Evaluation of Enhanced Leaf Modeling (ELM) in Eclipse V18: Impact on VMAT Plan Modulation, Delivery Efficiency, and Secondary Dose

Michael Ashenafi and Dandan Zheng

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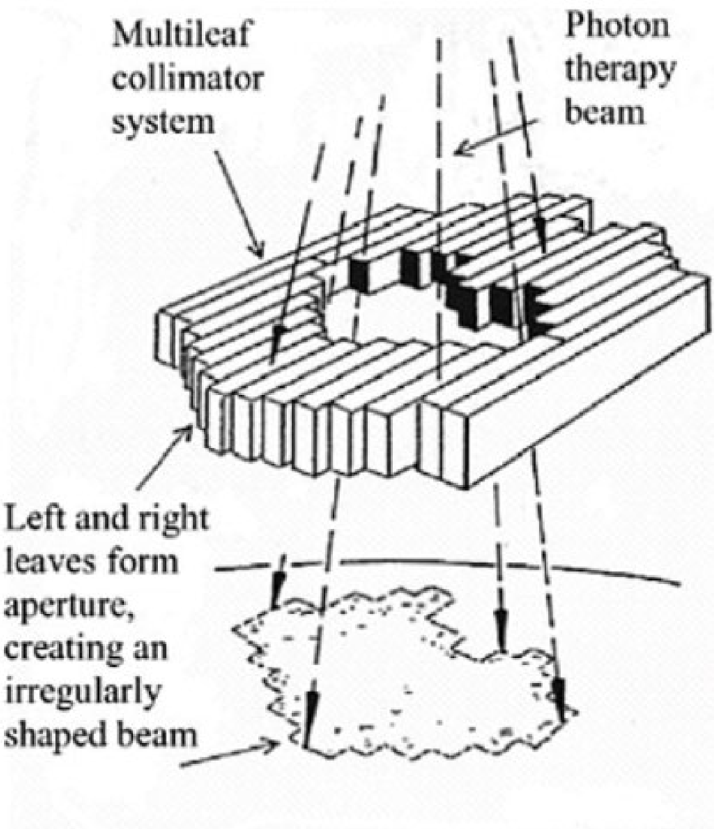
Introduction & Objective



A multileaf collimator (MLC) system.

What is Enhanced Leaf Modeling?

Enhanced Leaf Modeling (ELM) is a major upgrade in Eclipse Version 18 designed to precisely characterize Multi-Leaf Collimator (MLC) physical leaf geometry within the treatment planning system.

Primary Objective: Evaluate the clinical transition from Eclipse V15 to V18 with ELM to ensure no compromise in delivery efficiency, secondary dose checks, or patient-specific QA thresholds.

Picture: https://www.samaterials.com/multi-leaf-collimators-a-comprehensive-guide-with-cases.html

Metrics Evaluated

1. Complexity: Leaf motion & beam modulation variance assessed using the Plan Complexity Index.

2. Efficiency : Total Monitor Units (MU) per field tracked to indicate mechanical machine delivery speed.

3. Accuracy : Independent 3D secondary dose verification deviation measured via ClearCalc.

4. Fidelity: Experimental Gamma Index passing rate using 2%/2mm criteria measured via EPID.

Study Design & Cohort

Pre-Upgrade (V15)

VMAT Plans Analyzed: n = 78 clinical plans

Dose Calculation: AcurosXB algorithm

MLC Parameters: Standard leaf geometry parameters

Post-Upgrade (V18)

VMAT Plans Analyzed: n = 78 clinical plans

Dose Calculation: AcurosXB algorithm

MLC Parameters: Enhanced Leaf Modeling (ELM) enabled

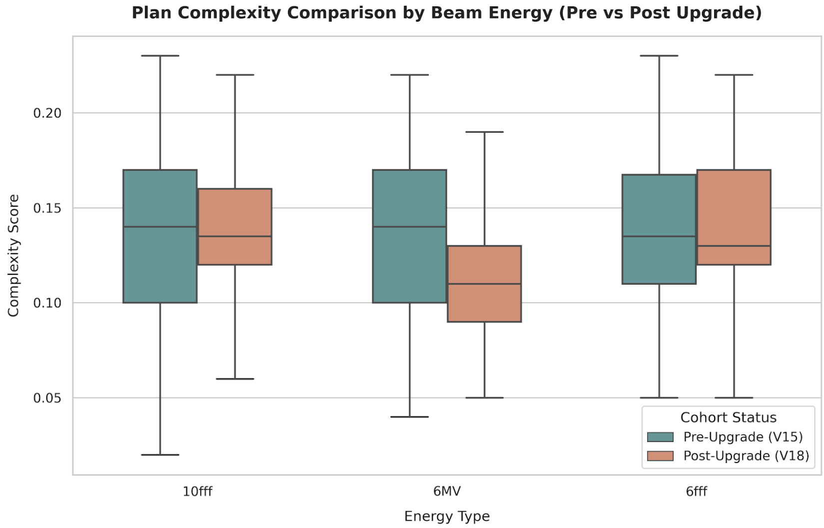
Treatment Sites

Treatment Site Category	Pre-Upgrade (V15, n=78)	Post-Upgrade (V18, n=78)
Prostate / Pelvis	51 (65.4%)	48 (61.5%)
Lung / Thorax	11 (14.1%)	13 (16.7%)
Spine / Sacrum	4 (5.1%)	6 (7.7%)
GYN Pelvis	4 (5.1%)	3 (3.8%)
Other Sites	8 (10.3%)	8 (10.3%)
Total Plans	78 (100%)	78 (100%)

