2026 JULY 19–22
VANCOUVER, BC
JOINT AAPM | COMP MEETING

Impact of multileaf collimator cleaning on enhanced leaf model configuration in Eclipse v18

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ABSTRACT

Purpose: Eclipse v18 introduces an enhanced leaf model (ELM) for multileaf collimator (MLC) configuration. The model requires dosimetric measurements acquired with MLC-shaped fields and is therefore sensitive to leaf condition. Although leaf cleaning is commonly recommended prior to ELM implementation, it demands substantial resources and lacks evidence of clinical gain, which has limited its clinical adoption. This study quantifies the impact of leaf cleaning on ELM configuration and IMRT plan quality.

Methods: Before leaf cleaning, open, closed, and sweep-gap fields were delivered on a TrueBeam linac equipped with high-definition MLCs. Dose was measured using a Farmer ionization chamber, with each measurement repeated five times and averaged for dosimetric leaf gap (DLG) modeling in ELM. Twenty clinical IMRT plans were optimized using the updated MLC model. PSQA was performed with portal dosimetry, and gamma pass rates were evaluated. The same measurements, modeling, and PSQA process were repeated after leaf cleaning. Differences in pre- and post-cleaning gamma passing rates were assessed.

Results: After leaf cleaning, the absolute DLG decreased for every beam, including reductions of 0.077 mm (11.5%) for 6 MV and 0.074 mm (10.0%) for 6 MV FFF. Correspondingly, the mean gamma passing rate increased from 98.7% to 99.5% (± 1.3%) using 3%/2mm criteria ($p < 0.001$). Among all fields, 54.1% improved with a mean increase of 1.7% (±1.1%), 29.5% showed a mean decrease of 0.4% (±0.5%), and 16.4% were unchanged. Site-specific improvements were largest for head and neck (+2.0% ± 1.8%), followed by Iliac (+1.8% ± 0.6%).

Conclusion: MLC leaf cleaning resulted in reduced absolute DLG values and increased gamma pass rates for PSQA, with notable site-specific gains. Our findings demonstrate a measurable clinical benefit to support the incorporation of MLC leaf cleaning prior to ELM implementation.

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INTRODUCTION

- Accurate MLC modeling in the treatment planning system (TPS) is essential for high-quality IMRT dose calculation and delivery.
- Prior to Eclipse v18, Varian MLCs were represented using a simplified leaf model. Eclipse v18 introduces an Enhanced Leaf Model (ELM) that incorporates realistic leaf geometry, including rounded leaf tips, drive screw cutouts, and leaf body thickness, improving MLC representation in TPS (1,2).
- ELM configuration relies on interleaf transmission and sweep-gap measurements (3), which are sensitive to the physical condition of individual leaves.
- Over time, accumulated contamination and mechanical wear increase interleaf friction (4) and backlash (5), altering dynamic leaf trajectories and potentially compromising the reliability of ELM commissioning measurements.
- However, MLC leaf cleaning is labor-intensive, resource-demanding, and costly, and quantitative evidence demonstrating its clinical benefit for ELM commissioning remains limited.
- This study quantifies the impact of MLC leaf cleaning on ELM commissioning measurements and clinical IMRT plan quality. Our goal is to provide quantitative evidence and actionable workflow to optimize ELM implementation.

METHODS AND MATERIALS

Enhanced leaf model commissioning

- A Varian TrueBeam linear accelerator equipped with high-definition MLCs was evaluated before and after MLC leaf cleaning for energies 6 MV, 6FFF, 10 MV, and 10 MV FFF.
- Six vendor-provided test fields (open, closed-leaf transmission, and sweep-gap) were delivered on the TrueBeam linac. See Table 1 for field details.
- Dose was measured with a PTW Farmer ionization chamber in a solid water phantom at 10 cm depth and an SSD of 90 cm.
- Each measurement was repeated five times. The measured data were averaged and imported into Eclipse v18 for ELM configuration.
- Measurement variability and the modeled interleaf transmission and DLG values were evaluated before and after leaf cleaning.

