses based on CT data and treatment parameters (e.g., field sizes, gantry angles, couch settings, beam energy, monitor units [MU], and MLC patterns), instead of phantom-based measurements.[13-15] Dose distributions can be displayed in the transverse, coronal, and sagittal planes.[13,14] The system has in its archives datasets required to build a predefined model for linear accelerators, including percent depth dose points, beam profiles, off-axis ratios, and output factors. In this study, the beam model for the Halcyon unit was commissioned based on the manufacturer's instruction manual, consisting of the following steps: initial beam data verification, open field plan verification, and simple patient plan verification.

Under initial beam data verification, the output factors were verified using a 100-cm solid water phantom setup at 100 MU, 5 cm depth, and 95 cm source-to-surface distance (SSD) for the following field sizes of the Halcyon unit (4 cm × 4 cm, 6 cm × 6 cm, 8 cm × 8 cm, 10 cm × 10 cm, 14 cm × 14 cm, 20 cm × 20 cm, 24 cm × 24 cm, and 28 cm × 28 cm) within a 0.5% difference from results obtained by a CC13 ionization chamber (IBA Dosimetry, Schwarzenbruck, Germany). Open field plan verification was performed at 100 MU, 6 cm depth, and 94 cm SSD for field sizes 2 cm × 2 cm, 5 cm × 5 cm, 10 cm × 10 cm, 14 cm × 14 cm, 20 cm × 20 cm, and 28 cm × 28 cm, making sure the results passed the recommended >90% gamma pass with a DD/DTA criteria of 3%/3 mm and 10% threshold. Simple patient plan verification consisted of the dose verification of anterior–posterior/posterior–anterior, parallel, 4-field, and 3-field plans at 100 MU, a 6 cm depth, and 94 cm SSD, evaluated within a 2% difference from results obtained by a CC13 ionization chamber.[14]

Patient-specific quality assurance tests

All collected IMRT and VMAT plans were recalculated into the Portal Dosimetry application. The same irradiation parameters as indicated by each treatment plan were applied to the EPID, such as couch and imager settings, dose distribution, and leaf motion pattern. The dedicated software evaluated the gamma index of composite images of the measured portal dose and the predicted dose.

In the same way, after the verification steps under Mobius3D commissioning, all plans were imported to the Mobius3D system, yielding the reconstructed dose distribution and the gamma passing result.

Statistical analysis

EPID-based measurements were evaluated at a >95% gamma pass under the outdated 3%/3 mm criterion from Task Group 119 and the updated 3%/2 mm criterion from Task Group 218.[3,5] The threshold dose was set at 10%. For independent software-based results, there are currently no standard criteria. In this study, Mobius3D data were evaluated at >95% gamma pass under the 3%/3 mm and 5%/3 mm criteria at the 10% threshold, which are parameters used by previous studies.[9,11,12,16,17] Comparison among methods was performed using the average percentage gamma pass values and mean differences. Pearson's correlation coefficients were also evaluated, wherein values from 0 to 0.20 are very weakly correlated, 0.21–0.40 are weakly correlated, 0.41–0.60 are moderately correlated, 0.61–0.80 are strongly correlated, and 0.81–1.0 are very strongly correlated. The coefficients are also evaluated alongside their corresponding *P* values, where $P < 0.05$ means the correlation coefficient is statistically significant. Otherwise, Pearson's coefficient cannot be relied on. Furthermore, the Bland–Altman plots and the confidence limits for each method were identified using the equation $(100 - mean) + 1.96\,SD$.

Results

Figures 1 and 2 display the interfaces of the Portal Dosimetry software and Mobius3D software, respectively. Table 2 displays the summary of statistical results comparing the 3%/3 mm and 3%/2 mm criteria in portal measurements, consisting of the mean gamma pass rates, mean differences, correlation coefficients, and *P* values. It was found that all individual EPID-based measurements in VMAT and IMRT for both criteria passed the >95% gamma pass limit, with averages ranging from 99.96% to 99.99%. With $P < 0.05$, the correlation coefficients are statistically significant and, thus, may be used for interpretation.