Clinical Trial Results

statistical evaluation of the clinical cohorts.

Plan Complexity Drop (-7.2% Reduction)



Reduced Modulation, Safer Delivery

The transition to Eclipse V18 ELM resulted in a statistically significant reduction in average plan complexity, dropping from **0.138 to 0.128** ($p = 0.011$).

This reduction represents less mechanical beam modulation, translating directly into safer, more robust, and more reliable VMAT delivery dynamics.

Subgroup Analysis: The reduction in beam modulation was most pronounced and statistically significant in plans utilizing **6MV energy ($p = 0.001$)**.

Delivery Efficiency Gains (-4.6% Reduction)

While the cohort-wide statistical significance was not crossed, a strong clinical trend shows average Monitor Units (MU) per field dropped across the board post-upgrade.

This represents an average reduction of **17 MU per field (4.6%)**. Less machine beam-on time improves clinical patient throughput and decreases machine duty cycle requirements.

Secondary Calculation & QA

Dosimetric Accuracy Remains High

Zero Calculation Drift: Secondary check comparison (ClearCalc) demonstrated almost identical baseline agreements (-1.51% vs -1.53%; p = 0.597).

High Delivery Fidelity: Average experimental gamma passing rates exceeded 99.7% in both pre- and post-upgrade cohorts under 2%/2mm criteria (p = 0.486).

No Workflow Adjustments: The implementation of ELM does not require any custom modifications to clinical secondary check workflows.

Overall Clinical Metrics

Metric	Pre-Upgrade (Avg.)	Post-Upgrade (Avg.)	Pre-Upgrade (Median)	Post-Upgrade (Median)	P-value (Welch's t-test)
Plan Complexity Index*	0.138	0.128	0.140	0.130	**0.011 (Significant)**
Field Monitor Unit (MU)	370	353	308	293	0.366 (Not Sig.)
ClearCalc (% diff)	-1.51%	-1.53%	-1.59%	-1.89%	0.597 (Not Sig.)
Gamma Passing Rate (%)	99.8%	99.7%	100.0%	100.0%	0.486 (Not Sig.)

**Plan complexity reduction remains highly statistically significant.*

Reference: Younge, et al. (2016). Predicting deliverability of VMAT plans using aperture complexity analysis. JACMP 17(4), 124–131.

Key Study Conclusions

Eclipse V18 ELM successfully reduces plan modulation while maintaining equivalent clinical calculation accuracy.

Independent 3D secondary dose verification confirmed no systematic calculation drift in the primary TPS engine.

No modifications to existing patient-specific clinical QA thresholds are necessary following upgrade integration.

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Evaluation of Enhanced Leaf Modeling (ELM) in Eclipse V18: Impact on VMAT Plan Modulation, Delivery Efficiency, and Secondary Dose

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ABSTRACT

Purpose: To evaluate the clinical impact of the Eclipse Version 18(V18) upgrade, specifically the implementation of Enhanced Leaf Modeling (ELM), on VMAT plan complexity, delivery efficiency, and dosimetric accuracy compared to the previous Version 15(V15).

Methods: A retrospective analysis was performed on two cohorts of VMAT plans: a pre-upgrade group (V15, n=78 plans) and a post-upgrade group (V18, n=78 plans). Both cohorts utilized the AcurosXB algorithm for dose calculation. Metrics evaluated included the Plan Complexity Index, Monitor Unit (MU), Patient Specific Quality Assurance (PSQA) with gamma pass rates at 2%/2mm, and secondary dose verification agreement using ClearCalc, utilizing Finite-Size Pencil Beam algorithm. Subgroup analyses were performed for 6MV, 6fff, and 10fff to assess the effect of energy. Statistical significance was determined using Welch's t-test ($p < 0.05$).

Results: The transition to V18 resulted in a statistically significant reduction in average plan complexity, decreasing from 0.138 to 0.128 ($p = 0.011$). This reduction in modulation was most pronounced in plans utilizing 6MV energy ($p = 0.001$). An average reduction of 17 MU per field was observed in the post-upgrade cohort, indicating a trend toward higher delivery efficiency, though this did not reach statistical significance across the cohort ($p = 0.366$). Dosimetric accuracy remained high and stable, with average Gamma passing rates exceeding 99.7% in both groups ($p = 0.486$). Furthermore, the agreement between the Treatment Planning System and ClearCalc was nearly identical between versions (mean deviation of -1.51% vs. -1.53%; $p = 0.597$), confirming no systematic drift in dose calculation relative to the secondary algorithm.

