Since Gore et al published their paper on Fricke gel dosimetry [1], the predominant method of evaluation of both Fricke and polymer gel dosimeters has been magnetic resonance imaging (MRI). More recently optical computer tomography (CT) has also been a favourable evaluation method. Other techniques have been explored and developed as potential evaluation techniques in gel dosimetry. This paper reviews these other developments.

1. X-ray computer tomography

Hilts et al showed that x-ray CT could be used to investigate changes in irradiated PAG polymer gels and demonstrated that in cases of high dose gradients this evaluation technique had potential [2,3]. Trapp et al further evaluated the technique for investigating different compositions of PAG polymer gels [4] (figure 1). It was shown that the CT-dose sensitivity increased with the concentration of comonomers used, and by varying the gelling agent from gelatin to agarose. Hill et al further investigated the change in CT number with dose for normoxic polymer gels [5]. Trapp et al showed that the observed contrast obtained in CT images of irradiated PAG gels was due to density changes in the gels [6] and was further demonstrated for normoxic MAGIC gels [7] by Brindha et al. Hilts et al suggested that polymer gels for x-ray CT evaluation should have a more optimal sensitivity for an extrinsic density change and maximum polymer yield in the gel dosimeter [8].

A significant limitation of x-ray CT evaluation is the relatively small change of CT numbers or Hounsfield units in the irradiated polymer gel with absorbed dose along with image noise [4]. Hilts and Duzenli showed that the issue of image noise could potentially be tackled through image processing techniques [9]. The phantom wall material used has the potential to induce artifacts in the resulting CT image and is particularly significant for glass [4]. To overcome these artifacts, alternative plastic wall materials have been investigated [5].

Audet et al undertook a clinical dosimetry study of CT gel dosimetry and showed that high dose regions produced by stereotactic irradiations could be accurately localized [10] (figure 2).
Further clinical dosimetry studies are required to fully evaluate the potential of the x-ray CT technique. However, as a result of the easy access to x-ray CT scanners in clinical departments, CT does potentially offer a relatively simple, convenient and inexpensive method of implementing clinical polymer gel dosimetry [8]. The main advantage of this evaluation technique is that limited access to MRI facilities is not an issue or is the need to build or purchase specialized optical scanning equipment. It should be noted that where, for instance, MRI has evaluation problems such as inhomogeneities or temperature dependence [11–13] , x-ray CT evaluation has its own limitations. However, as is the case with MRI evaluation of polymer gel dosimeters [14], it has been shown that x-ray CT evaluation techniques require the CT scanner be commissioned specifically for gel dosimetry before use [15].

2. Ultrasound

Mather et al showed that ultrasound could be used to investigate changes in irradiated PAG polymer gels [16,17] (figure 3). In these studies, acoustic speed of propagation, attenuation and transmitted signal intensity showed a strong variation with absorbed dose indicating the potential of this technique. Comparative studies of PAG and MAGIC polymer gels indicated that differences in acoustic properties with absorbed dose were due to differences in the elastic modulus of the materials [18]. Further acoustic studies [19] showed that the overall acoustic attenuation, dose sensitivity and dynamic range were dependant on dosimeter formulation. These studies, along with those of acoustic attenuation coefficients highlighted the complex nature of the acoustic properties of polymer gel dosimeters and indicated that further studies are required to fully understand the properties [20].
Figure 3. Acoustic attenuation and inverse transmitted signal intensity as a function of absorbed dose (reproduced from Mather et al (2002a)).

Mather and Baldock undertook a preliminary study to evaluate the potential of acoustic imaging of irradiated PAG polymer gel dosimetry phantoms [21] (figure 4). A ultrasound computer tomography (UCT) system was developed and evaluated. Resulting images from the UCT system indicated that transmission-generated images produced greater contrast than time-of-flight-generated images. However, time-of-flight-generated images produced superior geometrical accuracy of the dose distribution than transmission-generated images.

(a)  
(b)

Figure 4. UCT (a) transmission and (b) time-of-flight images (reproduced from Mather et al (2003)).

The motivation to develop UCT of polymer gels was to produce a more economically viable evaluation methodology. Further studies will determine whether UCT has a future in the evaluation of polymer gel dosimeters.

3. Vibrational spectroscopy

FT-Raman vibration spectroscopy of PAG polymer gel dosimeters was investigated [22] as a means by which the fundamental structure and properties of polymer gel dosimeters might be better understood thereby contributing to the further development of new and more stable gel dosimeters (figure 5). Subsequent to this, numerous other fundamental studies have been undertaken [23–29,8].
Ballock et al undertook a Raman microscopy study to investigate microscopic dose distributions in irradiated polymer gels [30,31] indicating the potential of vibrational spectroscopy in the evaluation of polymer gel dosimeters (figure 6).

Jirasek et al further used FT-Raman spectroscopy to investigate the track structures of proton beams in polymer gel dosimeters [28]. This study illustrated the difficulty in using polymer gel dosimeters to extract quantitative dose maps when exposed to proton radiation.

As is the case for ultrasound, further studies are required to determine whether Raman microscopy has a future in the evaluation of polymer gel dosimeters.

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