Proton spot dose perturbation by common dental materials

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PURPOSE

The dosimetric effect of proton delivery through common dental materials is as yet unvalidated and uncharacterized, impeding ideal transoral head-and-neck treatment geometry. A 159.9 MeV proton spot was delivered through common compositions of amalgams, crowns, and implant materials. The change in the dose was characterized in terms of relative stopping power and geometric dose perturbation.

AIM

The qualitative and quantitative characterization of the perturbation of pristine proton spots through common dental materials.

REFERENCES

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Zhang R, Newhauser WD. Calculation of water equivalent thickness of materials of arbitrary density, elemental composition and thickness in proton beam irradiation [published online ahead of print 2009/02/13]. *Physics in medicine and biology. 2009;54(6):1383-1395.*

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METHODS

Crown and implant materials were selected in collaboration with Advanced Prosthodontics to represent a historical sampling of commonly employed hardware. Relative stopping power of each material was measured experimentally using a multi-layer ionization chamber (MLIC). Dose perturbation of the 159.9 MeV proton spot was characterized on film using a simple phantom, simulating en-face and edge-on delivery through each material. The films were oriented in both coronal and axial orientations to characterize perturbation in each spatial dimension.

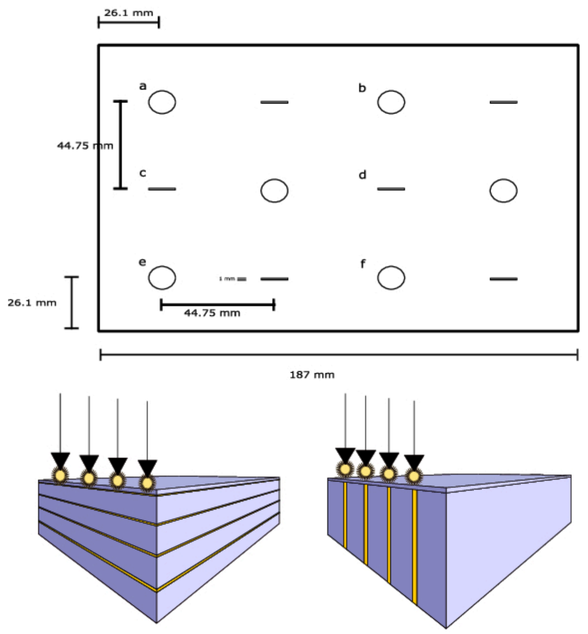

Figure 1. Diagram of dental materials phantom (top) and experimental setup (bottom). The Dental materials phantom consists of a feature cavities machined out of a solid, 1 cm thick block of PMMA. The disk cavities and material inserts were used to simulate en-face delivery and were fabricated 1 mm thick and 1 cm in diameter. The slit cavities and features were used to simulate edge-on delivery and were 3 cm long, 1 cm in width, and 1 mm in thickness. Studied materials included non-precious metal and lithium disilicate crowns (Au, Pd, Pt), and amalgams (Hg, Ag, Sn, Cu). The dental materials phantom was placed atop a stack of PMMA (bottom) blocks, organized in either coronal (left) or axial (right) orientation. A sheet of film (yellow) was placed between each PMMA block. In the axial set-up, the gantry was rotated by 1.8° with respect to gravity to avoid delivering the spot through film alone.

RESULTS

Relative stopping powers of the studied dental materials fell between 1.34 and 5.44, suggesting large potential effects on proton range with respect to water. Film measurements of each of the spots confirm this reduction in proton range and an upstream shift of the Bragg peak through each of the materials in both en-face and edge-on orientations. Sagittal film orientations show a shift of dose towards the proximal regions of the beam. Cold spots are also found immediately behind edge-on features. However, the dose exhibits a medial back-filling characteristic at greater depths.

