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Investigation on Tissue Equivalent Normoxic Polymer Gel Dosimeter using In-house Laser CT scanning system

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Abstract. Optical Computed Tomography has wide applications in the treatment of cancer. In continuation of this, an in-house Laser CT scanner has been built for "3D gel dosimetry". The Laser CT (LCT) scanner plays a major for Gel dosimeter or phantom readout and in clinical radiation therapy as a 3-Dimensional Radiation Dosimetry. A gel dosimeter which absorbs dose in a tissue-equivalent manner and allows the measurement of spatial distribution of the deposited dose is required. The normoxic PAGAT (Polyacrylamide Gelatin and Tetrakis) gel is used as a dosimeter for this analysis. When laser passes through this gel phantom, absorption and scattering takes place and combined to attenuation. The optical attenuation coefficient of the laser can be obtained by measuring its intensity after passing through the gel by means of a sensor. Reconstruction using Mat Lab algorithm provides 3D dose distribution.

1. Introduction

Now days Stereotactic Radiotherapy, 3D Conformal Radiotherapy and Intensity Modulated Radiotherapy are the modern and common radiation delivery technique intents accurate delivery of radiation dose. These techniques are based on increased complexity of radiation delivery methods and therefore require verification of dose distribution by a precise dosimetric method. Gel dosimeters are capable of recording dose distributions in 3 dimension manner. At present, magnetic resonance imaging has been most widely used for the evaluation of absorbed dose distributions in gel dosimeters. However, due to the cost, problem of accessibility, optical CT scanning of gel has been used by several investigators as an exact and substitute to Magnetic Resonance Imaging [1-4]. In this work we exhibit the construction of an in-house laser CT scanning system and some initial investigations using it with the normoxic PAGAT Gel Dosimeter.

2. Materials and Method

2.1. Gel Preparation

The gel used for this study was the normoxic PAG Gel named as PAGAT, which had been previously evaluated with X-ray CT and Magnetic Resonance Imaging system [5, 6]. The normoxic ''PAGAT'' gel described elsewhere [6-8] was prepared under normal atmospheric conditions. The gel preparation was carried out as follows: 5% gelatin was added to the magnetic stirred glass flask containing 89% of triple distilled water and allowed to swell for 10–15 min. Then the gelatin solution was heated to the temperature of 50 ^{0}C for complete dissolution of the gelatin. After obtaining the clear gelatin solution 3.5% BIS and 3.5% Acrylamide were added and stirred continuously until the mixture was dissolved homogeneously. The antioxidant 10 mM THP was added to the solution under stirring just before

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transferring the gel into Polyethylene Teraphthalate cylindrical recipients of size 10 cm diameter and 13 cm long. All the Polyethylene Teraphthalate cylindrical recipients containing the PAGAT gel were sealed properly to avoid the further diffusion of oxygen and were kept in a refrigerator for one full night for gelling. All chemicals were from Sigma Aldrich.

2.2. Gel Irradiation
To evaluate the dose response of polymer gel to gamma radiations, the polymer gel dosimeters were irradiated after the complete gellation. The center of the phantom was aligned with the crosshairs of the treatment field. The polymer gel dosimeters were irradiated with a direct square field size of 5 x 5 cm^2 for gamma rays using Co-60 source and the dose is 12 Gy. The source-to-surface distance (SSD) was 100 cm. One dosimeter was kept unirradiated for background subtraction. The irradiated gel dosimeters were left in a refrigerator for one day before imaging to allow the complete post irradiation polymerization.

2.3. Laser CT scanning system
The Laser CT scanner was constructed on the principle of a first generation X-ray CT is shown in figure 1. This scanner consisted of an aquarium, a rotating table, a red colour diode laser (650 nm) as light source, a detector (Photodiode). The aquarium of size 30 x 30 x 30 cm^3 was fabricated using an

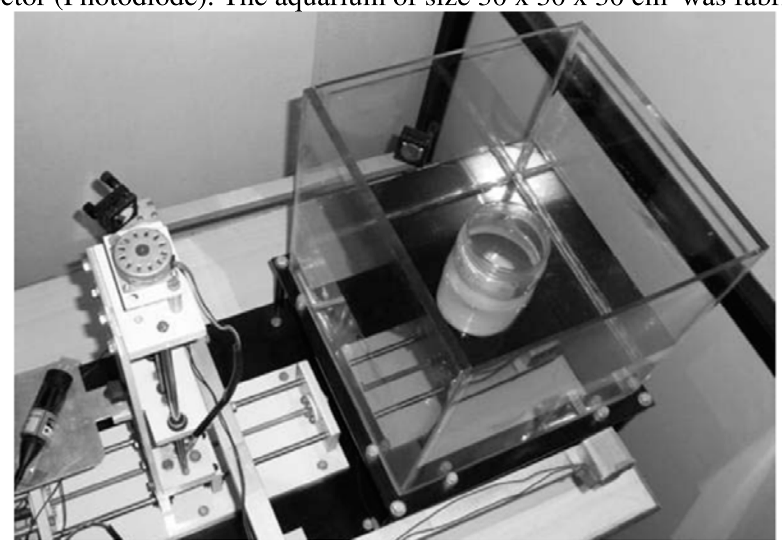

Figure 1. In-house fabricated Laser CT scanner.