Patient-specific quality assurance verification

- Twenty clinical IMRT/VMAT plans comprising 61 fields were reoptimized using the pre- and post-cleaning ELM configurations.
- Portal dosimetry PSQA was performed using 3%/2 mm criterion.
- Changes in gamma passing rates were evaluated overall, by treatment site, and across individual fields.

RESULTS

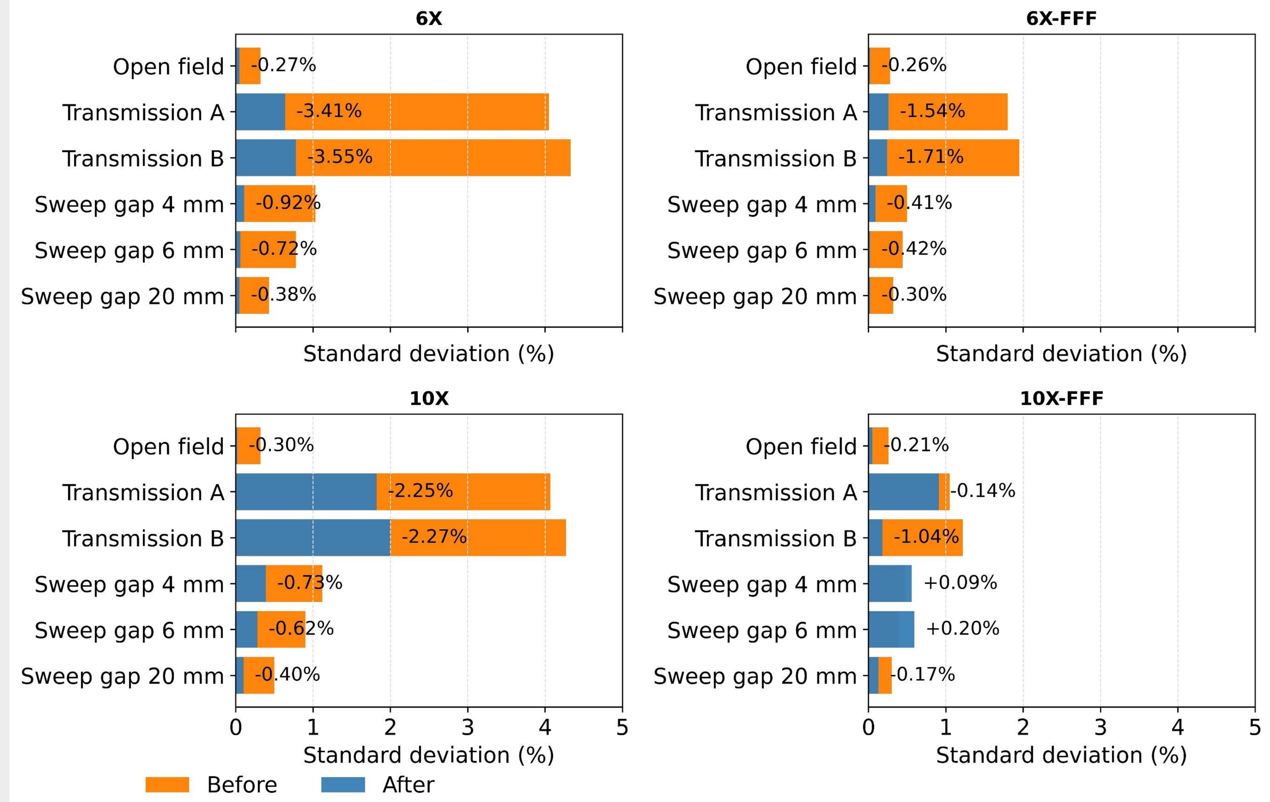
Key Summary

- MLC leaf cleaning reduced commissioning measurement variability, with the largest reductions observed in closed-leaf transmission. See Figure 1
- The absolute DLG values decreased for every beam, including reductions of 0.077 mm (11.9%) for 6 MV and 0.015 mm (2.2%) for 6 MV FFF. See Figure 2
- Overall PSQA performance improved after the cleaning, with mean gamma passing rates increasing from 98.7% to 99.5% using 3%/2 mm criteria ($p < 0.001$). Head and neck plans demonstrated the greatest PSQA improvement (+2.0% ± 1.8%) followed by illiac plans (+1.8% ± 0.6%). See Figure 3