Table 3 shows the comparison of Mobius3D data between 5%/3 mm and 3%/3 mm for VMAT and IMRT plans. Overall, the mean gamma pass rates ranged between 96.77% and 99.89%, which meet the >95% limit. The mean values at

Table 2: Summary of statistical comparisons between criteria in portal dose measurements

Criteria	Percentage mean gamma pass (SD)	Percentage mean difference	Pearson correlation	*P*
VMAT				
Portal 3%/3 mm	99.99 (0.02)	0	0.66	0.004
Portal 3%/2 mm	99.99 (0.03)			
IMRT				
Portal 3%/3 mm	99.98 (0.08)	0.02	0.92	0.001
Portal 3%/2 mm	99.96 (0.14)			

IMRT: Intensity-modulated radiotherapy, VMAT: Volumetric-modulated arc therapy, SD: Standard deviation

Table 3: Summary of statistical comparisons between criteria in Mobius3D calculations

Criteria	Percentage mean gamma pass (SD)	Percentage mean difference	Pearson correlation	*P*
VMAT				
Mobius 5%/3 mm	99.89 (0.24)	1.17	0.68	<0.001
Mobius 3%/3 mm	98.72 (1.67)			
IMRT				
Mobius 5%/3 mm	99.31 (0.96)	2.55	0.89	<0.001
Mobius 3%/3 mm	96.77 (3.12)			

IMRT: Intensity-modulated radiotherapy, VMAT: Volumetric-modulated arc therapy, SD: Standard deviation

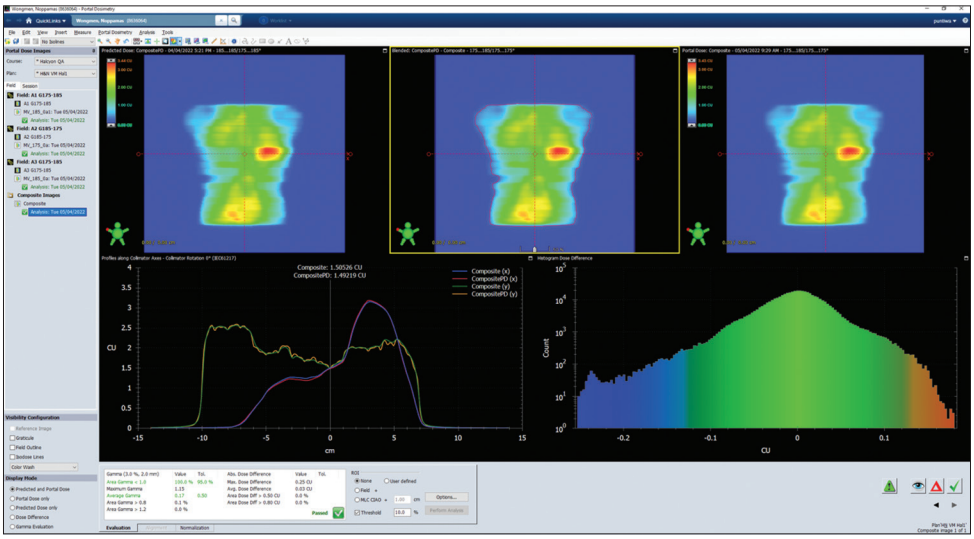

Figure 1: The Portal Dosimetry software interface showing the analysis of the predicted dose from treatment planning and the portal dose of a head-and-neck case

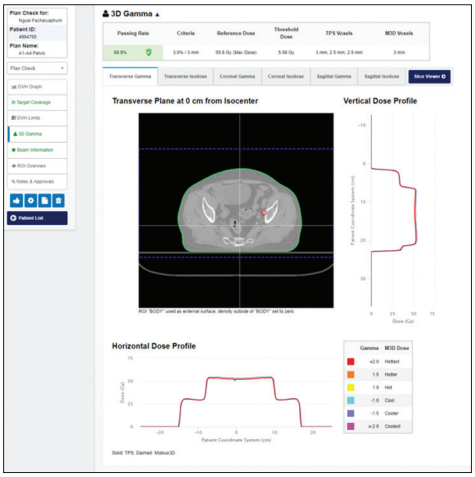

Figure 2: Mobius3D software interface showing the results of gamma analysis, with the vertical and horizontal dose profiles for a cervical cancer plan

5%/3 mm, which were at least 99.0%, were greater than at 3%/3 mm for both radiotherapy techniques.

