Clinical Implementation of Jaw Tracking for 3D-CRT: Dosimetric Evaluation and Patient-Specific QA Requirement

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ABSTRACT

Purpose: Jaw-tracking is a standard feature for IMRT and VMAT on TrueBeam accelerators, but its application in 3D-conformal radiotherapy (3D-CRT) is less common. Benefits may exist when utilizing electronic compensation. This study evaluates the dosimetric impact, delivery accuracy, and multi-machine reliability of dynamic-jaw (DJ) for 3D-CRT plans to determine if it can be safely implemented without routine PSQA.

Methods: Ten previously treated 3D-CRT cases (breast, spine, and liver) with field sizes > 3x3cm2 were recalculated using fixed-jaw (FJ) and DJ tracking. Comparative metrics included total MU, target mean dose, OAR maximum dose (parotids, contralateral breast, lung, and spine), Conformity Index (CI), and Gradient Measure (GM). PSQA was performed using EPID and ArcCheck, compared against TPS predicted fluence (2%/2mm gamma criteria). To minimize output variation, FJ and DJ QA plans were measured consecutively. Secondary dose verification was performed via ClearCalc. Finally, cross-machine deliverability was verified by delivering same plan across eight machines and comparing results via gamma analysis. Statistical significance was assessed using Welch's t-test ($p < 0.05$).

Results: DJ plans showed a negligible 0.5% increase in total MU, but no significant difference compared to FJ plans (p=0.98). Similarly, no significant differences were found for target mean dose (p=0.63) or OAR max dose (p=0.98). While DJ provided a 3.4% improvement in CI and a 1.7% increase in GM, these changes were not statistically significant (p=0.73 and p=0.93, respectively). Gamma analysis and secondary check results showed good agreement between techniques (p=0.78 and p=0.96, respectively). Deliverability was successfully confirmed across all machines with high agreement between delivered and TPS-predicted fluence.

Conclusion: Jaw-tracking for 3D-CRT is dosimetrically equivalent to fixed-jaw techniques while offering modest improvements in conformity and dose fall-off. For field size > 3x3cm2 jaw-tracking can be safely implemented without routine PSQA on accelerators adhering to TG-142 recommended standards.

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INTRODUCTION

Clinical Gap: Jaw tracking is a standard feature for dynamic modalities like static (IMRT/VMAT on TrueBeam LINAC, but its application in 3D-conformal radiotherapy is far less common.

Benefits: Jaw tracking reduces peripheral scatter and transmission dose to healthy tissue outside the MLC aperture by dynamically fitting the jaws to the treatment aperture. Varian recommends jaw tracking during dynamic MLC delivery to ensure compliance with international IEC protocols (IEC 60601-2-1:2020)[1].

Objective: This study evaluates the Dosimetric impact, delivery accuracy, and multi-machine reliability of **dynamic-jaw (DJ)** tracking for 3D-CRT plans to determine if it can be safely implemented in clinics without requiring routine, time-consuming Patient-Specific QA (PSQA) for field size > 3 x 3 cm^2.

METHODS AND MATERIALS

- Patient Cohort: 10 previously treated 3D-CRT cases across multiple treatment sites (breast, spine, & liver) originally planned with **fixed jaws (FJ)** were selected.
  - Ecomp. & Field in Field techniques
- Planning Workflow**:** Original **FJ** plans were duplicated and converted to DJ plans by enabling jaw-tracking, with jaws continuously tailored to the target structure. All plans were calculated using the AXB (v18) algorithm.
- Evaluation Metrics: Total MU, Target Mean Dose, OAR maximum dose (parotids, contralateral breast, lung, and spine), conformity index (CI), and Gradient Measure (GM).
- Quality Assurance & Deliverability:
  - Secondary independent dose verification performed using ClearCalc (v2.5).
  - Patient-Specific QA (PSQA):
    - All plans: Measured via EPID & ArcCheck using 2%/2mm gamma criteria.
    - One representative plan was run using PSQA EPID across 8 linear accelerators.
- Analyzed using Welch's t-test (significance threshold: $p < 0.05$).

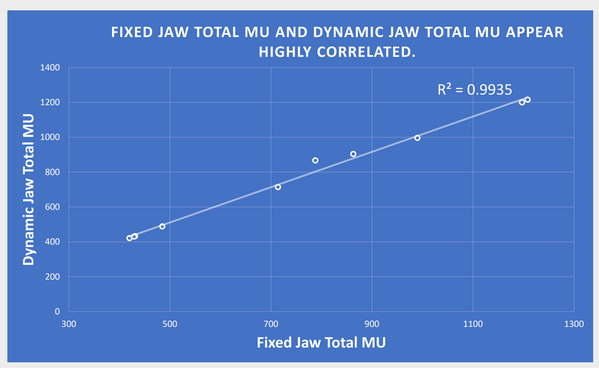

Figure 1: Total MU comparison graph showing equivalent delivery efficiency between FJ and DJ modalities

