

Assessment of DLG Correction Factor in Mobius3D Commissioning Affected by Couch Top

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Research

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Abstract

Purpose: This study assesses the dosimetric leaf gap (DLG) correction factor in Mobius3D commissioning affected by a couch top platform and calculates the optimal DLG value according to the point dose difference function.

Methods: DLG optimizations were performed for 3 LINAC machines and a total of 30 patient VMAT plans (i.e., 10 plans per each LINAC). Point dose calculations were performed using an automatic dose calculation system in Mobius3D as well as Mobis3D calculation using an MVP-based QA plan with a carbon fiber couch top. Subsequently, the results were compared with measurement data.

Results: The averaged point dose measured for the MVP with a couch top decreased by approximately 2% relative to that without the couch top. The average of the optimal DLG factors increased by 1.153 due to the couch top effect for a dose decrease of 2% at the measured point.

Conclusions: Users should adjust the DLG correction factor using a specific phantom (including MVP) with a couch top. If the factor adjusted by using MVP automatic dose calculation system, the factor should be increased by approximately 1.153 per 2% dose difference considering user's couch top effect.

1. Introduction

Quality assurance (QA) for every patient plan is a major part of the radiation treatment process to ensure that the prescribed dose is accurately delivered to the planned volume. QA techniques have evolved over time following the development of radiation treatment techniques. The conventional patient-specific QA process is typically performed by using a phantom-based system; during the process, specific point dose(s) and dose distribution are measured using a mapped plan from a patient treatment plan onto a phantom, and the measurement data were compared with those of planned data [1–7]. However, during the mapping process in the phantom-based QA system, the phantom used in the QA cannot represent the inhomogeneity of a patient's anatomy [8].

Recently, the Mobius3D® QA platform (Mobius Medical Systems, Houston, TX, USA) has been released for the evaluation of patient-specific QA. Mobius3D can calculate a dose distribution for a patient CT dataset directly by using an independent dose calculation algorithm from the primary radiation treatment planning system. Mobius3D has been widely implemented in various institutions and has been applied as a primary- and secondary-checking QA tool to evaluate not only conventional radiotherapy techniques but also advanced ones, such as intensity-modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) [9–15].

To mimic the characteristics of a LINAC beam, the Mobius3D beam must be modelled by the user; however the vendor suggests a minimum configuration for beam commissioning because Mobius3D was designed to perform accurate dose calculations by using reference beam data. One of the major procedures is to adjust the dosimetric leaf gap (DLG) correction factor. The DLG correction factor is

defined to account for additional beam transmission from the leaf shape of a multi-leaf collimator used in advanced treatments. During Mobius3D beam commissioning, the vendor recommends modifying the DLG value such that the mean dose difference between measurement and calculation is within 2%.

For commissioning, Mobius3D users commonly utilize the Mobius Verification Phantom (MVP) supplied by Mobius Medical Systems and a phantom verification section included in Mobius3D. The section provides the expected doses at the pre-defined chamber locations (i.e., a total of seven ion chamber holes) automatically calculated by a separate plan mapped from a patient plan onto an image dataset of the MVP. Although MVP-based DLG correction is a comparatively simple method, the expected doses corrected by DLG parameter cannot be reflected by the effect of a couch top. Note that, in accordance with AAPM TG-176 [16], beam attenuation through couch tops might have a range of approximately 2% and several studies have already reported the effect of the couch top on dose difference [17–21]. Unfortunately, in Mobius3D, the DLG correction factor affected by the couch top has not been evaluated quantitatively to date when evaluating the DLG parameter by using the MVP automatic dose calculation system.

In this study, the commissioning procedure for the DLG correction factors of Mobius3D was evaluated based on the effect of the couch top. For this, 3 LINAC machines and a total of 30 patients VMAT plans (i.e., 10 plans / LINAC) were selected, and volume-averaged doses in the same chamber position were calculated using Mobius3D and MVP with and without the couch top, respectively. Finally, the correlation factors between DLG and couch top were derived for each LINAC.