Table 1. Treatment plans used for ELM commissioning

Test field	Description
Open field	10 × 10 cm² open field
Transmission A	Carriage A leaves fully closed over the field
Transmission B	Carriage B leaves fully closed over the field
Sweep gap 4 mm	A 4 mm fixed-width gap swept across the field
Sweep gap 6 mm	A 6 mm fixed-width gap swept across the field
Sweep gap 20 mm	A 20 mm fixed-width gap swept across the field

Figure 1. Standard deviations of ELM measurements pre- and post- leaf cleaning



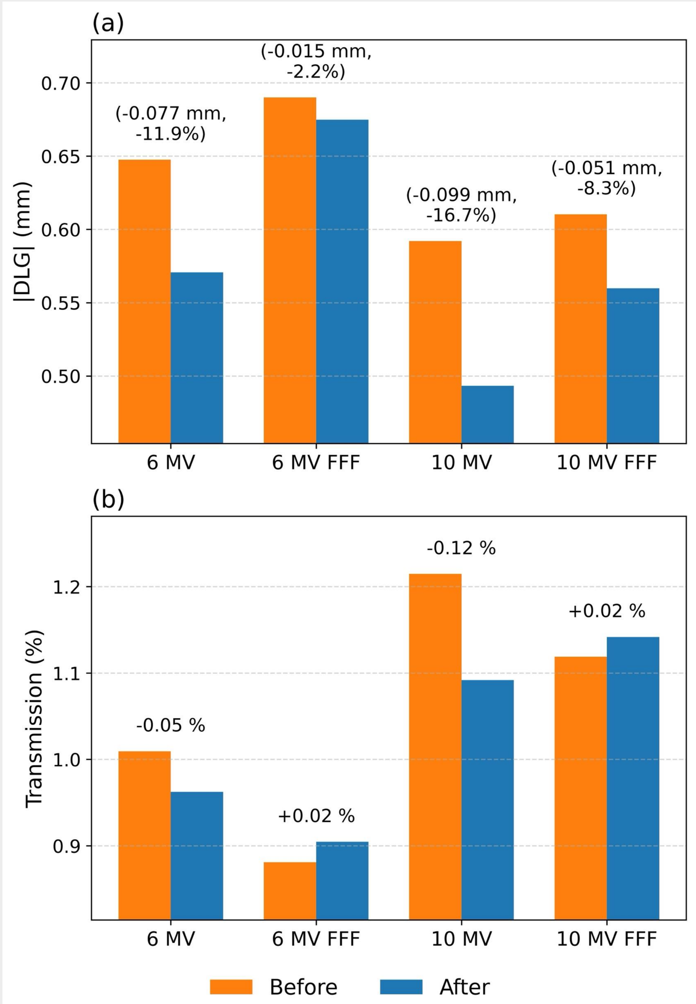


Figure 2. Comparison of DLG and interleaf transmission factors pre- and post-cleaning. DLG values are presented as absolute magnitudes (|DLG|).

