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Dental tissue as a TLD dosimeter

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ABSTRACT

Background: Thermoluminescence dosimetry is one of the dosimetry procedures used widely as routine and personal dosimeters. In order to extend this kind of dosimeters, dental tissue has been examined and was found promising as a TLD dosimeter.
Materials and Methods: In this study, 70 health teeth were collected. The only criterion, which was considered for selection of the teeth, was the healthiness of them regardless of age and gender of the donors. All collected samples were washed and cleaned and milled uniformly. The final powder had a uniform grain size between 100 – 300 micrometer. The sample was divided into four groups. Group A and B were used for measurement of density and investigation of variation of thermoluminescent characteristics with temperature respectively. Groups C and D were used for investigation of variation of thermoluminescent intensity with dose and fading of this intensity with time. In all cases the results obtained with dental tissue were compared to a standard LiF, TLD dosimeter.
Results: It was found that, average density of the dental tissue was 1.570 g/cm^3, which is comparable to density of LiF, which is 1.612 g/cm^3. It was also concluded that the range of 0-300 ^{o}C, dental tissue has a simple curve with two specific peaks at 140 and 250 ^{o}C respectively.
The experiment also showed that, the variation of relative intensity versus dose is linear in the range of 0.04 – 0.1Gy. The fading rate of dental tissue is higher than LiF but still in the acceptable range (14% per month in compare to 5.2% per month)
Conclusion: Dental tissue as a natural dosimeter is comparable with TLD and can be used in accidental events with a good approximation. *Iran. J. Radiat. Res.; 2003; 1(2): 113 – 117.*

Keywords: *TLD dosimetry, dental dosimetry, personal dosimeters, accidental dosimetry.*

INTRODUCTION

However radiation is very useful to cure some cancerous diseases, it may have very destructive effect on living organisms including human being if it is used incorrectly or uncontrolled.

Radiation dose delivered to a living object is one of the effective factors for measuring the harm received by a living object; doses are measured according to some changes, which can be estimate, by the same device called dosimeter. As an example, film badge worn by radiologists is one type of these dosimeters. Thermoluminescent dosimeters (TLD) are another type of dosimeters that produce light when is exposed to high amount of heat. Luminescent phenomena have different categories including phosphorescence and fluorescence.

Thermoluminescense is a long-term phosphorescence whose radiation emission time can be varied between few seconds to many years. (Cameron *et al.* 1968). Luminescent observed by stimulating with ultraviolet or

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ionizing photons is called radio thermoluminescent or TL.

TLD dosimeters usually are made of Lithium Fluoride (LiF), which have been used widely for their high sensitivity, good resolution, acceptable fading, good reproducibility and enough linearity of response. Some TLD materials can be found naturally (Such as Calcium Fluoride (CaF_2)) or can be constructed artificially. TLD properties are also observed in fish scale, bone, dental enamel tissue some hard organic material and organic metals (Cameron *et al*. 1968).

MATERIALS AND METHODS

Seventy human permanent teeth were collected disregarding without considering being the characteristics of their owners. The only criteria was their healthiness and free from decay. All collected teeth were from Tehran dentistories and were put into a 10% formalin solution after extraction.

All samples were scaled with a Hu-Friedy U15-30 scaling instrument and washed with water. The cleaned teeth were left in distilled water and then dried with air compress. The crown of the teeth was detached with a fraiser and tourbin and a miniunit, all from Diatech Company-Switzerland.

A Phillips mill unit powdered tooth crown with grain size from 100 to 300 μm. The powder was divided to 73 samples and four groups called A, B, C and D. The weight of each sample in groups B, C and D were 0.39 gram$\pm$ 0.0001. To compare the results with standard TLD, a few standard LiF TLD samples from Harshow-U.S.A were used in different stages. The reasons that 0.39 gr weight was selected are that standard weight of LiF sample is 0.39 gr and TLD reader is also calibrated with these samples.

TLD reader, which was used, is a Harshow 4000-from U.S.A.

All samples were irradiated with a Theratron 780 C cobalt 60 unit, from Canada.

Most important properties of dental thermoluminescent were evaluated in four groups as follows:

Group A, determination of density (nine samples).

Group B, producing the glow curve of dental tissue with one sample.

Group C, producing dose-response curve (54 samples)

Group D, evaluation of fading effect in dental tissue dosimeters (9 samples).

Determination of density in dental Dosimeter

Nine samples in-group A, with different weights were poured in a scaled cylinder with $1\,cm^3 \pm 0.01$ volume and the volume of each sample was measured. Density of each sample was found from dividing the mass to volume formula. The average density of nine samples was accepted as density of dental dosimeter.

Determination of glow curve

Sample in-group B with a standard TLD was irradiated to a dose of one gray and intensity of thermoluminescent was measured for 10^oC temperature steps from 0-300^oC.