Table 4 displays the statistical results comparing portal measurements at 3%/2 mm criterion against Mobius3D data at 3%/3 mm and 5%/3 mm. For VMAT plans, all individual Mobius3D calculations under the 5%/3 mm criterion passed with a mean gamma pass of 99.89%, while eight plans failed under 3%/3 mm at a mean gamma pass of 98.72%. All *P* values in the data set are <0.001, indicating Pearson's correlation coefficients as statistically significant and suitable to use for evaluation. The results show the coefficient values as weakly correlated, ranging from 0.2 to 0.3. Furthermore, Figures 3 and 4 visualize the Bland–Altman plots for all criteria comparisons in VMAT and IMRT, respectively.

For IMRT plans, Mobius 3%/3 mm yielded a mean gamma pass of 96.77%, whereas Mobius 5%/3 mm had a mean gamma pass of 99.31%. *P* values for IMRT are all under 0.001, suggesting statistically significant correlation coefficients. Mobius 5%/3 mm and Portal 3%/2 mm yielded a positive but weak correlation at 0.028, while Mobius 3%/3 mm and Portal 3%/2 mm had a negative correlation at −0.037. Furthermore, Table 5 shows the summary of confidence limits for all criteria, methods, and radiotherapy techniques. The reporting of confidence limits is useful in determining action levels and comparing data among different departments, as recommended by Ezzell *et al*. and Zhu *et al*.[3,11]

Table 6 presents the summary of the mean percentage gamma pass results for each treatment region in both VMAT and IMRT plans. Portal measurements for both criteria for all plans ranged from 99.9% to 100%. Mobius3D measurements in VMAT plans ranged from 98.1% to 99.9%. The results of

Table 4: Summary of statistical comparisons between portal 3%/2 mm and Mobius3D data

Criteria	Percentage mean gamma pass (SD)	Percentage mean difference	Pearson correlation	*P*
VMAT				
Portal 3%/2 mm	99.99 (0.03)	1.27	0.275	<0.001
Mobius 3%/3 mm	98.72 (1.67)			
Portal 3%/2	99.99 (0.03)	0.10	0.221	<0.001
Mobius 5%/3 mm	99.89 (0.24)			
IMRT				
Portal 3%/2 mm	99.96 (0.14)	3.19	–0.037	<0.001
Mobius 3%/3 mm	96.77 (3.12)			
Portal 3%/2 mm	99.96 (0.14)	0.65	0.028	<0.001
Mobius 5%/3 mm	99.31 (0.96)			

IMRT: Intensity-modulated radiotherapy, VMAT: Volumetric-modulated arc therapy, SD: Standard deviation

Table 5: Summary of confidence limits for all plans and criteria

Method, criteria	Confidence limits (%)
VMAT	
Portal 3%/3 mm	99.95
Portal 3%/2 mm	99.93
Mobius3D 3%/3 mm	95.45
Mobius3D 5%/3 mm	99.42
IMRT	
Portal 3%/3 mm	99.82
Portal 3%/2 mm	99.69
Mobius3D 3%/3 mm	90.65
Mobius3D 5%/3 mm	97.43

IMRT: Intensity-modulated radiotherapy, VMAT: Volumetric-modulated arc therapy, 3D: Three dimensional

IMRT plans for Mobius3D measurements are slightly more diverse, with pelvic/abdominal cases being the lowest for a 3%/3 mm criterion at 95.5%, followed by head-and-neck cases at 96.7% at a 3%/3 mm criterion. More plans failed under IMRT (23 plans) compared to VMAT (eight plans). For both radiotherapy techniques, the chest region took up the largest percentage of failed plans under 3%/3 mm at 5% and 11% for VMAT and IMRT, respectively. In addition, all failed plans under 3%/3 mm when evaluated at 5%/3 mm passed, except for one CA breast case under IMRT. Table 7 displays the confidence limits in each treatment region for all criteria in both VMAT and IMRT, which can be useful in evaluating specific combinations of radiotherapy technique and treatment site.