Conclusion: The implementation of Eclipse V18 ELM reduces VMAT plan complexity and improves delivery efficiency while maintaining the high dose calculation fidelity seen in V15. The stability of the secondary check results demonstrates that the upgrade provides reduced modulation complexity without requiring adjustments to existing clinical quality assurance tolerances.

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INTRODUCTION

Enhanced Leaf Modeling (ELM) is a major upgrade designed to accurately characterize Multi-Leaf Collimator leaf geometry within the Varian Treatment Planning System. While this upgrade aims to improve accuracy, it is critical to evaluate how these changes affect plan complexity and whether they require adjustment to existing quality assurance thresholds or independent secondary dose verification workflows.

Study Objective:
To evaluate the clinical impact of migrating from Eclipse Version 15 (V15) to Version 18 (V18) with ELM by analyzing:

- Plan modulation complexity[1]
- Delivery efficiency
- Dosimetric fidelity

METHODS AND MATERIALS

A retrospective analysis was performed on two cohorts of VMAT plans:

- Pre-Upgrade: 78 plans designed using Eclipse V15
- Post-Upgrade: 78 plans designed using Eclipse V18 featuring ELM.

Both cohorts utilized the AcurosXB algorithm for dose calculation.

To assess the impact of the upgrade, four primary metrics were evaluated and compared:

- Plan Complexity Index used to measure leaf motion and beam modulation variations.
- Delivery efficiency evaluated by tracking MU per field.
- Patient specific QA (PSQA) measured via gamma passing rate using 2%/2mm criteria.
- Secondary dose calculation assessed via ClearCalc (Radformation) to check for systematic calculation drift.

Plans were stratified by beam energy into 6MV, 6fff, and 10fff subgroups to analyze energy dependent effects.

Difference between the V15 and V18 cohorts were analyzed using t-test with statistical significance defined as $p < 0.05$.

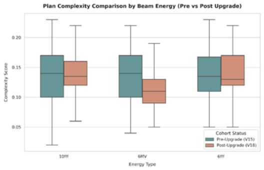

Figure 1. Comparison of Modulation Complexity Scores Across Cohorts and Energy Subgroups.

RESULTS

Complexity Reduction: Average plan complexity decreased by 7.2% (from 0.138 to 0.128; $p = 0.011$). This reduction in beam modulation was most pronounced in 6MV energy ($p = 0.001$). A lower complexity index represents less mechanical modulation, translating directly to safer, more robust and reliable VMAT delivery dynamics.

Delivery Efficiency: Observed an average reduction of 17 MU per field (4.6%) in the V18 cohort. While clinically beneficial, this cohort wide trend did not reach statistical significance ($p = 0.366$).

Stable Secondary Verification: Agreement between the primary TPS and ClearCalc independent calculation remained nearly identical (mean deviation of -1.51% vs. -1.53%; $p = 0.597$). This outcome confirms no systematic drift in primary TPS dose calculation relative to secondary independent algorithm.

Excellent Dosimetric Accuracy: PSQA delivery accuracy remained high and stable, with average gamma passing rates exceeding 99.7% for both versions ($p = 0.486$). This proves the introduction of ELM does not compromise physical delivery accuracy.

Metric	Pre-Upgrade (Avg.)	Post-Upgrade (Avg.)	Pre-Upgrade (Median)	Post-Upgrade (Median)	p-value
Plan Complexity Index	0.138	0.128	0.140	0.130	0.011
Field Monitor Unit (MU)	370	353	308	293	0.366
ClearCalc (% diff)	-1.51	-1.53	-1.59	-1.89	0.597
Gamma Passing Rate(%)	99.8	99.7	100.0	100.0	0.486

Table 1. Overall Clinical Metrics. Statistical significance is defined as $p < 0.05$. Plan complexity reduction remains highly statistically significant.

KEY STUDY CONCLUSIONS

Implementation of Eclipse V18 ELM reduces VMAT plan complexity and improves delivery efficiency while maintaining the high dose calculation fidelity seen in V15.

The stability of the secondary check results confirms that the upgrade introduces no systematic drift in primary TPS dose calculation relative to secondary independent algorithm.

No modifications to existing PSQA thresholds or independent secondary calculation validation criteria are necessary.

CLINICAL TRANSLATION & IMPACT

Eclipse V18 ELM reduces VMAT plan complexity and improves delivery efficiency without requiring any adjustment to existing patient specific clinical quality assurance tolerance.

REFERENCES

1. Younge, et al. (2016). Predicting deliverability of VMAT plans using aperture complexity analysis. *JACMP* 17(4), 124–131.

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