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Study on Radiosensitization Using Nanoparticles in Fricke Xylenol Gel Dosimeters

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1. Introduction

The challenging scenario of cancer treatment underscores the need for continuous research in radiotherapy innovations to enhance therapeutic outcomes and patients' quality of life. The application of gold nanoparticles (AuNPs) as radiosensitizers stands out for their ability to enhance the effects of ionizing radiation [1]. This enhancement not only suggests a therapeutic response with improved clinical results but also points to the potential for personalized treatment adaptation, considering the diversity of tumor responses due to the interaction of radiation with the medium. This approach particularly leverages the flexibility in dosimetry, enabling precise and secure treatment monitoring [2].

Fricke xylenol gel dosimeters (FXG) offer advantages such as a well-known solution chemistry and tissue equivalence across a broad range of photon energies. Additionally, they are a viable and cost-effective dosimeter that, despite being non-reusable, can be implemented in dosimetry laboratories [3].

Building upon the promise of more precise radiation delivery resulting from the careful interaction between AuNPs and the dosimetry medium, this suggests not only more effective treatments but also shows the potential for customizing therapies to meet individual patient needs [2].

In this context, the fundamental aim of this study is to significantly contribute to the understanding of the basic mechanisms of radiosensitization using AuNPs in FXG dosimeters. Unlike conventional approaches that often involve biological elements, the proposed radiosensitization in this study stands out for its emphasis on the direct interaction between ionizing radiation and an extremely sensitive dosimetry medium, aiming to verify the increase in sensitivity due to the presence of AuNPs.

2. Methodology

The synthesis of AuNPs was based on adaptations of Turkevich's method [4]. The gold was dissociated using an acidic solution of hydrochloric and nitric acids present in the ratio 3:1. Then, chloroauric acid ($HAuCl_4$) was obtained, an important component for the synthesis of gold nanoparticles (AuNPs). With a small amount of chloroauric acid, water and gum arabic, a solution is created to which a reducing agent (sodium citrate) is added, which results in the formation of gold nanoparticles. To evaluate the size of the samples, Dynamic Light Scattering (DLS) and Transmission Electron Microscopy (TEM) were used.

To produce FXG, a standard recipe utilizing xylenol orange as an indicator for ferric ions was employed, after which different amounts of AuNPs solutions with 1, 3 and 5% (in relation to the total FXG volume) were added. Formaldehyde was also added to help with stability [5]. When the gels were formed, they were irradiated with a calibrated gamma radiation source with doses of 1, 2, 3, 4 and 5 Gy. All samples were measured in the UV-Visible spectrophotometer to evaluate the increase in dose according to the increase in ferric ions absorbance and an Optical Computerized Tomography (OCT) was also used to evaluate the different attenuations with dose variation.

3. Results and Discussion

Results for evaluating size and morphology using TEM showed an average size of 10 nm. The DLS measurement of AuNPs showed an average hydrodynamic diameter of 40 nm. This difference was expected, as the presence of dispersants can induce errors in DLS measurements [6].

To evaluate the dosimeters, the first step is to obtain the absorbance spectrum by UV-Vis and as expected, the analyzed samples presented two absorption bands, one at 440 nm and the other at 580 nm, referring to ferrous (Fe^{2+}) and ferric (Fe^{3+}) ions, respectively. As the dose applied to the dosimeter increases, the ferrous ions go through the oxidation process, decreasing their concentration and increasing the concentration of ferric ions. In Fig. 1 it was possible to perform a linear regression with the absorbance values referring to the ferric ions in the solution to confirm their linear behavior as a function of the dose in the dose range of interest.

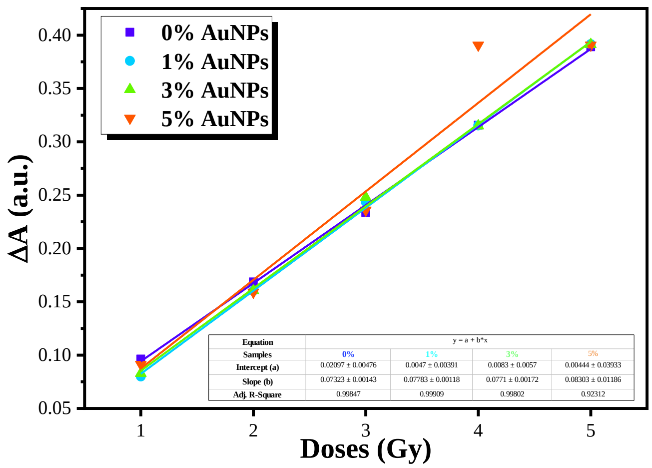

Figure 1: Linear regressions and R^2 values of the spectrophotometric responses of FXG solutions with different concentrations of AuNPs as a function of dose.

The Fig. 1 shows the linear regressions according to the variation of AuNPs. It is possible to see that the results that were most promising were the samples without and with 1% AuNPs, according to the adjusted coefficient of determination. The angular coefficient of the calibration curves that related the variation in absorbance (ΔA) with the dose was adopted as a measure of radiosensitivity [7].

The results were promising, showing that a small amount of 1% AuNPs significantly increased the sensitivity of the dosimeter. The samples that have a higher value of AuNPs did not increase their sensitivity much or presented greater problems in establishing the synthesis.

Table I shows the attenuation values found by the OCT technique, which confirm the increase in attenuation with the addition of AuNPs at doses of 1 and 5 Gy.

Table I: Attenuation coefficient values related to dose and at different concentrations of AuNPs.

	Attenuation (cm^{-1})	
Samples	1 Gy	5 Gy
0%	0.0376 ± 0.00148	0.149 ± 0.00149
1%	0.0433 ± 0.000798	0.157 ± 0.00162

3%	0.0386 ± 0,0424	0.153 ± 0.0485
5%	0.036 ± 0.000952	0.123 ± 0.00769

According to the values in table I, which confirms the increase in attenuation with the addition of AuNPs, and considering the relative uncertainty, the sample that exhibited the lowest relative error in increased attenuation is the FXG with 1% AuNPs.

4. Conclusions

Therefore, it can be concluded that the addition of 1% AuNPs to FXG enhances radiosensitivity, and higher concentrations result in greater errors or lower sensitivity.

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