The role of gelatin in a methacrylic acid based gel dosimeter

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Abstract. In this work, the dose response of a methacrylic acid based gel dosimeter containing different concentrations of gelatin is examined to clarify the role of gelatin in the polymerization process. Direct temperature monitoring of the gel throughout the irradiation process is adopted as the method. In addition, to investigate the function of gelatin on polymerization, another experiments are performed after replacing gelatin with some acids. From the results, it is concluded that gelatin is an indispensable component in the polymerization reaction which acts as a "trigger", and that the peptide structure in gelatin also assumes an important role.

1. Introduction

With rapid advances being made in radiotherapy treatment, the three-dimensional (3D) polymer gel dosimeter has been studied as a possible dosimeter for measuring the complex 3D dose distribution directly.

In a polymer gel dosimeter, gelatin is generally used as a matrix to coagulate the solution and to prevent diffusion of the created polymer. The reaction between gelatin matrix and monomers has been investigated in several previous studies [e.g., 1-5]. However, the mechanism of action of the polymer gel dosimeter and the influence of various characteristics of the polymer gel dosimeter (such as stability and susceptibility) have not yet been fully clarified.

In this work, the dose response of a methacrylic acid based gel dosimeter containing different concentrations of gelatin is examined to clarify the role of gelatin in the polymerization process. Since polymerization in the polymer gel dosimeter is an exothermic reaction, direct temperature monitoring of the gel throughout the irradiation process was adopted as the method for studying the gel’s mechanism.

In addition, to investigate the function of gelatin on polymerization, another experiments were performed after replacing gelatin with some acids.

2. Materials and methods

MAGAT type gels were prepared for this study. As shown in the table, nine different concentrations of gelatin were compounded with an equal volume of water and equal concentrations of methacrylic acid and THPC. The only sample of 120 g/L gelatin gelatinized at room temperature (22°C). In
addition to the gels described above, we prepared another type of solution, which included amino acid (glycine, alanine and proline) instead of gelatin, to examine the effect of gelatin structure and residues. The composition of these solutions was almost the same as that shown in the table, except that 7% w/w amino acid was added instead of gelatin.

The irradiations were performed using the 6 MV photon beam of a medical linear accelerator (MITSUBISHI Co. EXL-12SP). The three beams delivered 5, 10, and 20 Gy in each kind of sample with a constant dose rate of 2 Gy/min. The temperature measurements were performed using a digital thermometer. The probe of a thermometer was vertically inserted into the center part of the cylindrical glass vial (4 cm diameter and 7 cm height) through a hole in the cap. The temperature was measured consecutively for one hour including the period of irradiation.

After temperature measurement, the opacity of the gel dosimeter was estimated by using pictures of the samples. The irradiated vial was put in front of a light table with an optical step tablet and a picture was taken with a digital still camera. The mean pixel value (from 0 to 255) around the center of the vial was obtained roughly by using the suitable ROI.

| Chemical | Concentration |
|----------|---------------|
| water    |               |
| MA       | 0.7 M         |
| gelatin  | 0, 2, 3, 5, 10, 20, 40, 60, 120 g/L |
| THPC     | 2 mM          |

3. Results and Discussion

Figure 1 shows one of the temperature variations as a function of time during and after irradiation. The case of 40 g/L of gelatin concentration is presented as an example, because a same tendency was also observed for the other concentrations. As the figure shows, a rapid rise in temperature due to radiation-induced polymerization is observed at the beginning of irradiation. As the dose increases, the variation becomes more obvious.

The maximum values in the temperature variation are plotted as a function of the concentration of gelatin in Figure 2. In the figure, the value increases rapidly and reaches its maximum around 20-40 g/L of gelatin irrespective of irradiation dose. It is remarkable that no variation in temperature was observed in the gelatin free solution (0 g/L) despite an increase in temperature was seen even in a very low gelatin concentration solution, such as 2 g/L (about 0.2% w/w). This result suggests that gelatin is an indispensable component of the polymerization reaction in the MAGAT type dosimeter.

The opacity of the irradiated gel was obtained from the pixel values of the images. As shown in Figure 3, the values decrease as the dose increases in the region of gelatin concentration generally used (about 40–120 g/L). However, it was found that the tendency turned at concentrations of less than 10 g/L. This result suggests that the mechanism of polymerization in a low concentration of gelatin is different from that in a higher concentration.

Moreover, in order to investigate the role of gelatin in polymerization, another temperature measurements were performed with amino acids (glycine, alanine and proline) instead of gelatin. Figure 4 shows the results with different solutions containing each amino acid. In the figure, increases in temperature were observed in all three samples containing an amino acid after 20 Gy of irradiation. Although the change in opacity was not observed in these samples, the viscosity of the solutions increased after irradiation. In a measurement using acetic acid and propionic acid, which do not have amino groups, no responses were observed. The results indicate that polymerization can occur in solutions without gelatin but with an amino acid. Therefore, it is suggested that the -NH-CH-CO-skeleton, which is a common structure in gelatin and amino acids, contributes to the polymerization reaction rather than the higher order structure of gelatin or any other particular amino acid residues.
4. Conclusion
In this work, we investigated gelatin’s additional role in the polymerization reaction in a methacrylic acid based gel. From the results of temperature monitoring of samples during the irradiation process, it is concluded that gelatin is an indispensable component in the polymerization reaction which acts as a "trigger", and that the peptide structure in gelatin also assumes an important role. Various amino acids and their derivatives are expected to carry out a similar role.

On the basis of our results, the unprecedented usage of gelatin or amino acids as a “trigger” is required for gel composition. A further direction of this study will be to examine the characteristics of such a system [6], and clarify the mechanism of polymer gel, with the aim of developing it to a high performance polymer gel dosimeter.

References
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Figure 1 The temperature variations with time and different doses (5, 10 and 20 Gy) for the MAGAT type gel with 40 g/L of gelatin. The dotted lines show the end time of irradiation, 150 s, 300 s and 600 s from the origin.

Figure 2 The changes of maximum temperature variations with different gelatin concentrations and doses.

Figure 3 The changes of opacity with different gelatin concentrations and doses.

Figure 4 The temperature variations in the amino acid solutions irradiated with a dose of 20 Gy. The vertical dotted line indicates the end time of irradiation, 600 s from the origin.