Investigation of the linearity of response in dental tissue:

Samples in-group C were divided to 6 subgroups each of them with 9 samples.

Subgroup one was kept as control and background measurements.

Subgroup two, three, four, five and six were irradiated to doses of 0.02, 0.04, 0.06, 0.08 and 0.1 Gy respectively. To make the results comparable with a standard dosimeter when irradiating these subgroups, one standard LiF, chip was also irradiated.

Fading in dental dosimeters

Samples in-group D were irradiated to dose of 0.1 Gy to investigate the fading effect in dental tissue. For each sample the intensity of thermoluminescent was recorded. The samples were kept in dark room temperature (25^oC) and their TL intensity were measured after 1.5, 3, 6, 12 and 24 hours. The reading was repeated after

5, 10, 15, 20, 25 and 30 days after irradiation. The reading of a standard LiF sample also was repeated with each dental sample to compare the TL intensity of dental tissue and LiF dosimeters.

RESULTS

1) Density of nine dental samples were found to be 1.586, 1.523, 1.650,1.553, 1.621, 1.621, 1.575, 1.570 and 1.532 g/cm^3 and their average was found to be 1.570 g/cm^3 while the density of LiF was 1.612 g/cm^3.

2) Glow curve of dental powder in temperature between 0-300°C showed two specific peaks at 140 and 250°C. The intensity of TL in these peaks showed the capability of dental tissue as a TL dosimeter. (Makeever *et al.*1988) This intensity was found to be 73.5% of that of standard LiF TLD (figure 1).

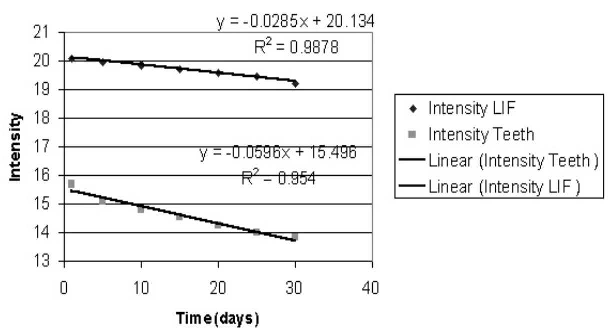

Figure 1. Comparison of LIF and Teeth Intensity.

3) Dose response experiments showed that intensity versus dose is comparable with LiF and is linear in the range of 0.02 to 0.1 Gy. The correlation between these points for dental dosimeter is R^2 = 0.95, while this value for LiF is R^2 = 0.98 (figure 2). In this research low doses were investigated but higher doses are also are measurable with this dosimeter.

4) Fading of lithium florid in this research was approximately estimated to be 5.2% per month; while in dental dosimeters this value was 14% per month (Figure 3).

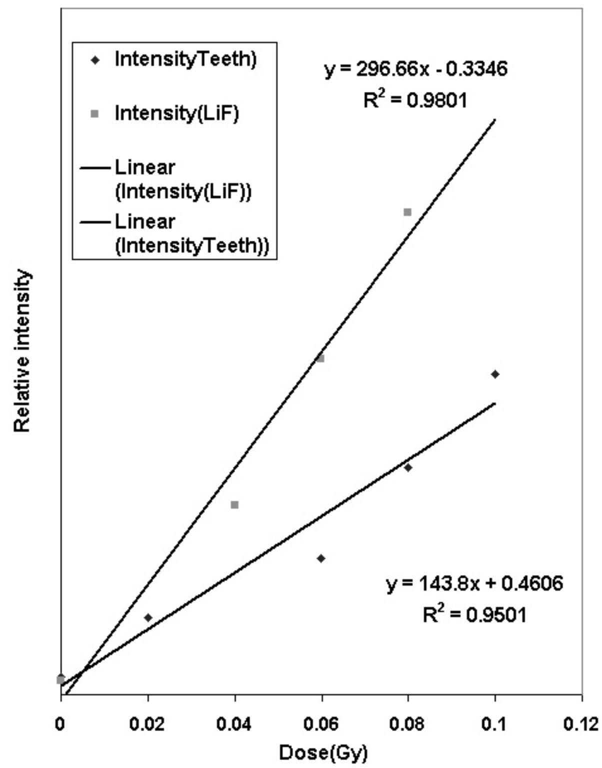

Figure 2. Comparison of responses of dental dosimeter with LiF TLD dosimeter.

