The influence of chemical composition on quenching in proton irradiation of a new deformable 3D dosimeter

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BACKGROUND

Three-dimensional (3D) dosimetry can be a useful tool for quality assurance of the delivered dose in proton therapy. Solid state detectors irradiated with proton beams have significant problems related to *quenching* – an under response of the signal in the Bragg peak.

A deformable, silicone-based, radiochromic, 3D dosimeter was used to study the quenching in proton beams as a function of chemical composition. It has previously been shown that the dosimetric properties of this 3D dosimeter can be altered by tuning the chemical composition [1].

AIM

- First proton beam irradiation of new 3D silicone-dosimeter.
- Evaluate quenching as a function of chemical composition.
- Compare dose response with protons with that of photons.

METHODS

Production

Dosimeters (1 × 1 × 4.5 cm^3) produced with variations in the chemical concentrations:
- Dye 0.10 - 0.40 % (w/w)
- Curing agent 5 - 9 % (w/w)
- Chloroform 1.5 - 5.0 % (w/w)

Irradiation
- 60 MeV **protons** with pristine Bragg peaks (**Figure 1**)
- 6 MV **photons** (data not shown)
- Plateau doses from 0 to 50 Gy.

Read-out
- Measure absorption, before and after irradiation
- Δ optical density (OD) = postscan – prescan
- Laser wavelength: 635 nm

1

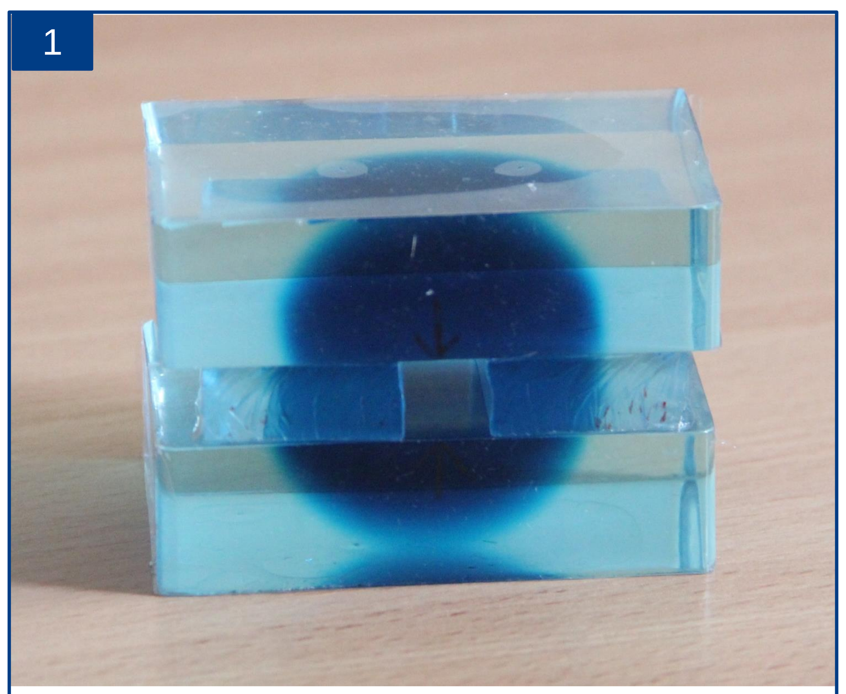

Figure 1. Irradiation set-up used for proton irradiations. Scattering material (used for multiple irradiations) surrounded the cuvette-sized dosimeter, to ensure sufficient backscatter. The beam entered from the viewing angle.