2. Materials And Methods

2.1. Mobius3D commissioning

For the test of this study, even if the vendor recommends minimizing the beam customization by user [14, 22], our beam models of the Mobius3D system were commissioned (except for DLG optimization) for 6 MV X-ray beams of three Elekta Infinity LINACs equipped with Agility 160 MLC to reduce the risk of error caused by beam model; that is, the beam model parameters (i.e., PDD values and Off-axis ratio) for each LINAC were customized according to water phantom-based measurement data.

2.2. Plan selection

DLG optimizations were performed for 3 LINAC machines and for a total of 30-patient VMAT plans. All plans were generated and optimized by RayStation 5 (RaySearch Laboratories, Stockholm, Sweden), and the plans were selected for different lesions considering the ratio of assigned patients in each treatment room. Table 1 shows the plan numbers according to the treatment site; note that SBRT/SRS plans and specific plans that have a narrow beam were overlooked in this study, and all treatment plans were planned using more than two arc beams.

Table 1

Treatment sites of the patient volumetric-modulated arc therapy plans selected for the DLG optimization test

No.	Lung	Bone	Thymus	Liver	Esophagus	etc.	Total
LINAC #1	5	2	1	1	1	-	10
LINAC #2	2	4	1	-	1	2 (Lymph node)	10
LINAC #3	2	4	0	1	2	1 (Pancreas)	10

2.3. Dose calculation in Mobius3D

For dose calculation on the MVP with and without couch top, the CT image of MVP was obtained. Subsequently, the density of the MVP was overridden to 1.03 g/cc, which was obtained both from the analysis procedure of the CT to density conversion and from the MVP user guide manual. A specific volume at the center of the MVP (i.e., position C) was generated following the design of the A1SL ionization chamber (Standard Imaging, Middleton, WI, USA) inserted; herein, the contouring volume (0.06 cc) is virtually identical to the active volume of the A1SL chamber (0.053 cc). The couch top was also overridden as a type of support in TPS. Note that our couch tops equipped for three LAINCs are of the same model, namely “Carbon fiber tabletop”. Figure 1 shows a screenshot of a patient plan mapped onto the MVP with the couch top, as an example. All plan data considered in this study were mapped onto the MVP with the couch top, and each DICOM dataset (i.e., DICOM image, DICOM-RT Structure, DICOM-RT plan, and DICOM-RT dose) was imported into the Mobius server system for dose calculations. Regarding dose calculation on the MVP without a couch top, Mobius3D could provide calculated point doses at seven ion-chamber locations automatically when the “calculate phantom dose for plan check” option is enabled. Figure 2 depicts an example screenshot of a Mobius plan check for (a) point dose and dose distribution based on an MVP with an overridden couch top, and (b) automatic calculation of seven point doses using only the MVP.

2.4. Measurement of point doses in phantom

To measure the point dose in the MVP, the A1SL chamber was placed on position C and the point doses were measured using three LINACs (i.e., Elekta Infinity). Subsequently, the doses were measured for each plan used in Sect. 2.3. The measured points were positioned in a stable dose area of plans while avoiding steep dose-gradient regions. Note that the A1SL used in this study was calibrated two months before the time of measuring the point doses. Figure 3 displays the MVP equipped on an A1SL chamber plug.

2.5. Calculation of optimal DLG factor

To calibrate the additional beam transmission caused by the multi-leaf collimator, Mobius3D allows changes to the DLG value. The detailed functionality according to the DLG optimization procedure was not viewed in the Mobius system, but it was known that the increase in the calculated dose was almost linear as a function of the DLG offset value [22].