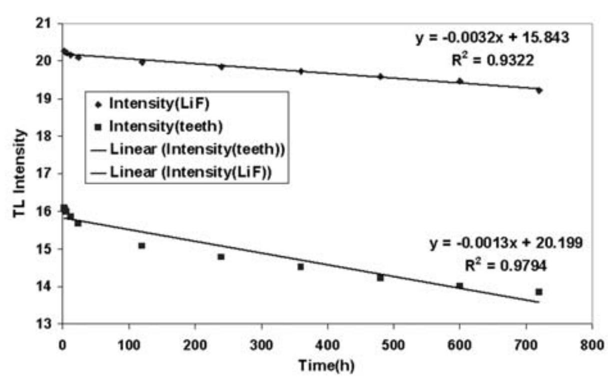

Figure 3. Comparison of Tl intensity with time for LiF and dental dosimeters.

DISCUSSION

According to our investigation, no new research has been done on thermoluminescent properties of dental tissue. These properties are mentioned only in a few references (Cameron *et al.* 1968).

The dosimeters are used to measure the dose for human body; therefore they should have similar behavior to the body tissues. One of the important factors is density. Density of soft tissue is very close to the density of water (1 g/cm^3). The density of dental powder was found to be 1.57 g/cm^3, which is higher than that of water. The density of an unmilled tooth is even higher than its powder. For this reason, if one is to use the dental tissue as a widespread dosimeter, it is preferable to use the dental powder instead of a solid unmilled extracted tooth.

Dental glow curve

In each material, many phenomenons are effective on the thermoluminescence phenomena and each set of recombination centers and traps are function of temperature dependent in a special way.

For this reason, for each material, the glow curve is different and has different peaks in the specified temperatures.

As an example for pure LiF and in the range of 200-400^{o}C, fifteen different peaks are visible. Each peak relates to specific phenomena of electron trapping.

The most important factors in the number of the peaks and their height are the empty positions in crystal lattice, impurity ions, density of the ions and distortions in the lattice. In other word, glow curve shows the possibility of electron escape from the traps due to temperature of that material.

In low temperature, this possibility is zero and the intensity of luminescent is also zero, therefore the numbers of charges in the traps are constant.

Escape of charge from trap will increase with temperature and luminescent intensity reaches to a peak. After each peak, the number of charges decreases and intensity also reach at zero. This explains that the freedom of charge carriers from traps is controlling the glowing curve, not the luminescent centers. The height of the tallest peak in glow curve in reality is the efficiency of that substance as a thermoluminescent dosimeter. In this research, efficiency of dental tissue was approximately 73% of the efficiency of standard LiF dosimeter. It needs more investigation to clarify whether is there any possibility to increase this efficiency with changing the ingredient or construct ion of dental tissue? Presence of Magnesium and Titanium as impurities in the LiF chip change the efficiency of this TLD dosimeter by 14% in compare with pure LiF. (Cameron *et al.* 1968, Horomitz 1984).

Linearity of response with dose:

In general, dose response curve in thermoluminescent dosimetry has two shapes, linear and sigmoid.

Sigmoid curve

This curve appears in high dose range (e.g. in radiotherapy ranges) and has its own characteristics as follows: Normally it has a background; In low doses, there is a reduction in response, which is called effect of dose intensity and at least, there is a smooth region at very high doses.

The linear curve

In this region, there is a direct relation between dose and its response, so that, it is possible to find dose with knowing the intensity or vice versa.

In the linear curve, normally no shoulder is observed.

The desirable dosimeter should have a linear response in a vast range. Some of the TLD dosimeter does not have such a behavior and should be calibrated before use.

The fact that both the dental dosimeter and LiF dosimeter have a decline in thermoluminescent property depends to a few factors Such as: Composition of dosimeter and in the case of dental tissue, the percentage composition of enamel and dentin; Technical error, and variation of temperature, accuracy of equipment and experimental stability and fading effect in dental thermo luminescent.

One important factor in selection of TLD material is the stability of the number of trapped charge carriers in that temperature. Therefore it is necessary to clarify the rate of charge carriers coming out of traps due to ambient temperature (temperature fading), light (light-fading), or fading due to any other factor (reasonless-fading).

Fading depends on the depth of electronic traps, which means the fading is faster if the traps are shallow and the fading is slower if the traps are deep (Cameron *et al.* 1968).

Therefore, for dosimetry purposes, the main peak in glow curve should be in temperature range of 200-300^{o}C as the traps in this range are very deep and sufficient for stability of peaks in glow curve (Cameron *et al.* 1968, Makeever 1988).

The other advantage of an ideal dosimeter is, its ignorable fading with elapsing of time in the ambient temperature. 10 to 20% reduction fading per month is acceptable in TLD dosimetry. However the percentage fading in dental dosimeter is higher than LiF dosimeters but still it is in the acceptable range. Reported values for LiF are between 5-10%.

With some research on LiF the fading of LiF is reduced from 5% per month to 5% per year. This is a possibility to reduce the fading of the dental dosimeter to a more acceptable value (Horomitz 1984).

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