Discussion

This study explored the dosimetric performance of the Mobius3D software compared to the conventionally used measurement-based method, EPID, in the patient-specific QA of VMAT and IMRT plans. The a-Si EPID has been extensively verified and used as a QA tool in radiotherapy due to its high resolution and quick acquisition time when compared to other planar methods, such as film and array detectors.[6-8] Based on Table 2, the results yielded by the EPID for both VMAT and IMRT plans in the 3%/3 mm and 3%/2 mm criteria passed the >95% standard, which is in concordance with Lee *et al*., who evaluated VMAT plans by EPID under the same criteria at 99.0% and 99.47%, respectively.[12] Kim *et al*. also performed a similar study using a 3%/3 mm criterion with gamma pass rates ranging from 97.53% to 99.43% for two different linear accelerator units.[15]

Based on the mean differences, this study's comparison between the outdated (3%/3 mm) and updated (3%/2 mm) criteria for portal measurements shows almost no differences at 0% and 0.02% for VMAT and IMRT plans, respectively, indicating interchangeability of criteria. Furthermore, with $P < 0.05$ [Table 2], this suggested useable Pearson coefficients. For VMAT, the correlation value between the two criteria is strongly correlated at 0.66, while for IMRT, it is very strongly correlated at 0.92. It can be inferred that for both VMAT and IMRT, the relationship between Portal 3%/3 mm and Portal 3%/2 mm is linear. Thus, for comparison purposes against Mobius3D data, the updated criterion of 3%/2 mm can be used.

Compared to the values of Mobius3D data in Table 3, Kim *et al*. yielded similar values for Mobius3D at 5%/3 mm ranging from 96.45% to 99.32%.[15] In contrast, Lee *et al*. reported a mean gamma pass rate of 99.8% for Mobius 3%/3 mm in VMAT plans.[12] With $P < 0.05$, the correlation between criteria in VMAT plans is strongly correlated, whereas the correlation between criteria in IMRT plans is very strongly correlated. Thus, the relationship between values in Mobius 5%/3 mm and Mobius 3%/3 mm is linear.

Under VMAT plans, the eight failed plans in the Mobius3D data using a 3%/3 mm criterion may be an indication of it being too stringent when compared to the EPID measurements under the same criteria, which passed the >95% gamma passing limit. At Portal 3%/2 mm, the mean difference against Mobius3D 5%/3 mm is smaller at 0.10% compared to Mobius3D 3%/3 mm at 1.27%, suggesting a good comparability between Portal 3%/2 mm and Mobius 5%/3 mm. This is further supported by the lesser number of points and the more compact range of differences in Mobius 5%/3 mm comparisons, as displayed in Figure 3. Based on this, it can be inferred that Mobius3D measurements at 5%/3 mm may be a more appropriate QA criterion. This finding is similar

