

Ultra Cheap 3D-Printed Electron Cutout For Elekta Linear Accelerators

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ABSTRACT

Purpose: To develop and characterize a low-cost, 3D-printed, patient-specific electron cutout filled with steel ball bearings (BBs) for use with Elekta linear accelerators, and to assess current electron radiotherapy (ERT) practices and clinical perspectives on existing and emerging electron cutout technologies in California.

Methods: A 10x10 cm² electron cutout was developed using a 3D-printed shell filled with low-cost steel BBs and a reusable copper support bracket. A 7-cm circular aperture was fabricated and tested against a CNC-copper cutout. TG and LR profiles were measured at dmax for 6–15 MeV electrons at 100 cm SSD on an Elekta Infinity using a PTW1500 array. Aperture size was assessed with EBT3 film, and transmission of solid cutouts at 2 cm water-equivalent depth was compared with CNC-copper and Cerrobend. A clinical survey on ERT practices and perceptions of 3D-printed cutouts was distributed to AAPM members.

Results: Dose profiles from the 3D-printed cutout were comparable to CNC-machined copper, with 80–20% penumbra widths <1 mm for 6 and 9 MeV beams and <2 mm for 12 and 15 MeV beams. Full width at half maximum and transmission (<5%) were also comparable, and the 7-cm circular aperture was confirmed at 100 cm SSD. Twenty-four AAPM members responded to the survey; all offered electron radiation therapy, typically comprising 1–5% of treatments. Cutouts were primarily Cerrobend (58.3%) or CNC-copper (33.3%). Cerrobend users cited toxicity concerns, while CNC-copper users cited long fabrication times. Awareness of 3D-printed solutions was high, with reduced fabrication time and elimination of toxic materials as key benefits, though workflow integration remained a concern.

Conclusions: A steel BB-filled, 3D-printed electron cutout demonstrates comparable dosimetric performance to CNC-copper cutouts while addressing key clinical limitations of existing technologies. This approach shows promise as a safe, cost-effective, and clinically viable alternative for ERT.

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INTRODUCTION

Electron radiotherapy (ERT) is widely used for treating superficial lesions due to its high surface dose, rapid dose falloff, and relatively low cost. However, unlike photon-based techniques such as IMRT, clinical ERT workflows and hardware, particularly electron cutouts for field shaping, have seen limited innovation in recent years.

Conventional cutouts are typically fabricated from Cerrobend, a toxic alloy requiring specialized handling. Although alternative materials and fabrication methods have been explored, including CNC machining and 3D printing, clinical adoption of these approaches remains limited. Notably, while prior work has demonstrated 3D-printed electron cutouts for Varian systems^{1,2}, similar implementations have not yet been reported for Elekta linear accelerators.

In this study, we investigate a practical, low-cost 3D-printed electron cutout design for Elekta systems using a polymer shell filled with steel ball bearings. Dosimetric performance is compared with conventional cutouts, alongside a survey of current clinical practices, to evaluate feasibility for routine clinical implementation.

METHODS AND MATERIALS

A 10x10 cm² electron cutout was developed using a 3D-printed shell filled with low-cost steel BBs and a reusable copper support bracket. A 7-cm circular aperture was fabricated and tested against a CNC-copper cutout.

TG and LR profiles were measured at dmax for 6–15 MeV electrons at 100 cm SSD on an Elekta Infinity using a PTW1500 array. Aperture size was assessed with EBT3 film, and transmission of solid cutouts at 2 cm water-equivalent depth was compared with CNC-copper and Cerrobend.

A clinical survey on ERT practices and perceptions of 3D-printed cutouts was distributed to AAPM members.