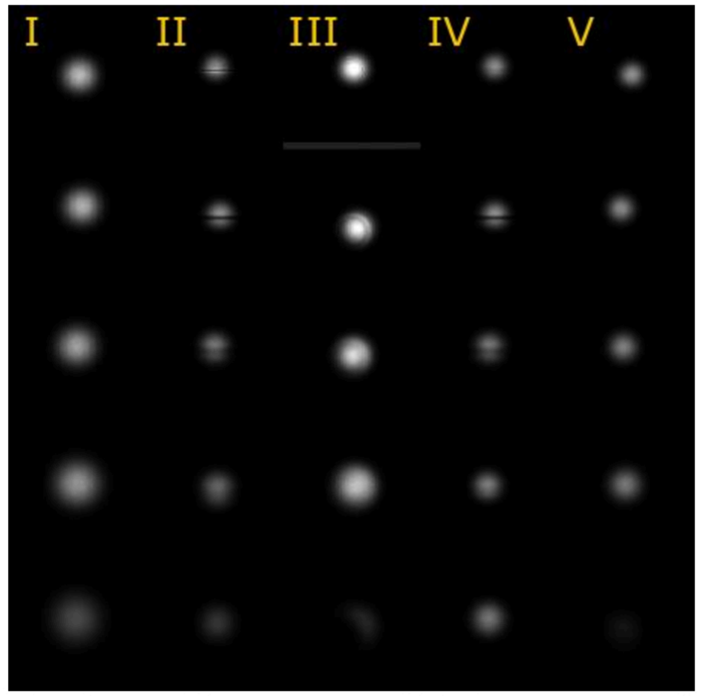

Figure 2. Coronal film measurements of 159.9 MeV proton spots with (I) no feature; (II) amalgam slit; (III) amalgam disk; (IV) lithium disilicate slit; or (V) lithium disilicate disk in the beam path. Measurement depths from top-to-bottom are 11.4 mm, 51.4 mm, 91.4 mm, 131.4 mm, and 171.4 mm. All features exhibit range shortening in comparison to the control (I). Beyond 91.4 mm, the cold spot behind each slit feature disappears, suggesting medial back-filling of dose.

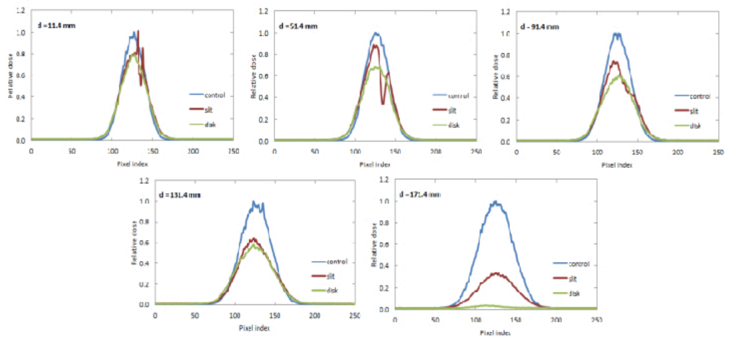

Figure 3. Coronal profiles through 159.9 MeV proton spots delivered through non-precious metal crowns at several depths of measurement. The slit feature (red) exhibits substantial dose perturbation at lower depths. Beyond 91.44 mm, dose exhibits medial back-filling, compensating for intensity losses directly behind the feature material. In comparison to a beam delivered through PMMA alone (blue), delivery through features suggest range shortening as seen at the greatest depths.