To optimize the DLG factor in Mobius3D, we used the DLG Correction Factor Optimization spreadsheet provided on Mobius's official website (<https://www.varian.com/products/software/quality-assurance/mobius3d>). As aforementioned, the optimal DLG parameters could be estimated from the linearity of dose differences; hence, the spreadsheet was designed based on linear regression to calculate the optimal DLG correction factor. In this study, three DLG correction values (-0.5, 0 (default), and 0.5) were selected initially to estimate the optimal DLG value; subsequently, the mean dose difference with respect to the final DLG value was evaluated using the same plans. These procedures were repeated for each LINAC machine.

3. Results And Discussion

The percentage differences relative to the measurement data for both MVP and MVP with couch top structure for each point are illustrated in Fig. 4. Note that the point dose error in Fig. 4 was defined as $(D_{\text{calc}} - D_{\text{meas}}) / D_{\text{meas}}$, where D_{calc} denotes the dose calculated by using Mobius3D, and D_{meas} represents the dose measured by the A1SL chamber inserted in the MVP at position C. From the results, the MVP-based calculations tended to yield higher average target doses (i.e., $2.48\% \pm 0.08\%$, $1.89\% \pm 1.06\%$, and $1.86\% \pm 0.71\%$) than those of MVP with couch top for the three LINACs.

To calculate the optimal DLG factors (F_{DLG}), we utilized the linear regression method by using an Excel sheet provided on Varian's website. Figure 5 shows the average dose difference according to the DLG correction factor. Here, the lines were linearly extrapolated, and the R^2 values for all linear regressions exceeded 0.997.

Comparing the results for the MVP and the MVP with a couch top, the y-intercepts had differences ranging from 1.03 to 1.51, and the slopes were virtually identical. Consequently, the mean value of F_{DLG} was changed by the characteristic of the LINAC machines, but more importantly, the values of F_{DLG} were affected by the couch top. In summary, F_{DLG} was increased by 1.153 due to the couch top effect for a dose decrease of 2% at the measured point.

4. Conclusions

In this study, the DLG correction factors of Mobius3D were determined using MVP phantoms both with and without the couch top, and the obtained results were compared to each other. The averaged dose difference of the point dose measured for the MVP with a couch top decreased by approximately 2% relative to that without the couch top; the trend of our calculated results is closed to that included in the AAPM TG-176 report. In terms of the DLG correction factor, the calculated value (F_{DLG}) was increased by

1.153 due to the couch top effect for a dose decrease of 2% at the measured point. Consequently, to optimize the DLG correction factor in Mobius correctly, users should use a specific phantom (including MVP) with a couch top. If the factor was optimized by using MVP automatic dose calculation system, the factor should be increased by approximately 1.153 per 2% dose difference considering user's couch top effect.

In the version of the Mobius system used when evaluating these results (version 2.2.0), the couch top could not be implemented in the MVP-based automatic calculation system; moreover, even the new version (version 3.0), which was released in October 2019, does not currently support this functionality. In addition, the DICOM dataset used in the automated system could not be modified. We believe that the couch issue in the Mobius system is already known by the Varian official support team; hence, a future updated version of Mobius will enable us to implement a couch top (or density overridden structures) for real MVP-based evaluation and/or to use a user-specific phantom DICOM set for automatic calculation in the Mobius system.

Abbreviations

QA	Quality assurance
IMRT	Intensity-modulated radiation therapy
VMAT	Volumetric modulated arc therapy
DLG	Dosimetric leaf gap
MVP	Mobius verification phantom
LINAC	Linear accelerator
PDD	Percentage depth dose
TPS	Treatment planning system
CT	Computed tomography

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

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Authors' contributions

Conception, design, and drafting the manuscript were performed by M.C. Han, J. Kim, C-S. Hong, K. H. Chang, S. C. Han, K. Park, D. W. Kim, and J. S. Kim

Data collection and interpreting were performed by M. C. Han, M. K. Park, and Y. Y. Noh, C-S. Hong, and J. S. Kim.

All authors read and approved the final manuscript.

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Not applicable.