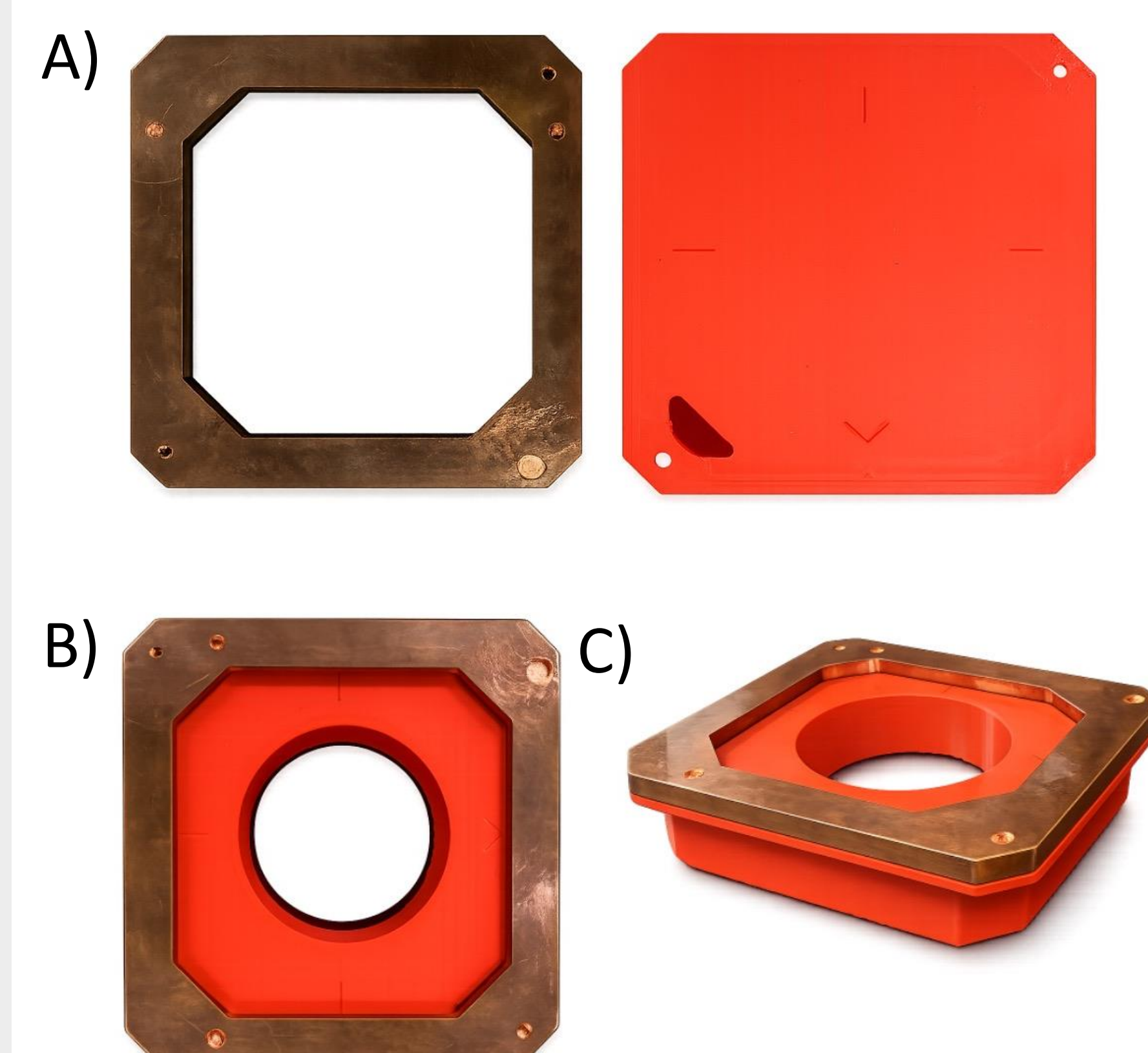


Figure 1. (A) 10x10 cm² Copper Bracket with 3D Printed Cutout Body. (B) Fully Assembled Cutout (TOP). (C) Assembled Cutout (SIDE)

