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Investigating Setup Variability Using Couch-Indexed 3D-Printed Mounts in Routine Linear Accelerator QA

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ABSTRACT

PURPOSE: Test whether couch-indexed 3D-printed mounts reduce user-dependent setup variability without compromising routine LINAC QA measurements.
METHODS: Mounts for a monthly cube and BeamChecker Plus indexed through a Varian Lok-Bar at standardized 100 cm SSD positions on TrueBeam and Edge. Evaluation included CT characterization, perturbation, repeated manual versus indexed setups, timing, and a ~3-week pre/post clinical comparison.
RESULTS: Perturbation was acceptable; controlled testing favored output, and setup was 4.2–7.4 s faster. Clinically, output variability decreased on TrueBeam (+0.05 pp) and Edge (+0.25 pp); profiles were mixed.
CONCLUSION: Mounts were practical. Early data suggest an output benefit; longer-term profile data are needed.

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INTRODUCTION

Clinical problem: Manual laser alignment and SSD adjustment add user-dependent variation that can blur long-term LINAC QA trends.
Design premise: 3-D printed mounts via Lok-Bar indexing fixes the couch attachment point, while device-specific geometry of 3-D printed mounts constrains the phantom position.
Study question: Can indexed positioning reduce setup-related spread without meaningfully perturbing the measurement or burdening workflow?
Objectives: Build mounts for two routine QA devices; establish machine-specific reference positions; compare perturbation, reproducibility, and setup time; and evaluate early clinical trends.

METHODS

Devices: *Varian* TrueBeam and Edge, Monthly cube + ion chamber for output; *Standard Imaging* QA BeamChecker™ Plus for output, flatness, and symmetry.
Geometry: 3-D printed mount attached to Varian Lok-Bar with machine/device-specific couch coordinates at 100 cm SSD on TrueBeam and Edge.
Perturbation: Five immediate repeat runs with and without each mount per energy.
Validation: Two user groups; each completed three manual and three indexed setups per energy. Output, profiles, and time were recorded.
Clinical trend: Approximately 3 weeks mounted versus the immediately preceding 3 weeks non-mounted. SD and CV quantified variability. Monthly cube analysis awaits additional data.

Fig. 1. Cube mount

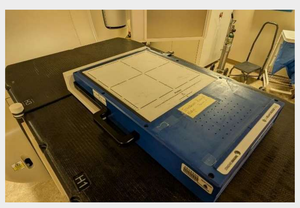

Fig. 2. BeamChecker mount

RESULTS

Mechanical fit: Both mounts repeatedly engaged the Lok-Bar without significant rocking or lateral play; BeamChecker mount mean CT number was 128.6 HU.
Perturbation: Maximum observed output shift was 0.13% for the cube and 0.086% for BeamChecker.
Controlled validation: Output variability decreased for most BeamChecker energies; cube results improved at all Edge energies but were mixed on TrueBeam. Profile metrics were mixed.
Workflow: Indexed setup saved 4.2-7.4 s per run.
Early clinical use: Output improved at all 12 energies (mean ΔCV: TrueBeam +0.05 pp; Edge +0.25 pp). Profile changes were smaller and mixed; axial worsened most (mean ΔSD: −0.06 and −0.17 pp).

Table 1. Results at a glance. BC = BeamChecker. Clinical means by machine; positive Δ = lower variability with mount (pp).

Study phase	Comparison / magnitude	Takeaway
Nonclinical: perturbation	Mount vs no mount Max shift: cube 0.13%; BC 0.086%	**No meaningful effect**
Nonclinical: repeat setups	Manual vs indexed Lower variability: 18/24 tests (cube 8/12; BC 10/12)	**Mostly favored indexing**
Setup-time validation	Manual vs indexed 4.2–7.4 s faster/run	**Small time gain**
Early clinical: output	All 12 energies improved Mean ΔCV: TrueBeam +0.05 pp; Edge +0.25 pp	**Improved on both; larger on Edge**
Early clinical: profiles	Mean ΔSD: Flat / TR / AX (pp) TrueBeam: −0.03 / −0.03 / −0.06 Edge: −0.01 / +0.06 / −0.17	**Mostly small; AX had largest worsening**
Bottom line: Output variability decreased on both machines; profile changes were smaller and machine dependent.		

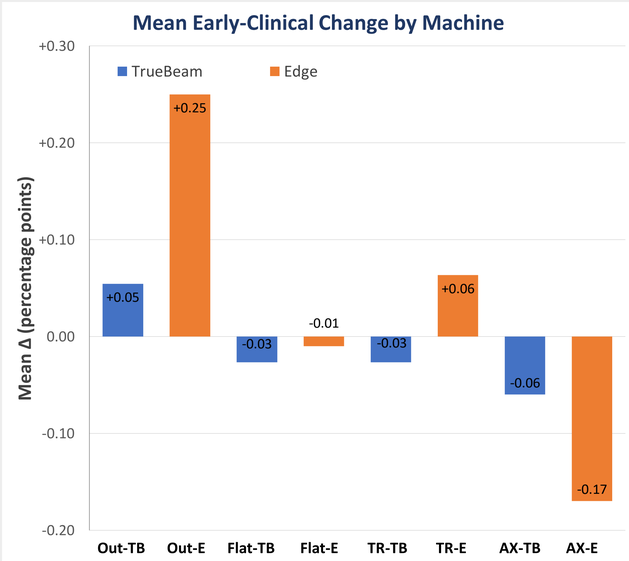

Fig. 3. Mean clinical change by machine (TrueBeam n=9 energies; Edge n=3). Positive = lower variability with mount; output uses ΔCV and profiles use ΔSD.

DISCUSSION

Output signal: The most consistent benefit was lower output variability, especially on the Edge during routine mounted use.
Profile caution: Machine-specific means were small for flatness (TB −0.03; Edge −0.01 pp) and mixed for transverse (−0.03; +0.06 pp); axial worsened most (−0.06; −0.17 pp).
Interpretation: Indexing removes device-placement degrees of freedom, but not short-term machine output, detector response, residual alignment, or measurement noise.
Workflow: Time savings were consistently positive but small; the more important operational gain is setup standardization.
Limitations: Short (~3-week) pre/post clinical windows; possible minor residual play despite stable mounting, limited users, and clinical differences may reflect factors beyond the mount.
Next step: Continue mounted data collection and further investigation into profile metrics before changing baselines or claiming a profile-reproducibility benefit.

CONCLUSIONS

- Both couch-indexed mounts were mechanically stable and practical for routine use.
- Measured perturbation remained small and not clinically problematic.
- Preliminary clinical data support improved output reproducibility across all TrueBeam and Edge energies.
- Profile changes were smaller and machine dependent; axial symmetry showed the largest worsening.

Take-home: Promising for output standardization, but longer-term data are required.

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