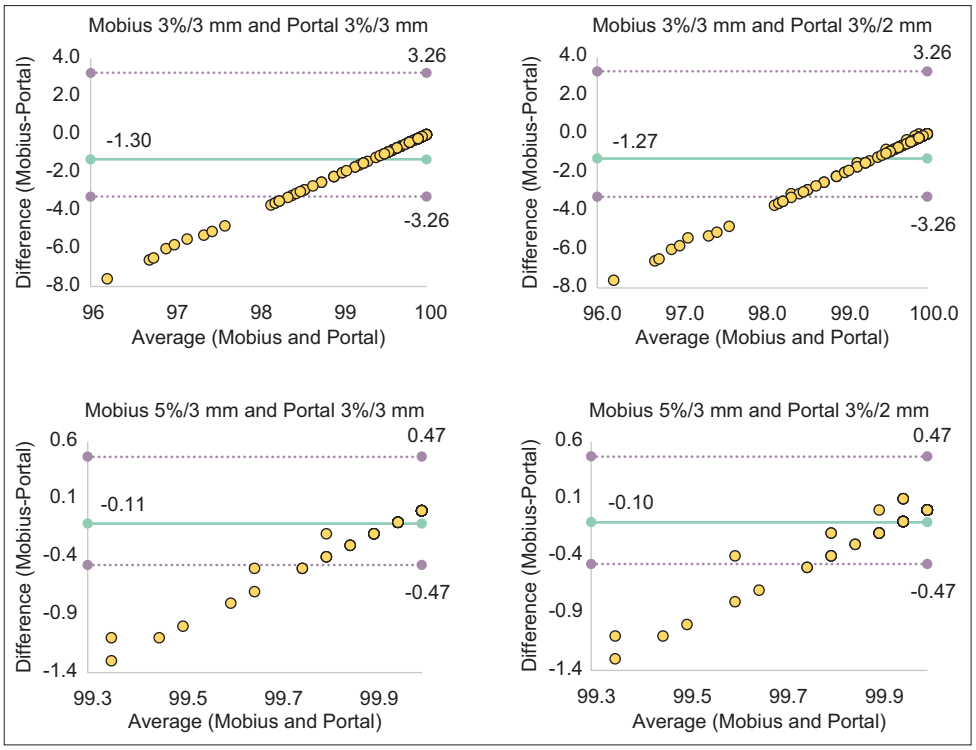

Figure 3: The Bland–Altman plots among all criteria for volumetric-modulated arc therapy plans

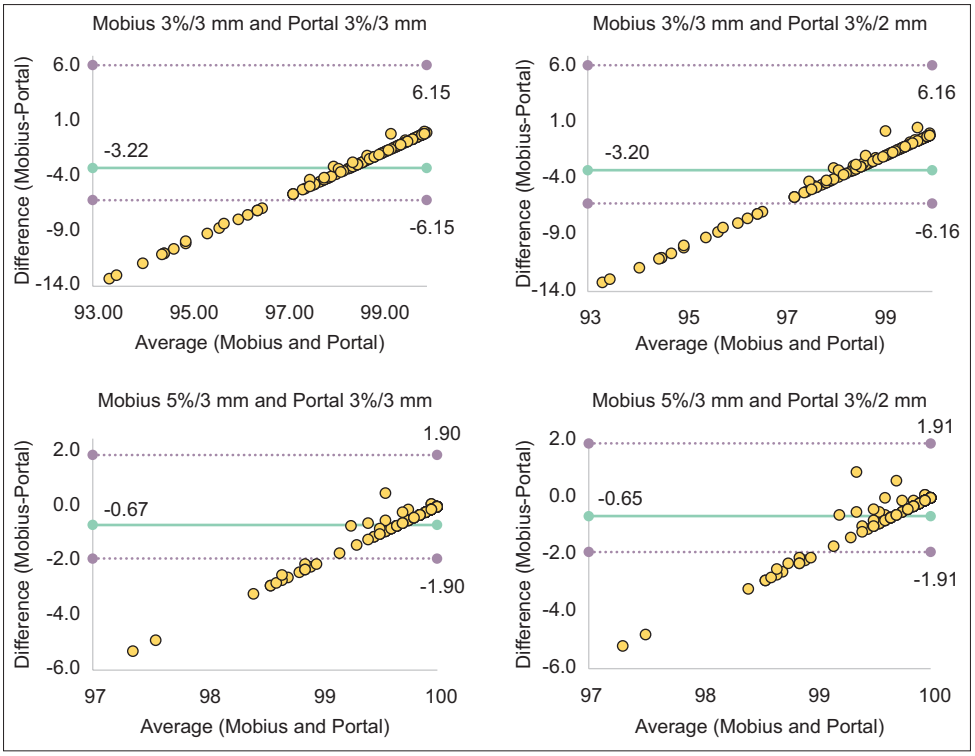

Figure 4: The Bland–Altman plots among all criteria for intensity-modulated radiotherapy plans