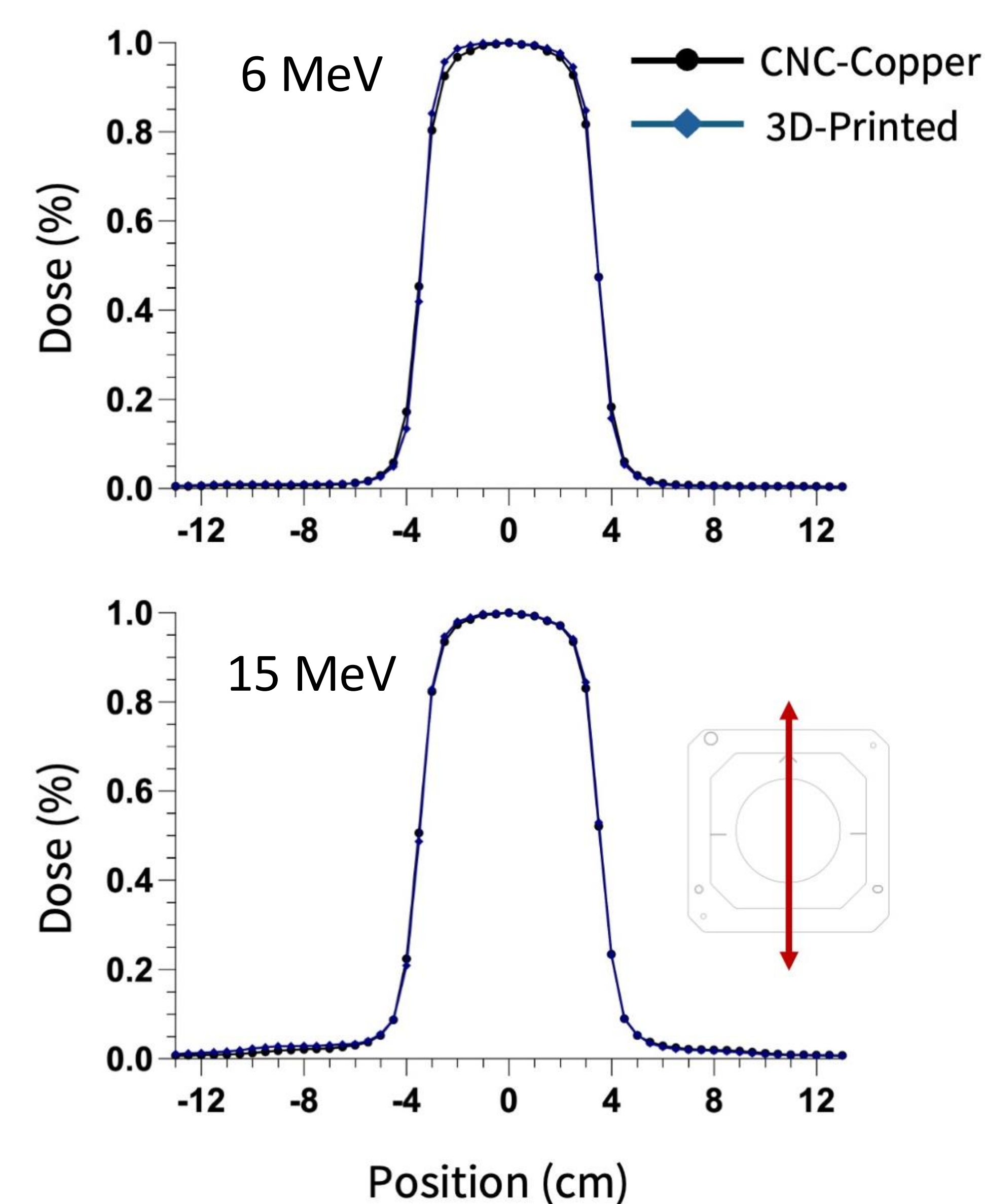
RESULTS

Dose profiles from the 3D-printed cutout were comparable to CNC-machined copper, with 80–20% penumbra widths <1 mm for 6 and 9 MeV beams and <2 mm for 12 and 15 MeV beams. Full width at half maximum and transmission (<5%) were also comparable, and the 7-cm circular aperture was confirmed at 100 cm SSD.

Twenty-four AAPM members responded to the survey; all offered electron radiation therapy, typically comprising 1–5% of treatments. Cutouts were primarily Cerrobend (58.3%) or CNC-copper (33.3%).

Cerrobend users cited toxicity concerns, while CNC-copper users cited long fabrication times. Awareness of 3D-printed solutions was high, with reduced fabrication time and elimination of toxic materials as key benefits, though workflow integration remained a concern.