2

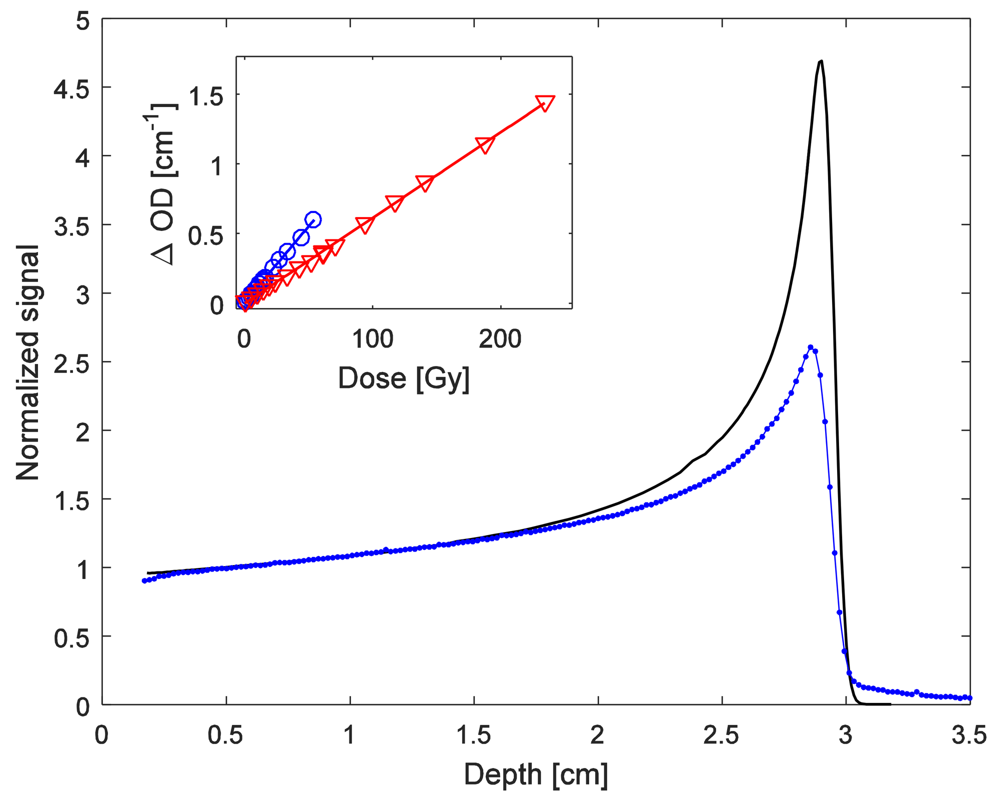

Figure 2. The depth dose curve for silicone 3D dosimeter (blue, dotted) and ionization chamber (black) reveals the quenching effect close to the Bragg peak. Insert: The dose response (change in optical density as a function of dose) was linear both in the plateau region (blue circles) and the Bragg peak (red triangles).

3

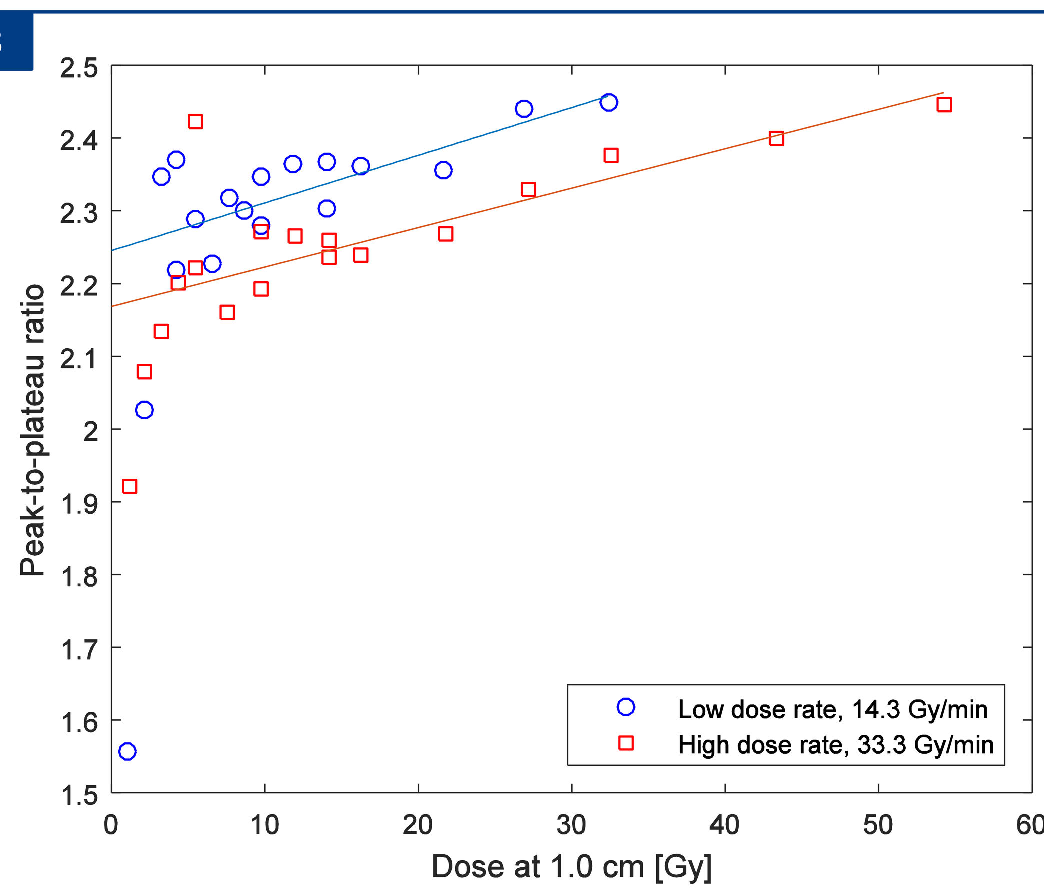

Figure 3. The peak-to-plateau ratio, taken 1.0 cm into the plateau, shows a linear dependency on dose. The ratio was also dependent on the dose rate used. The ionization chamber gave a peak-to-plateau ratio of 4.3.