imported Perspex with wall thickness of 1 mm on the laser transmission faces. Using oil seal technique, the rotating table was fixed in the aquarium and a bipolar stepper motor was connected for rotation. This rotating table could be rotated at an angle of 1^o. The linear motion of the source and the detector was achieved by the horizontal rails connected with a ball screw which was driven by another bipolar stepper motor. Figure 2 explains the schematic function of the Laser CT scanner. A sensor has to measure the intensity of a laser beam after passing through the sample (in y direction). This laser beam has to scan the sample in ‘x’ and ‘z’ direction. The cylinder-shaped sample has to be rotated (θ) around its symmetry axis which is parallel to the ‘z’ axis. One challenge is the refraction of the laser beam when passing through the bottle walls which are not at right angle to the beam line. This effect can be minimized by keeping the gel vessel within an aquarium which is filled with a liquid of the same refractive index as the gel, realized by a water and glycerol mixture. For all three movements it has to be considered, whether the sample or the laser beam should move. The movements are executed by stepper motors driven by stepper motor drivers, which are controlled by the software using a Data Acquisition Card (DAq card). The analog inputs were converted into digital outputs by connecting this DAq card as an interface between the computer and the Laser CT scanner.

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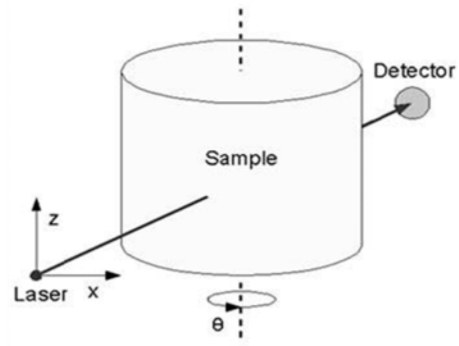

Figure 2. Schematic sketch of Laser CT scanner's functionality.

2.4. Scanner Control and Image Reconstruction

The software will control the scanner, acquire and store the data and perform the necessary calculations for data procession and transformation. The "Image Reconstruction Software" (IRS) converts the scanner data into 3-dimensional image data. The purpose of this software is to apply an "Inverse Radon Transformation" to the scanner raw data. Matlab readily provides the "Filtered Back-Projection algorithm", an efficient algorithm for the Inverse Radon Transformation. Thus the IRS consists of only few lines of Matlab script, reading a TIFF formatted file with the scanner raw data, applying the filtered back-projection algorithm and writing the result into another TIFF formatted file.

3. Results and Discussion

Figure 3 & figure 4 represents the top view of pre & post irradiated gel phantoms. The transparency

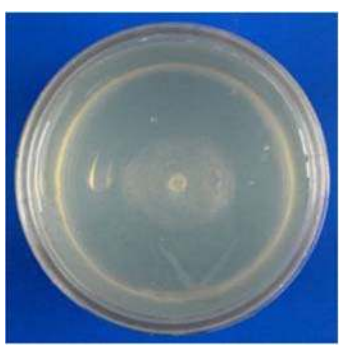

Figure 3. Top view of Pre irradiated Gel Phantom.

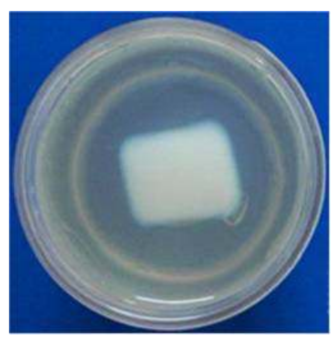

Figure 4. Top view Post irradiated Gel Phantom.

variation clearly differentiates the pre & post irradiated phantoms. The pre-irradiation image was subtracted from the post-irradiation scan and the subtracted image were analysed. The reconstruction for a single slice has been done using the Filtered Back Projection algorithm implemented in Mat lab software. Data analysis like getting Dose profile for the reconstructed slices and subtraction of post irradiated images from pre irradiated images was performed with in-house code developed in Mat Lab. Figure 5 represents the image of the pre irradiated gel slice where, a line is drawn on the pre and post

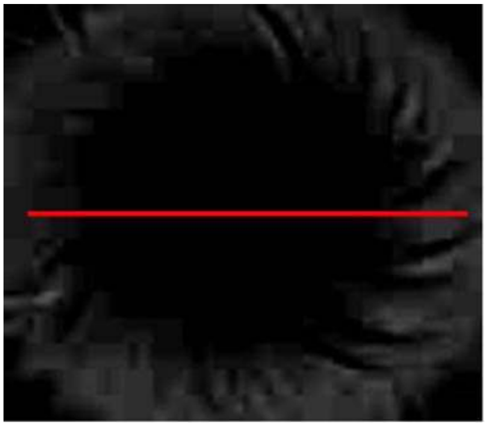

Figure 5. 2D Image of CT Reconstructed Slice of Pre irradiated gel.