Competing interests

The authors declare that they have no competing interests

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Figures

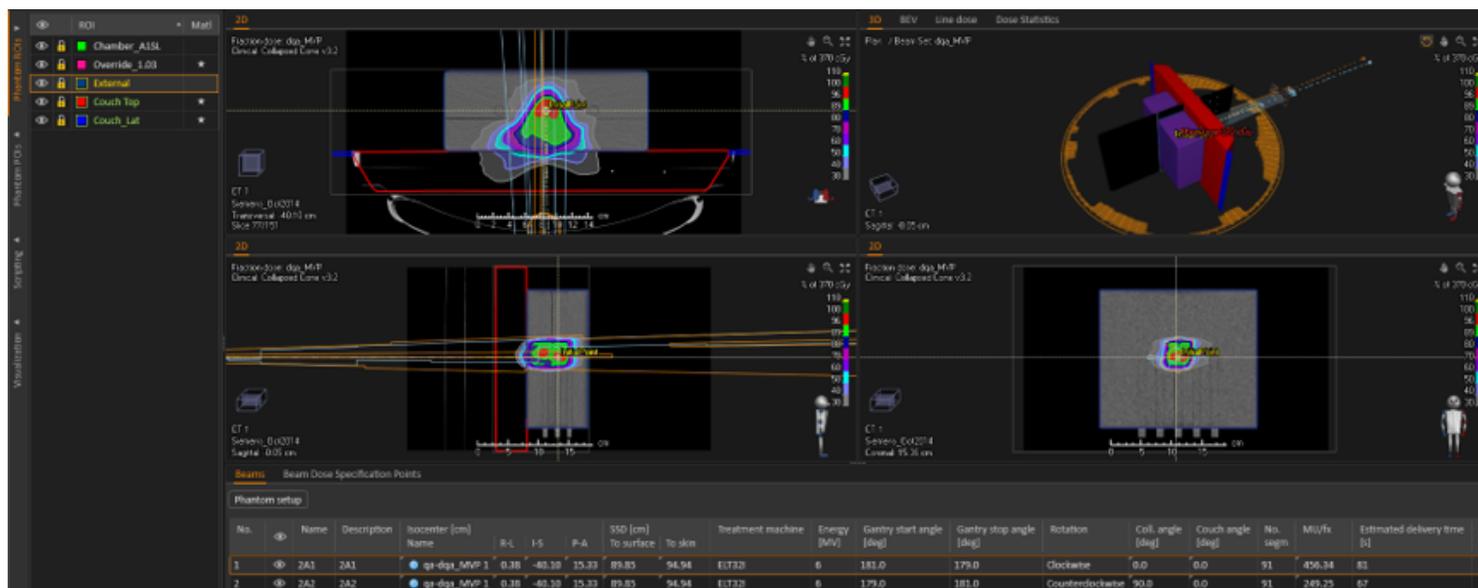


Figure 2

Screenshot of a patient plan mapped onto the MVP with the couch top

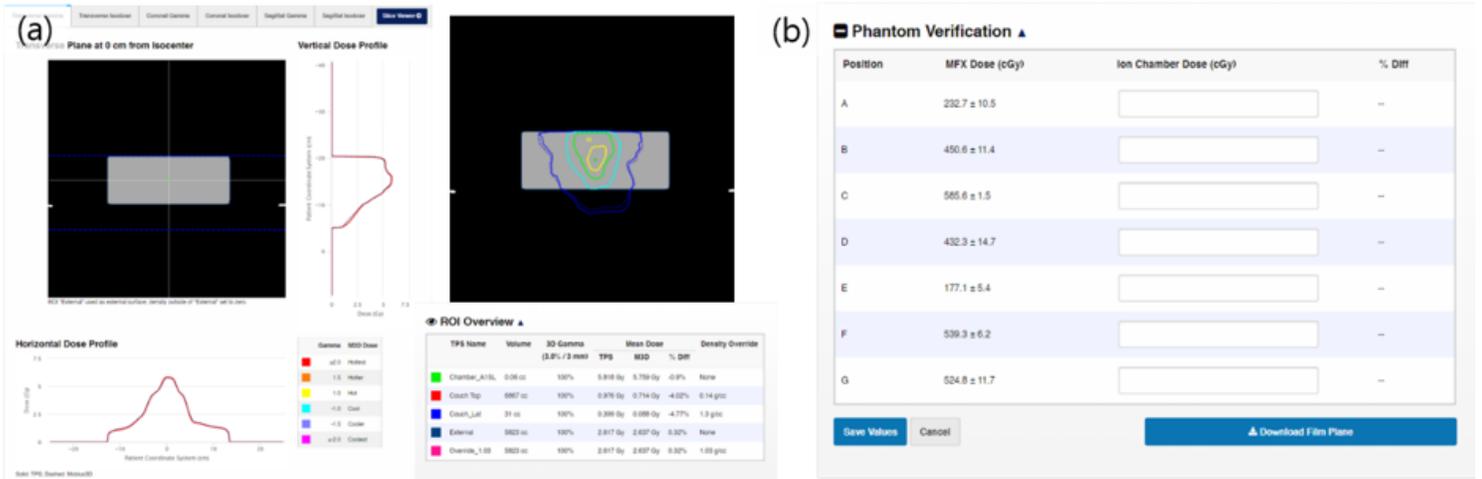


Figure 4

Example of Mobius plan check results for (a) point dose and dose distribution based on an MVP with an overridden couch top, and (b) automatic calculation of seven point doses using only the MVP.