RESULTS

- MU Impact: **DJ** tracking plans showed a minimal 0.5% increase in average total MU, demonstrating no statistically significant difference compared to traditional **FJ** plans (p = 0.98).
  - Switching to DJ did not alter delivery efficiency (Figure 1).
- Equivalent Dosimetry: No statistically significant differences were observed for target mean dose (p = 0.63) or OAR maximum dose (p = 0.98). While overall p-values were equivalent, specific cases (like contralateral breast in Case 1) achieved reduction from 5.6% (**FJ**) to 2.6%(**DJ**).
- Conformity & Target Fall-off: **DJ** provided a 3.4% improvement in the CI (p = 0.73). The Gradient Measure showed a slight increase but remained statistically equivalent between both modalities (2.08cm vs 2.12cm, p = 0.93).
- Robust Delivery Accuracy: PSQA gamma analysis and ClearCalc demonstrated agreement between both modalities.
- Observation: DJ automatically shield regions outside the immediate treatment aperture. (Figure 2).
- Cross-machine deliverability: Successfully confirmed with high agreement between all 8 linear accelerators.

Test	FJ - AVG	DJ - AVG	Ratio	Diff. (%)	welch t-test
Total MU	763.4	766.8	1.00	0.4%	**0.98**
Target Mean Dose (% of Rx)	102.1	101.9	1.01	-0.2%	**0.63**
OAR Max Dose (% of Rx)	31	30.5	1.02	-1.6%	**0.98**
Conformity Index	1.22	1.17	1.03	-3.4%	**0.73**
Gradient Measure (cm)	2.08	2.12	0.98	1.7%	**0.93**
PSQA min. passing (%)	99.08%	99.26%	1.00	-0.2%	**0.78**
CC absolute max. deviation(%)	3.30%	3.32%	0.99	0.7%	**0.96**

FJ – Fixed Jaw; **DJ** – Dynamic Jaw; CC – ClearCalc; **Rx** – Prescription Dose; **PSQA** – Patient Specific Quality Assurance
Conformity index value - The volume enclosed by the prescription isodose surface divided by the target volume.
Gradient Measure — The difference in cm between the equivalent sphere radius of the prescription and the 50% prescription isodoses.

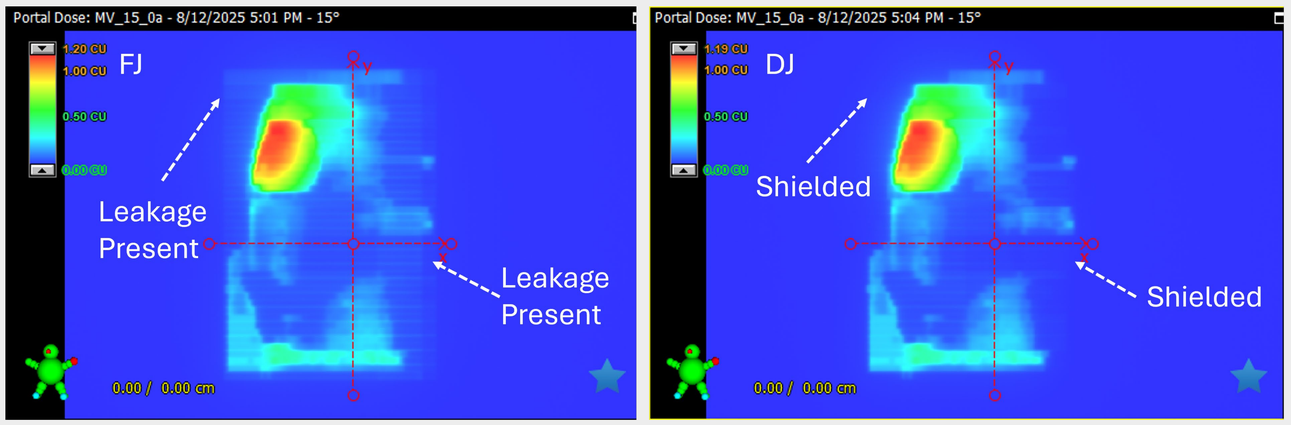

Fig. 2: Portal Dosimetry for FJ and DJ. White arrows point to the presence of noticeable out-of-field MLC leakage and interleaf transmission dose in the FJ plan, and the successful elimination of this leakage in the shielded DJ plan.

CONCLUSIONS

- Dosimetric Equivalence: Jaw-tracking for 3D-CRT delivers plan quality and delivery efficiency that is fully equivalent to traditional fixed-jaw techniques.
- Modest Plan Improvements: Transitioning to dynamic jaws offers a minor, non-significant improvement in conformity and demonstrated reduction of out field leakage.
- PSQA Exemption: jaw-tracking can be safely deployed for field sizes > 3 x 3 cm^2 without routine PSQA on linear accelerators adhering to TG-142 standard quality controls, utilizing standard secondary check systems.

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REFERENCES

1. Siemens Varian TrueBeam Jaw Tracking TB4.1-QTS-06-A

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