to a study by Basavatia *et al*., where Mobius 5%/3 mm and EPID 3%/3 mm yielded a higher agreement compared to Mobius 3%/3 mm.[16] However, when Lee *et al*. compared the Mobius3D and EPID at 3%/3 mm, the Mobius3D was found to perform slightly better at a 0.33% difference for nine VMAT plans.[12] At $P < 0.001$, Pearson's coefficients are weak, suggesting nonlinearity.

For IMRT plans, 22 plans under Mobius 3%/3 mm failed, yielding a mean gamma pass of 96.77%, whereas one plan failed

Table 6: Summary of the mean percentage gamma passes for each treatment region

Treatment region	Average % gamma pass (SD)			
	Portal 3%/3 mm	Portal 3%/2 mm	Mobius3D 3%/3 mm	Mobius3D 5%/3 mm
VMAT				
Head and neck	100 (0.00)	100 (0.02)	98.6 (1.37)	99.9 (016)
Chest	100 (0.00)	100 (0.03)	98.1 (1.21)	99.8 (0.19)
Pelvic/abdominal	100 (0.02)	100 (0.04)	99.4 (1.99)	99.9 (0.32)
IMRT				
Head and neck	100 (0.10)	99.9 (0.13)	96.7 (2.21)	99.2 (0.69)
Chest	100 (0.02)	100 (0.10)	95.5 (3.88)	99.7 (0.59)
Pelvic/abdominal	100 (0.11)	100 (0.17)	98.2 (2.33)	99.0 (1.29)

IMRT: Intensity-modulated radiotherapy, VMAT: Volumetric-modulated arc therapy, SD: Standard deviation, 3D: Three dimensional

Table 7: Summary of confidence limits for each treatment region per criterion per technique

Treatment region	Confidence limits (%)			
	Portal 3%/3 mm	Portal 3%/2 mm	Mobius 3%/3 mm	Mobius 5%/3 mm
VMAT				
Head and neck	100.00	99.96	95.91	99.59
Chest	100.00	99.94	95.73	99.43
Pelvic/abdominal	99.96	99.92	95.50	99.27
IMRT				
Head and neck	99.80	99.65	92.37	97.85
Chest	99.96	99.80	87.90	96.47
Pelvic/abdominal	99.78	99.67	93.63	98.54

IMRT: Intensity-modulated radiotherapy, VMAT: Volumetric-modulated arc therapy

under Mobius 5%/3 mm with a mean gamma pass of 99.31%. Furthermore, as is also displayed in the summary of the Bland–Altman plots for IMRT in Figure 4, the results for IMRT are like that in VMAT in that the least mean difference was exhibited between Mobius 5%/3 mm and Portal 3%/2 mm at 0.65%, which is also characterized with a shorter range of differences.

More IMRT plans failed compared to VMAT plans, suggesting that the IMRT technique may be more likely to encounter errors and uncertainties. A study by Betzel *et al*. found that dynamic IMRT was less sensitive to variations in MLC settings, dose rate, and gantry positions compared to IMRT, which they attributed to the larger MLC opening in dynamic IMRT.[18] Since IMRT utilizes a sliding window method, it becomes more susceptible to errors due to the large amount of overlapping MLC segments and the larger number of MUs used. The VMAT, which rotates, makes the dose deposition more tolerant of errors as the gantry accelerates or decelerates. VMAT also uses less MU overall to achieve the same results as in IMRT.[18] As the Mobius3D utilizes a commissioned beam model to perform its calculations, the independent software may have an advantage in detecting MLC-related errors compared to measurement-based methods.[10] Still, as previously mentioned, the 3%/3 mm can be a strict criterion for the Mobius3D with 22 failed plans, where only one failed under 5%/3 mm. Kim *et al*. (2021) reported the gamma pass rates for Portal 3%/3 mm and Mobius3D 5%/3 mm to have a small difference of 1.1%.[15] In this current study, the mean differences between Mobius 5%/3 mm and Portal 3%/2 mm and Mobius 3%/3 mm and Portal 3%/2 mm in IMRT are 0.65% and 3.19%, respectively, suggesting a better agreement with Mobius 5%/3 mm. Furthermore, at $P < 0.001$, all relationships were found to be nonlinear with Pearson's coefficients nearing 0. The reporting of confidence limits, as shown in Tables 5 and 7, is useful in determining action levels and comparing data among different departments, as recommended by Ezzell *et al*. and Zhu *et al*.[3,11]