4

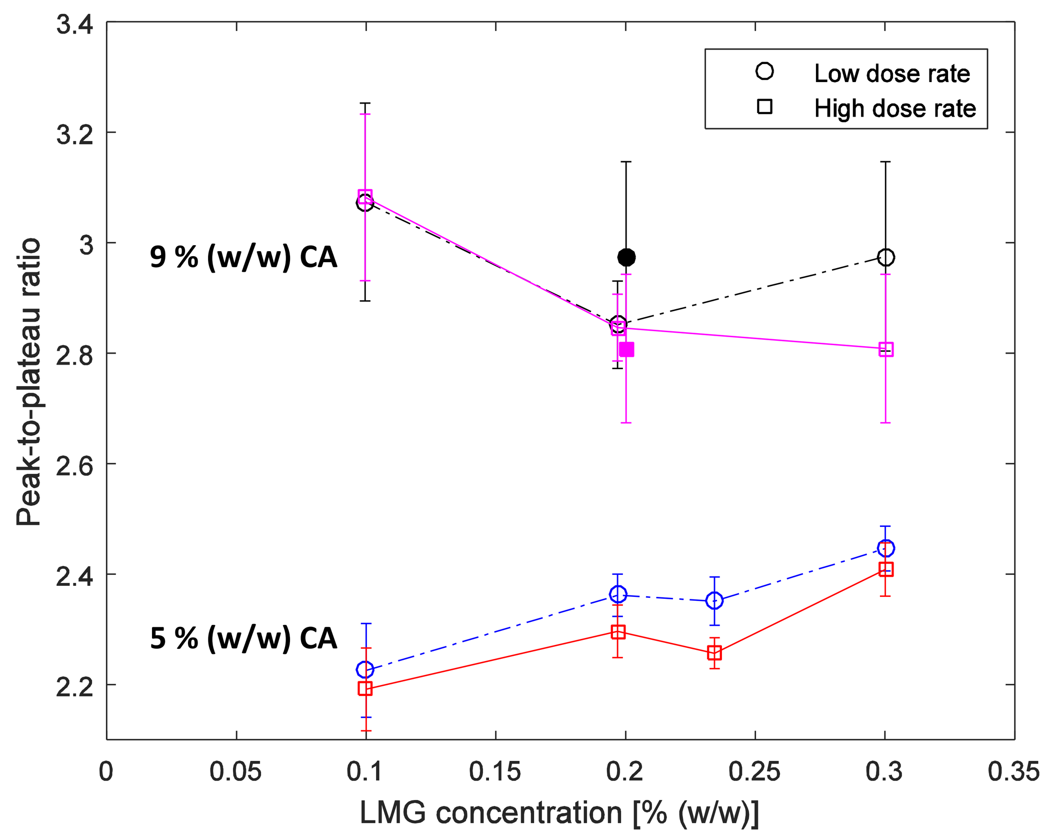

Figure 4. The peak-to-plateau ratio, taken at 15 Gy from the linear fit in figure 3, for different dosimeter concentrations. A large difference is observed from 5 to 9 % curing agent concentration, while a smaller variation is observed with the dye (LMG) concentration. The ratio was generally higher for the low dose-rate measurements.

RESULTS & DISCUSSION

- Linear dose response for all dosimeters (**Figure 2, insert**):
  - with photons (data not shown)
  - with protons
- 1.3 times higher dose response with photons than protons (data not shown)
- Peak-to-plateau ratio increases with dose (**Figure 3**)
- Peak-to-plateau ratio increase significantly from 5 to 9 % (w/w) curing agent (**Figure 4**). Dosimeters with 9 % (w/w) curing agent have significantly lower dose response than those with 5 % (w/w).
- Significant effect of dose rate on both dose response and quenching effect.

CONCLUSION

Clinical use of 3D dosimeters for proton therapy will require modelling of the depth dose curve to account for quenching.

REFERENCES

[1] Høye *et. al.* 2015 *Phys. Med. Biol.* **60** 5557–70

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