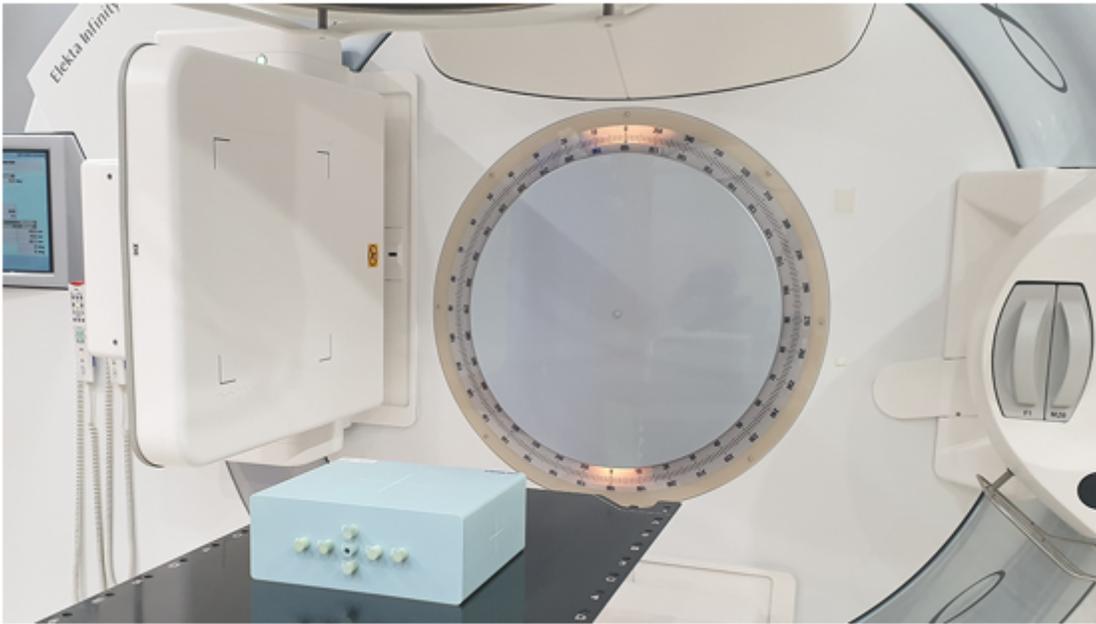


Figure 6

Mobius verification phantom (MVP) with A1SL chamber plug

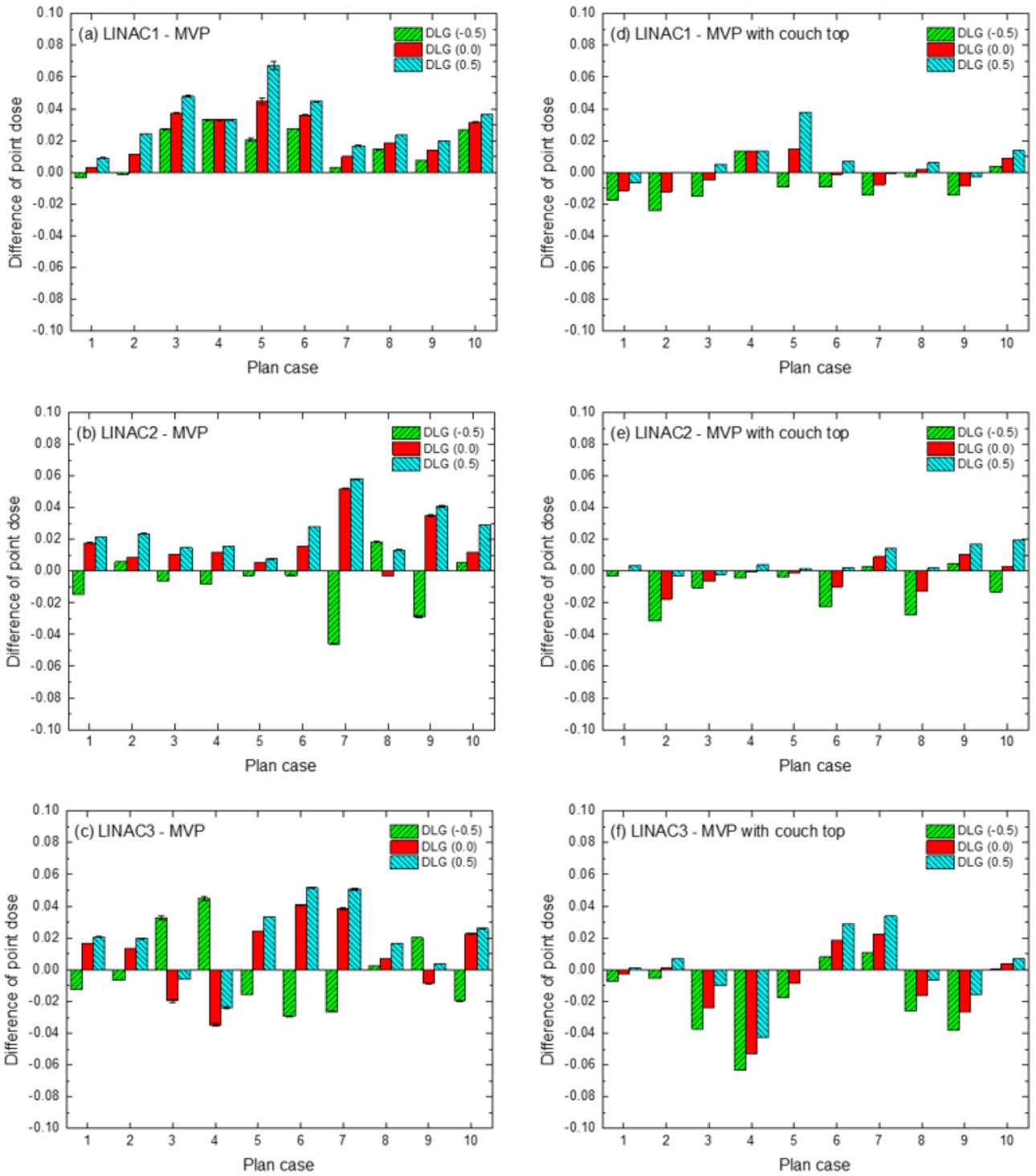


Figure 8

Comparison of point dose differences between doses calculated by Mobius3D and doses measured according to varying DLG correction factors.