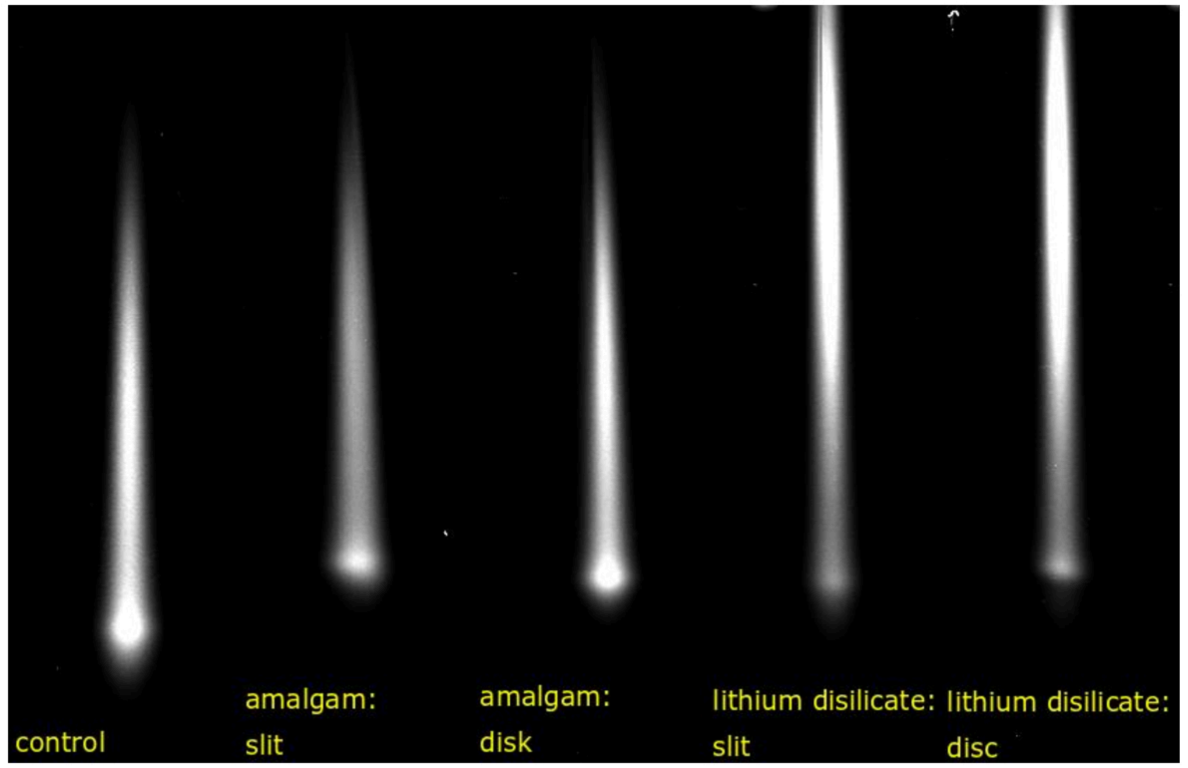

Figure 4. Sagittal film measurements of 159.9 MeV proton spots delivered through PMMA alone (left) as well as through features of varying shape and material. Measurements exhibit traits consistent with those in figures 2 and 3, with the apparent shortening of proton range. Slit measurements exhibit cold spots immediately distally to the feature material along with medial dose back-filling towards the distal end of the beam.

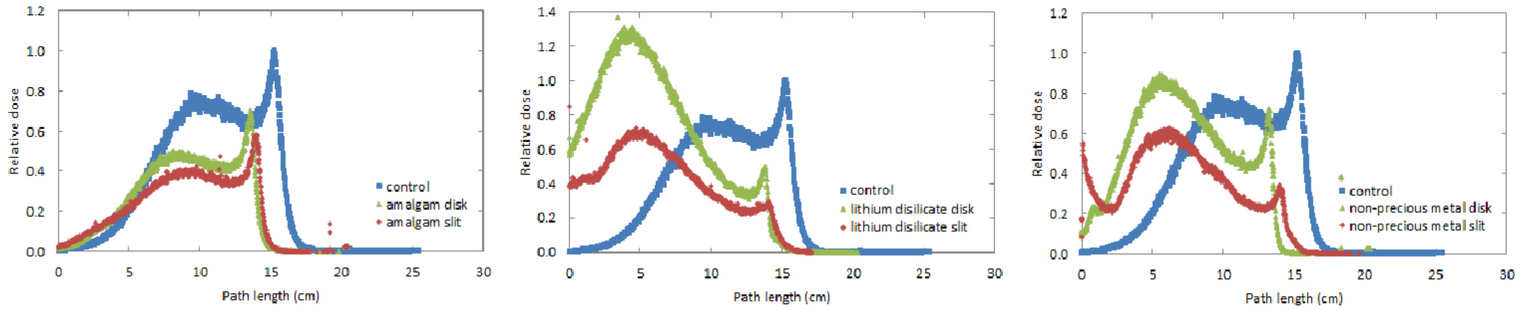

Figure 5. Sagittal profiles of the 159.9 MeV proton spot through disk (green) and slit (red) features for amalgam (left), lithium disilicate crown (center), and non-precious metal crown (right) materials. Delivery through feature materials exhibit range shortening when compared to the control as well as a shift in dose towards the proximal, plateau region.

CONCLUSIONS

Dose perturbation of single proton spots was observed. Delivery through each dental material resulted in shortening of the proton range, and general reductions in intensity. Further, more severe cold spots were found directly behind edge-on features. Beyond these cold spots, however, the dose was shown to back-fill medially.