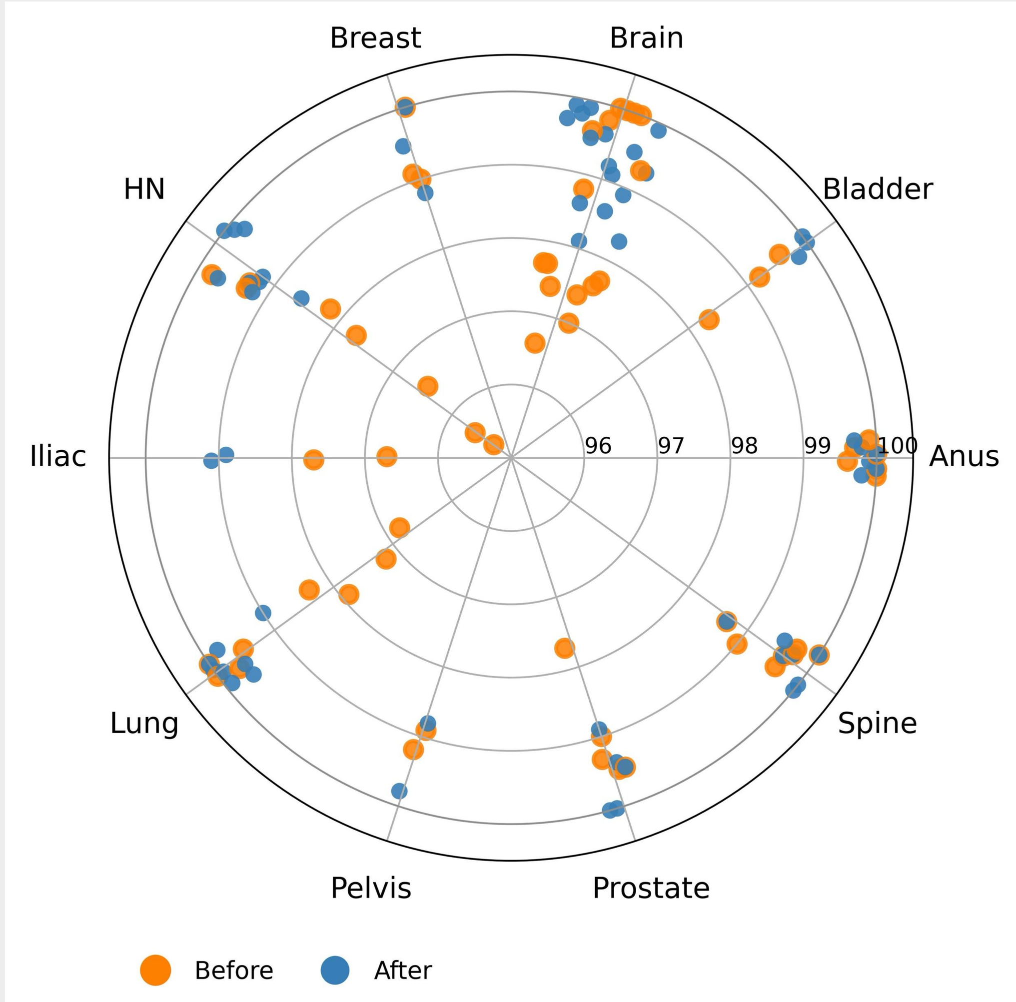


Figure 3. Site-specific PSQA results before and after MLC leaf cleaning. The radial axis indicates gamma passing rate (%) using 3%/2mm criterion. HN denotes head and neck.

DISCUSSION

- Our study highlights a timely clinical topic, as many radiation oncology departments are transitioning to Eclipse v18.
- Despite dosimetric benefits of this upgrade have been well established (1,2), quantitative evidence evaluating how physical machine conditions alter ELM commissioning baseline data remains absent in current literature.
- Our findings bridge this gap by establishing a direct, quantitative link between MLC leaf cleaning, commissioning data accuracy, and downstream clinical plan dosimetry.
- MLC leaf cleaning requires substantial time, coordination, and clinical resources. Our findings provide data-driven evidence to help radiation oncology departments weigh the operation value of leaf cleaning against clinical resources required during the transition to Eclipse v18.

CONCLUSION

- MLC leaf cleaning consistently reduced commissioning measurement variability, reduced the magnitude of configured DLG values across all beams, and improved clinical dosimetric agreement.
- The greatest benefits were observed in highly modulated plans.
- Collectively, these findings demonstrate that MLC leaf cleaning enhances commissioning fidelity and support its incorporation into ELM implementation workflow for Eclipse v18.

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