Preliminary study of Gamma-ray response of electron paramagnetic resonance (EPR) signals using teeth of rats

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1. Introduction

Tooth is an excellent material for Electron paramagnetic resonance (EPR) retrospective dosimetry. biodosimetry using EPR is useful for evaluating the radiation dose received by the population as a result of various radiation accidents [1]. EPR or electron spin resonance (ESR) dosimetry has been widely used as a distinct physical technique for dose reconstruction that involves the quantification of radiation-induced stable radicals in the teeth and bones. EPR dosimetry of a human tooth enamel has been employed extensively to measure the radiation doses in various scenarios. Although this method utilizes the teeth extracted from animals, the doses are provided to estimate the radiation exposure in humans [2]. Unfortunately, human teeth are not always available. In such situations teeth from animals could be used for retrospective dosimetry. Among them, rodents are considered good candidates for the dosimeter role because they can often be located in the vicinity of radiation accidents. Rats are the selected reference animal and plant in publication ICRP 103 for the calculation or measurement of doses in radiation-exposed environments. Therefore, in order to evaluate the radiation exposure environment, dose evaluation was performed on rat teeth using EPR.

The aim of the present study is to establish the method of EPR dosimetry with teeth of rats. It includes the technique of sample preparation and estimation of their radiation sensitivity.

2. Methods and Results

2.1 Sample preparation

Female 7-week-old Slc:SD rat from Central Lab. Animals, Seoul, Korea were used after one week of quarantine and acclimatization. To extract the rat's teeth, the skulls were separated from the rest of the body. Rat teeth used in this study were molar teeth. The teeth of 7 rats were used, and a sample of approximately 790 mg was obtained. The molars from both the unirradiated and irradiated batches were separately placed in 10 ml of supersaturated potassium hydroxide aqueous solution in polypropylene tubes and ultrasonically treated at 80 ℃ for 5 h to remove the attached bone and organic contents. The sample was then washed with deionized water in an ultrasonic bath for 12 h at 80 ℃, dried at 40 ℃ for 5 h, and weighed. The rat sample was made into a powder and irradiated.

Figure 1. Separated rat teeth

2.2 Irradiation

The irradiation device used for the mouse sample in this study was a gamma-ray irradiator (Biobeam-8000, STS GmbH, Germany) with a ^{137}Cs source (2,200 Ci) installed at the Dongnam Institute of Radiological & Medical Sciences. The gamma irradiator was set such that the dose rate absorbed by the water was 3.25 Gy·min-1.

2.3 EPR measurements and analysis

The EPR measurements were performed using a Bruker EleXsys E500 X-band spectrometer.

The rat teeth samples were evaluated individually, with each having a single orientation while being held in a quartz tube with a sample support system for reproducible positioning in the cavity. The dose-dependent parameter of the sample spectrum of the mice was evaluated as the vertical peak-to-peak intensity of the dominant peak.

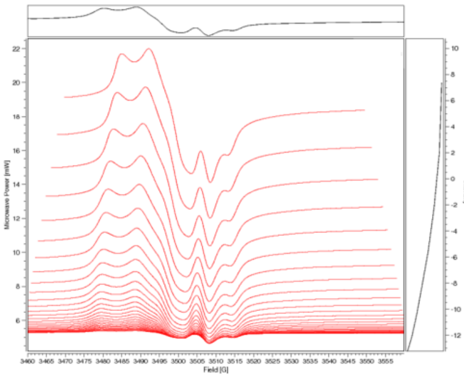

Figure 2. Microwave power dependence of X-band EPR spectra for rat teeth samples

2.4 Dose response curve

As the dose increased from 200 to 800 Gy, the EPR signal increased in proportion to the dose. The dose-response curve for the peak-to-peak EPR signal intensity with the increasing dose is shown in Figure 2. The dose-response curve showed a coefficient of determination, R^2, of over 0.998 when calculated using the linear fitting equation.

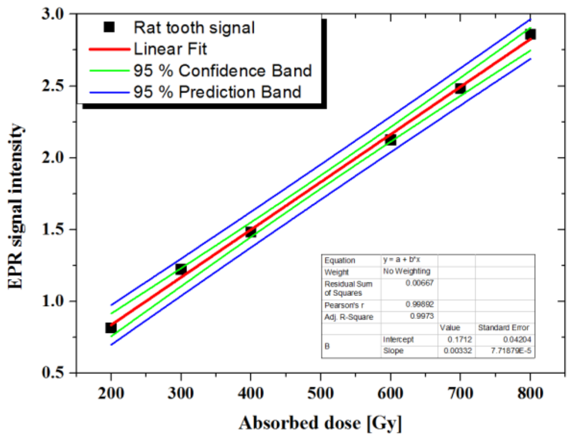

Figure 2. EPR dose-response curve of rat teeth using a sample mass of 100 mg. The response is linear from 200 to 800 Gy.

2.5 Uncertainty of the measurements

To evaluate the uncertainty of the measurements, the repeatability of the measurements under the same conditions was assessed. The repeatability of the measurements of the rat teeth samples irradiated at 800 Gy is illustrated in Figure 3. The standard deviation of the repeatability of the measurements was estimated to be 0.02, and the uncertainty was estimated to be 0.01. The uncertainty of measurement was assessed using the following parameters: reference irradiation, repeatability, mass determination, EPR reference correction, system drift, temperature correction, interspecimen contamination, and calibration curve, where by the relative expanded uncertainty was estimated to be 7.4% (95%, k = 2).

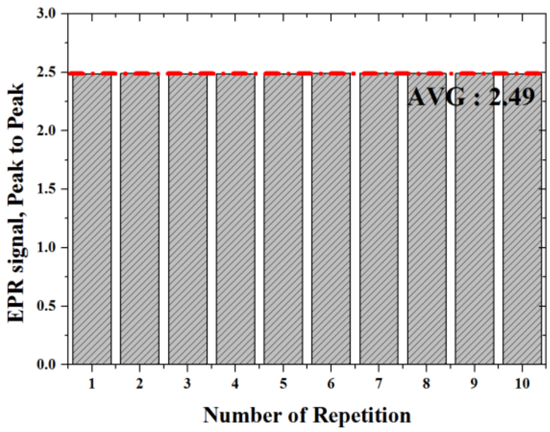

Figure 3. Response of the rat teeth sample at a repeated dose of 800 Gy

3. Conclusions

The prospect of physical dose estimation in experimental radiation biology research was demonstrated in this study. Additionally, the potential to use rat and rodents for these environmental dose measurements was explored. However, dosimetry for low doses was difficult due to the amount of rat teeth and the difficulty of enamel separation. Enamel separation pretreatment of rat teeth will be established, and further experiments will be conducted using bone and incisors. Future studies will include correction factors that can be obtained by comparing with human teeth using solely rat teeth, along with dose evaluation in a low-dose area.

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