A) LR Dose Profile Comparison



B) Dose Transmission

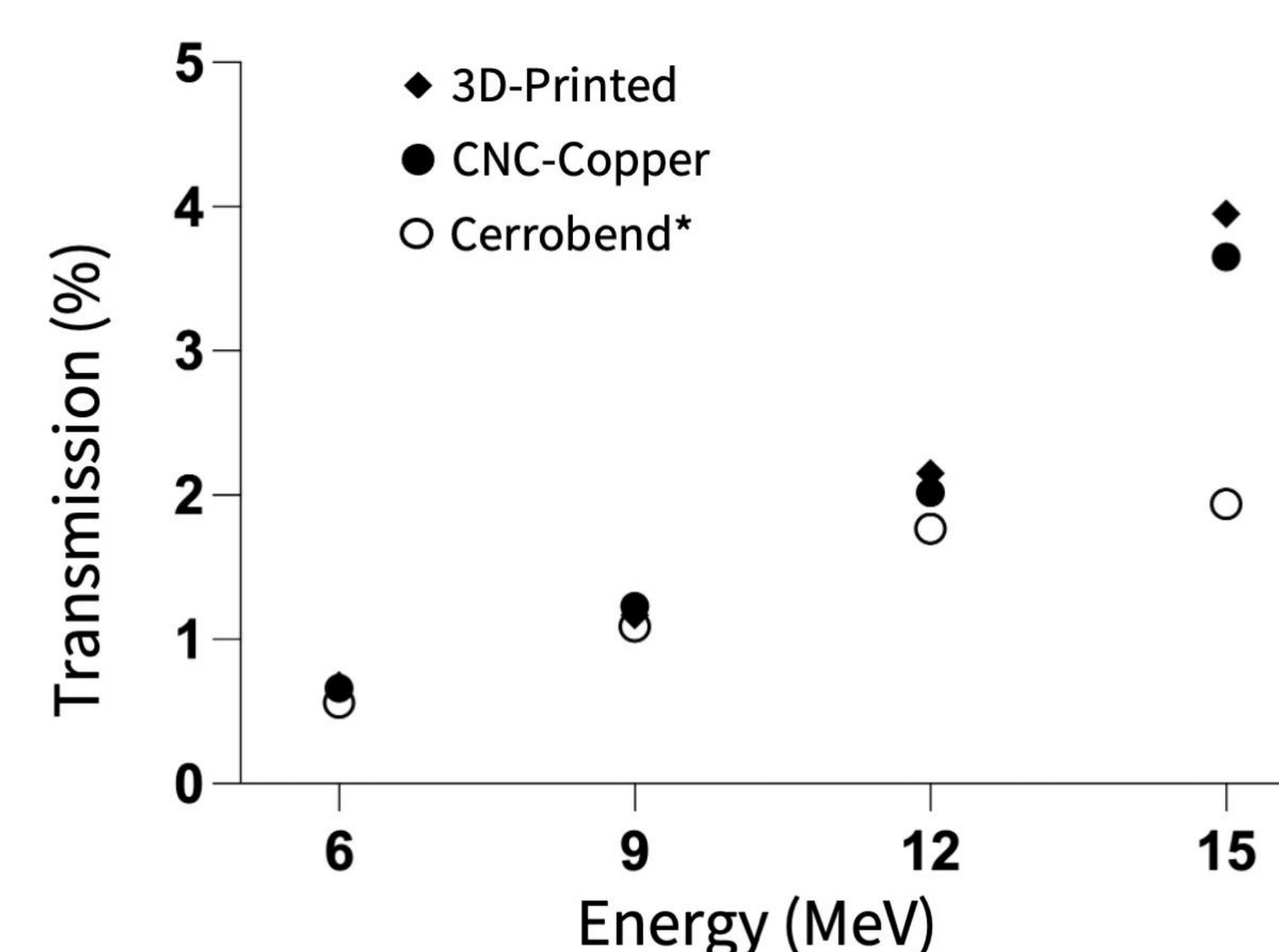


Figure 2. (A) 6 MeV and 15 MeV LR profiles of 3D printed and copper 7 cm diameter circle cutouts at dmax. (B) Dose transmission of solid cutouts at 2 cm eq-depth for all available energies.

What type of Patient-Specific Collimator do you use?