Compared to other treatment regions, the chest plans tended to fail more than others. Basavatia *et al*. discussed similar results with the breast and head-and-neck treatment plans having greater amounts of failing points compared to other treatment sites, such as the prostate and gynecological regions.[16] Furthermore, the Mobius3D system has a known limitation when evaluating plans in the chest region due to the vast heterogeneity differences between air density and tissue density. Studies have shown that errors in the lung region ranged between 5% and 10%.[11]

Sources of error can be treatment planning, spatial uncertainties, dosimetric errors, accelerator condition, or the measurement/analysis tool.[5,11] In the event of a poor agreement between the reference distribution and evaluation distribution, the first is to acknowledge the limitations of the independent software and double-check the commissioning process. Second, the linear accelerator output must be checked if it matches the data in both the TPS and the independent software. Third, the IMRT or VMAT plan must be reevaluated for possible errors. As a last resort, the manufacturer can be called to verify the problem.[11]

The Mobius3D software is an efficient tool in patient-specific QA due to its ability to perform calculations based on commissioned beam data, which allows for error identification that measurement-based methods may lack. It reduces risks due to human error and accounts for the patient's heterogeneity.[9-10] On the basis of differences in mean gamma passes, the Mobius3D at 5%/3 mm can perform similarly to portal dose measurements at 3%/2 mm for VMAT plans at 0.1%, especially for head/neck and pelvic/abdominal cases where the failure of plans was minimal. In IMRT-based treatments, even with about 0.7% mean difference in Mobius3D 5%/3 mm and Portal 3%/2 mm, the performance and error identification in IMRT plans should be done more carefully due to the amount of failed plans, particularly in the chest region.

Conclusions

This study used 120 VMAT plans and 120 IMRT plans to explore the dosimetric performance of the independent software, Mobius3D, in patient-specific QA compared to portal dose measurements by the EPID. After the careful commissioning of the Mobius3D, this study found that at a 5%/3 mm criterion, the Mobius3D may yield percentage gamma pass rates like measurements obtained by Portal 3%/3 mm and Portal 3%/2 mm, whose relationship was found to be strongly correlated. Mobius 5%/3 mm mean gamma passes were 99.89% for VMAT and 99.31% for IMRT. Portal 3%/2 mm mean gamma passes were 99.99% for VMAT and 99.96% for IMRT. The Mobius3D at 5%/3 mm can perform like Portal 3%/2 mm for VMAT plans at 0.1% difference, especially for head/neck and pelvic/abdominal cases, where the failure of plans was minimal. In IMRT-based treatments, at a 0.7% difference between Mobius3D 5%/3 mm and Portal 3%/2 mm, a large amount of chest plans failed. The summary of confidence limits for VMAT plans for Portal 3%/3 mm, Portal 3%/2 mm, Mobius 3%/3 mm, and Mobius 5%/3 mm is 99.95%, 99.93%, 95.45%, and 99.42%, respectively. Furthermore, the summary of confidence limits for IMRT plans for Portal 3%/3 mm, Portal 3%/2 mm, Mobius 3%/3 mm, and Mobius 5%/3 mm is 99.82%, 99.69%, 90.65%, and 97.43%, respectively. As the software is largely dependent on commissioned data, rigorous commissioning and a comprehensive QA program should be implemented.

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Conflicts of interest

There are no conflicts of interest.

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