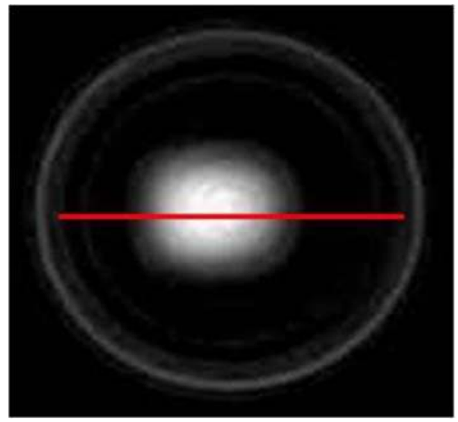

Figure 6. 2D Subtracted Image of CT Reconstructed Slices of Post irradiated gel.

irradiated gel slice to get their corresponding dose profile. Figure 6 represents the subtracted slice of the post irradiated gel phantom. Figure 7 represents the dose profile for the pre irradiated gel slice with distance across the gel dosimeter. Figure 8 represents the dose profile at 4cm depth for a post irradiated gel slice with distance across the gel.

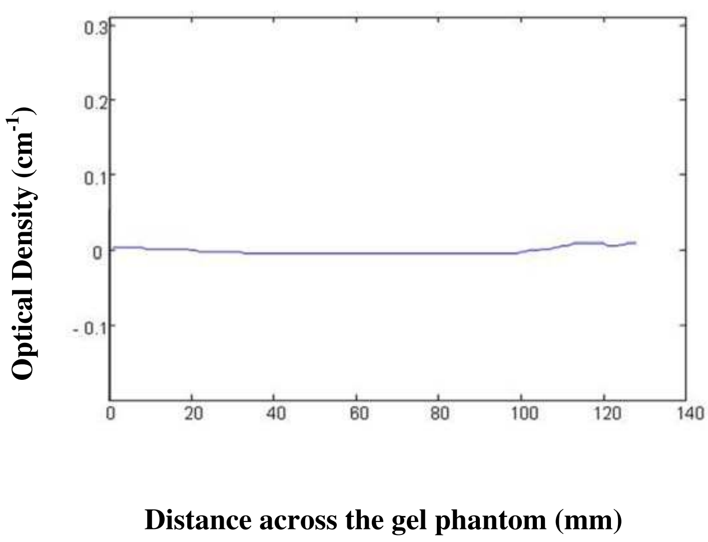

Figure 7. Dose Profile for Pre irradiated gel slice (Distance across the gel phantom vs Optical Density).

In figure 7 and figure 8, the distance across the gel phantom has been plotted in the x axis and optical density has been plotted in the y axis.

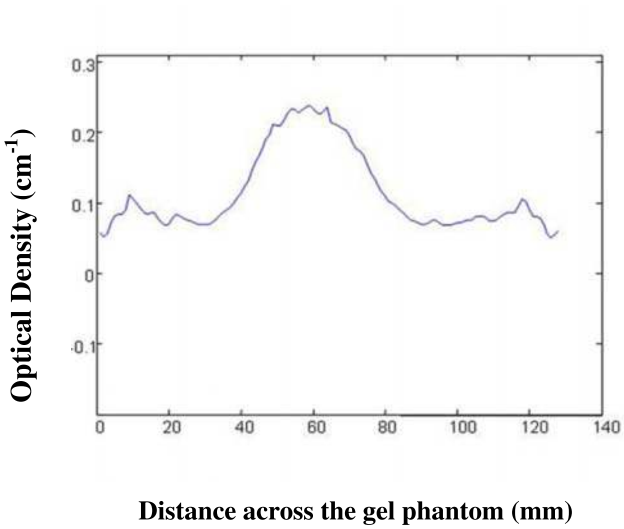

Figure 8. Dose Profile for Post irradiated gel slice at 4 cm depth (Distance across the gel phantom vs Optical Density).

4. Conclusions

A Laser CT scanner for reading a tissue equivalent gel was constructed indigenously and its initial performance for reading an irradiated gel dosimeter was investigated. The intensity measurement and the motions of the scanner were performed with the sample. The maximum resolution obtained using this scanner was 0.5 mm. The Reconstructed Image for the irradiated slice and its data analysis was performed with in-house code developed in Mat Lab. From the results, we conclude that the scanner is suitable for reading normoxic gels for clinical dosimetry.

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