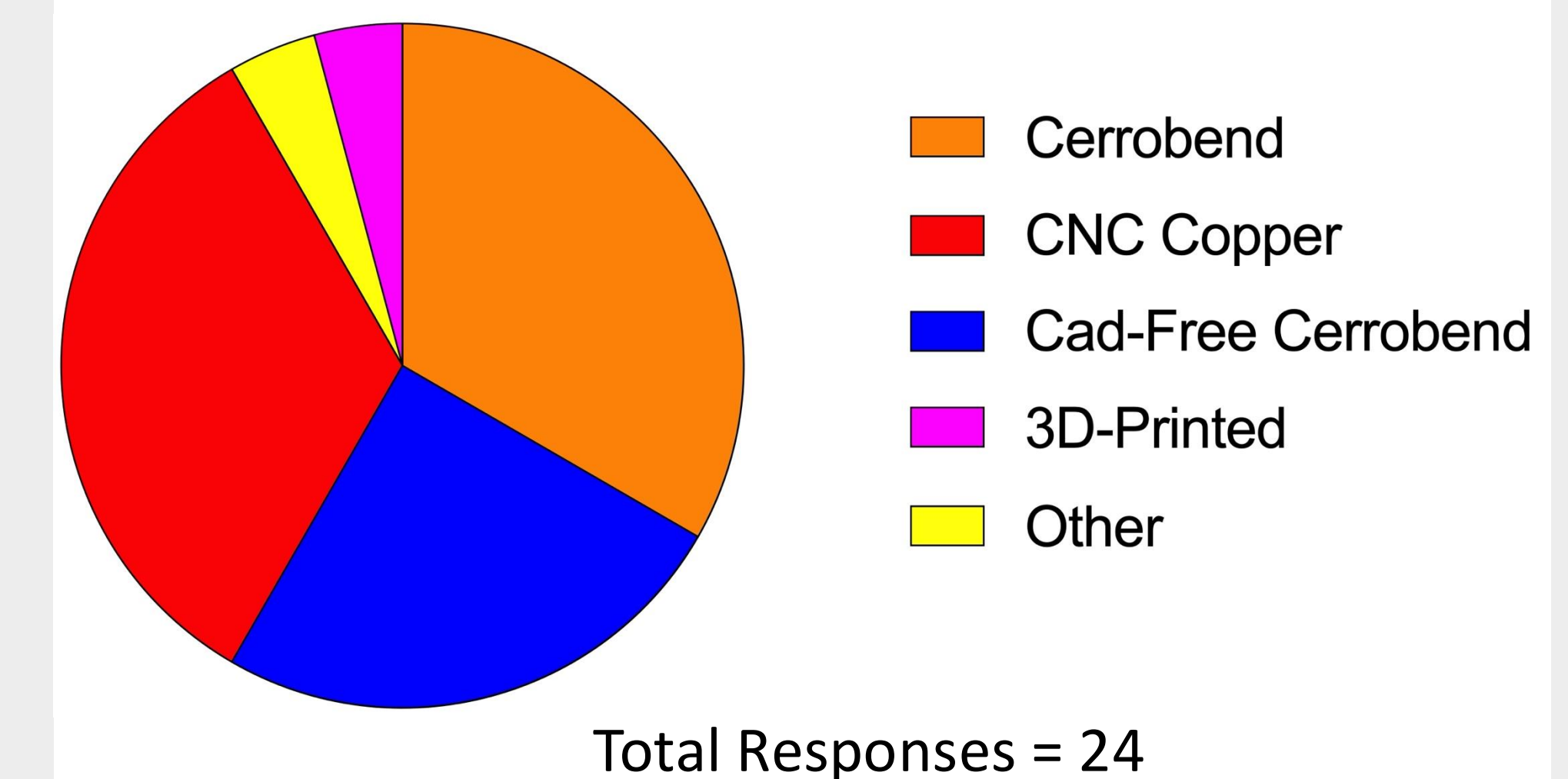


Figure 3. Current electron cutout practices in California (Southern and Northern AAPM Chapter clinical survey). Total responses are 24, this is one representative question of many from the complete survey.

DISCUSSION

This study demonstrates that a 3D-printed electron cutout filled with steel BBs can achieve dosimetric performance comparable to CNC copper, with similar penumbra, and low transmission.

Although higher-density materials such as tungsten enable thinner designs, steel was selected due to its significantly lower cost and wider availability, making this approach more accessible. As a result, a thicker cutout is required to achieve equivalent attenuation. A copper support bracket is used to secure the BBs, reducing risk of spillage and helping to minimize corner leakage that could arise from BB shifting².

Survey responses indicate that while electron therapy represents a small proportion of treatments, there is broad awareness of 3D-printed cutout approaches, with reduced fabrication time and elimination of toxic materials identified as potential advantages, alongside considerations regarding workflow integration.

CONCLUSIONS

A steel BB-filled, 3D-printed electron cutout demonstrates comparable dosimetric performance to CNC-copper cutouts while addressing key clinical limitations of existing technologies. This approach shows promise as a safe, cost-effective, and clinically viable alternative for ERT.

REFERENCES

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