Preliminary investigation of the dosimetric properties of ClearView™ dosimeter

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Abstract. ClearView™ is a single-use radiochromic 3D dosimeter designed by Modus Medical Devices Inc. Some of the dosimetric characteristics of this gel, such as response as a function of dose and as a function of energy were investigated. Moreover, a 400 mL jar was irradiated with a 1x1 cm² field and PDD and cross-profiles were compared to those obtained with active detectors. Small volumes of gels were found to exhibit a linear response to dose in the dose range 10-80 Gy. Promising PDD and cross profiles were obtained. Artefacts obtained in high resolution for the PDD are suspected to come from small inhomogeneities in the gel.

1. Introduction
Gels dosimeters have the ability to retain dosimetry information in three dimensions thus making them good candidate for the dosimetry of advanced radiotherapy techniques which delivered complex dose distributions [1-5]. ClearView™ is a single-use radiochromic 3D dosimeter designed by Modus Medical Devices Inc for remote or on-site read-out by Optical CT. ClearView™ gels are based on a gellan gum matrix which incorporates a tetrazolium salt. The gel also contains propylene glycol, as a radical scavenger. Its melting point is around 70°C. Under ionizing radiations, it turns slightly pink/purple. This color change is due to the chemical formation of a formazan dye within the gel. The dose range is 10-80 Gy while the recommended dose by the manufacturer is 40 Gy. Dosimetric characteristics of the ClearView™ gel, such as batch uniformity, stability, response as a function of dose and as a function of energy, were studied and some are detailed here. Moreover, a 400 mL jar of gel has been irradiated with a 1 x 1 cm² photon field and percent depth dose (PDD) and profiles obtained with the gel were compared to diodes and chamber measurements.

2. Materials and Methods

2.1. Storage, irradiation and reading conditions
Gels were provided by Modus Medical Devices Inc in 400 mL jars and in 1 cm x 1 cm x 4 cm spectrophotometer cuvettes. They were stored in a fridge and removed from it at least 8 hours prior to irradiation to allow gel to come to room temperature. During this step, they were protected from light. Gels were irradiated at room temperature (21°C) with an Elekta Synergy linear accelerator. Then they were kept at room temperature without light exposure at least 45 min as recommended by the manufacturer to allow signal to develop. Then, they were read at room temperature.
2.2. Dose response of ClearView™ gel

Spectrophotometer cuvettes filled with ClearView™ gel were irradiated with 4MV photons in the same beam geometry consisting of a 30 x 30 cm² field with a source to surface distance of 100 cm. Cuvettes were placed at isocenter and two different batches of gel were irradiated with doses ranging from 10 to 80 Gy in steps of 10 Gy for the first batch and with doses of 10, 25, 40, 55 and 70 Gy for the second batch. The absorbance of irradiated cuvettes was measured 45 minutes after irradiation with a UV1800 (Shimadzu) spectrophotometer. In order to determine the wavelength at which the maximum absorbance is observed after irradiation, spectrum was measured over the range 400-800 nm with intervals of 2 nm. The reference cuvette was a non-irradiated cuvette. In addition, regarding the second batch, cuvettes were also read 90 minutes and 3 hours after irradiation in order to study the evolution of absorbance with time.

2.3. Response as a function of energy

The energy dependency was investigated changing the beam energy. Spectrophotometer cuvettes (3 cuvettes per energy) were irradiated at 40 Gy in a 30 x 30 cm² field with an energy of 4, 10 and 18MV, the dose rate being the same for the three energies. Absorbance change was measured 45 minutes after irradiation.

2.4. Relative dosimetry

A 400 mL ClearView™ jar was irradiated vertically without the lid in PMMA slabs with a 1 cm × 1 cm field (4 MV, 1.6 Gy/min 50 Gy at isocenter). Isocenter was placed at 3 cm in depth from the gel surface. Gel was read using the Vista™ Optical-CT (590 nm wavelength, 410 projections) 45 minutes after irradiation. 3-D reconstructions were performed in medium and high resolutions and analyzed using MicroView 2.1.2 software (GE Healthcare). PDD and cross profiles acquired with the gel were compared with PDD and cross profiles acquired with PTW 31014 PinPoint chamber and PTW 60016 and 60017 diodes in a water tank.

3. Results and discussion

3.1. Dose response of ClearView™ gel

The color change of the gel on the 0-80 Gy dose range is shown in Figure 1. The change in absorbance as a function of wavelength for the cuvette irradiated to 40 Gy for the two different batches is shown in Figure 2. The maximum of absorbance occurs at a wavelength of 530 nm for the first batch and of 560 nm for the second batch. As the gel is currently under development, the difference of maximum absorbance wavelength observed may come from a different formulation of the gel. The gel response (attenuation coefficient) as a function of dose for the 530 nm or 560 nm wavelengths as well as for the two wavelengths available in our Vista™ Optical CT system (590 and 632 nm) is displayed in Figure 3. The response is linear for the two batches and for all the wavelengths with a correlation of $R^2$ around 0.98. Regarding temporal response of ClearView™ (Figure 4), no change is observed when the reading occurred between 45 minutes and three hours after irradiation.

![Figure 1. ClearView™ color change on the 0-80 Gy dose range.]
3.2. Response as a function of energy

In the investigated energy range, gel response is independent of energy (Table 1).

Table 1. Absorbance at 560 nm for the three photon beam energies.

|                  | 4 MV | 10 MV | 18 MV |
|------------------|------|-------|-------|
| Mean absorbance  | 0.063| 0.063 | 0.060 |
| Standard deviation| 0.006| 0.008 | 0.005 |
3.3. Relative dosimetry
In Figure 5, PDD and cross profiles acquired with the gel are compared to PDD and cross profiles measured with PTW 31014 chamber and PTW 60016 and 60017 diodes. PPD acquired with the gel in high resolution (HR, 0.5 mm³ voxel) is very noisy. The artefacts noticed around 30 mm and 65 mm in depth may be due to small gel inhomogeneities; they are no longer present in medium resolution (MR, 1 mm³ voxel). From 0 mm to nearly 60 mm in depth, a good agreement is observed between MR gel PDD and PDD acquired with the detectors. Above 60 mm, the MR gel PDD is noisier because of the dose range corresponding to a low sensitivity of the gel. A good agreement is found between cross profiles acquired with the gel and the detectors: 90% of points pass the gamma index with criteria of 3%/3 mm. Points which don’t pass the gamma index are located in the penumbra region where gel FWHM (9.3 mm) is slightly larger than detectors FWHM (8.6 mm for PTW 31014 chamber).

![Figure 5. Comparison of PDD (left) and cross profiles (right) acquired with the gel and detectors. HR and MR indicate high resolution and medium resolution scanning.](image)

4. Conclusion
Some of the dosimetric properties of ClearView™ have been investigated. The maximum absorbance is around 550 nm depending on the gel batch. A linear response to dose in the dose range 10-80 Gy has been observed. ClearView™ shows promising features for use in radiotherapy for relative dosimetry. Further work will focus on the identification of the parameters that may impact ClearView™ response and on the quantification of error. An absolute dose comparison is also in progress.

5. Acknowledgements
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6. References
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