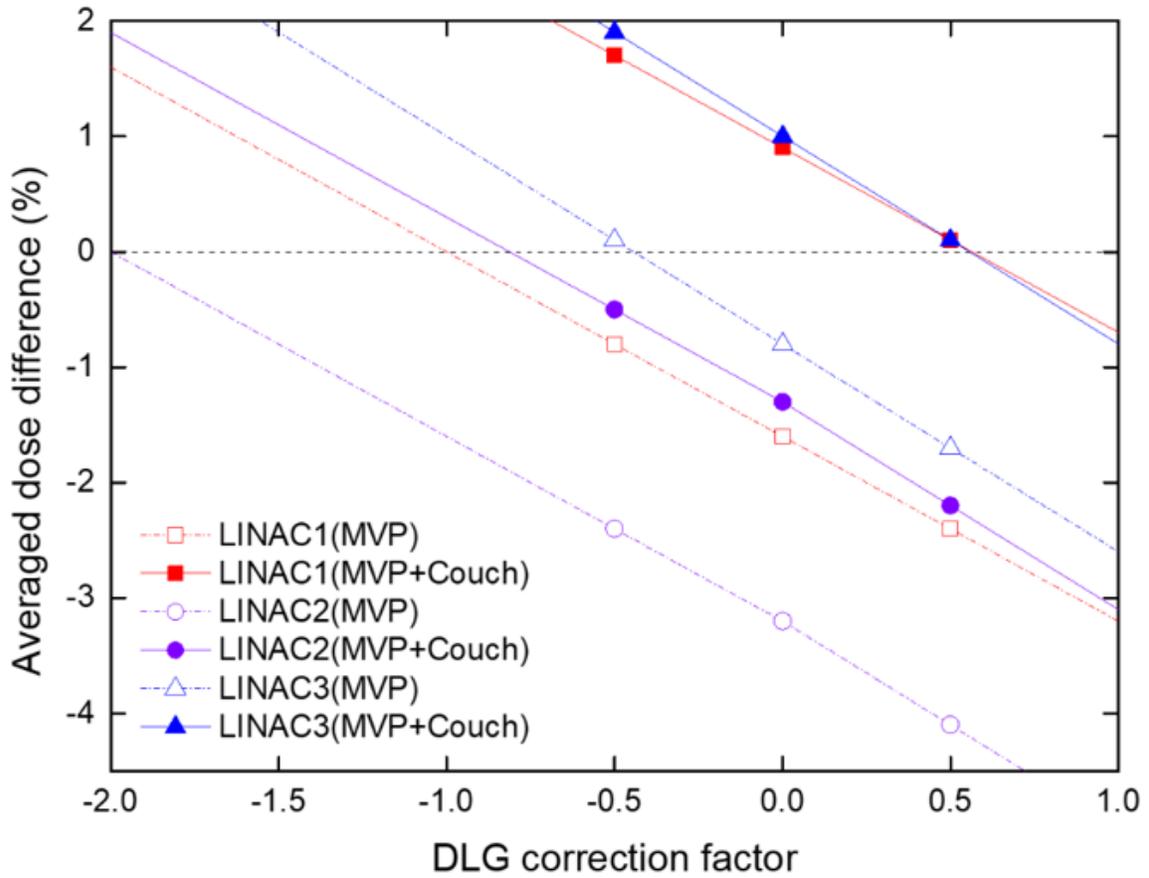


Figure 10

Average dose differences according to the DLG correction factor. The points were measured by the A1SL chamber and the lines were linearly extrapolated from the points.