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Research Article

Dose and fading time estimation of glass ceramic by using artificial neural network method

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ABSTRACT

Ceramic materials commonly used for dental prosthetics and restorations shows luminescent properties. Dental ceramics are considered the most natural-looking restorative materials for aesthetic rehabilitation due to their transparency. They are commonly used for dose response and fading assessment by using thermoluminescence method in various fields of dosimetric applications. In present study, we use artificial neural networks (ANN) toolbox of Matlab to predict irradiation dose and fading time using glow curve data from dental glass ceramic which is thermoluminescent (TL) dosimetric material. Temperature, dose value and fading time are used for input and TL intensity used for output component of the proposed ANN model. 18 neurons are used for hidden layer to analyze the experimental results of the model. Experimental and simulation results are compared and similarity is found as about 99 % in this present study.

Introduction

The ceramic is a sort of biomaterial utilized in dental restorations and prostheses. Ceramic is potently susceptible to radiation and the proportion of absorbed radiation dose is depends on the intensity of both TL and OSL signals [1]–[5]. Ceramic materials commonly used employed in dental prosthetics and repairs shows luminescent properties. Due to their use in the human body, these materials are particularly interesting when the retrospective dosimeter is required for individual usage, but monitoring of dose is not planned [6]. Typically, the properties of quartz and feldspar minerals often vary significantly from the thermal history; consequently, domestic and building ceramics do not have to have the same dose response properties [7], [8]. Dental ceramics are considered the most natural-looking restorative materials for aesthetic rehabilitation due to their transparency. Dental ceramic materials can be produced in colours indistinguishable from natural teeth. In addition, ceramics with an outer surface of metal oxides do not allow dental plaque to be absorbed by products, therefore, unlike composite resin, it eliminates the problem of surface colour changes. For these reasons, dental ceramics have become an aesthetic

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restorative material that is increasingly used in dentistry [9]–[13]. Fading is a significant parameter for dosimetric materials and the loss of TL signal between read out and irradiation is known as fading.

Artificial neural networks (ANN) are developed by using nerve cell which is known as neuron of the living. ANN is known since many years and has been applied in a different fields of scientific. An ANN consists of input, hidden and output layers with a variable number of nodes connecting the input and output layers as shown in Figure 1. A fairly simple and small-sized of an ANN has some powerful features in information processing, even compared to the human brain. The first ANN model is a perceptron introduced in the 1960's [14] to model information processing of the brain. A neural network consists of layers of neuron where every neuron is connected with other neurons in both the previous and following layer. During training, the weights are changed iteratively with a back propagation technique that is most commonly used for the training of neural networks [15]. We also used the back propagation and mean squared error technique as loss function in this study. ANN is used by researchers for engineering applications increasingly because of the easy ability to learn directly from target outputs. Moreover ANN can adapt and solve the problem according to new data [16]. Therefore, for engineering applications, ANN can be used an effective tool [14], [17] such as prediction of dose value and fading time [18]. ANN is a very promising tool which is applied in different ways of physics such as dose estimation [2].

Materials and Methods

Dental ceramics available on the Swedish dental market (IPS e.max Ceram, Ivoclar Vivadent SW) and previously examined (Ekendahl et al., 2013). Its composition is: SiO_2 (60-65%), Al_2O_3 (8-12%), Na_2O(6-9%), K_2O(6-8%), ZnO (2-3%), CaO, P_2O_5, F(2-6%), other oxides (2-8%) and pigments (1%). For dose and fading time estimation studies, a total of 30 and 18 newly glass ceramics are used, respectively. All measurement are done at room temperature, the ceramics are each irradiated once with $^{90}Sr - {}^{90}Y$ β-source (delivering 0.04 Gy/s)

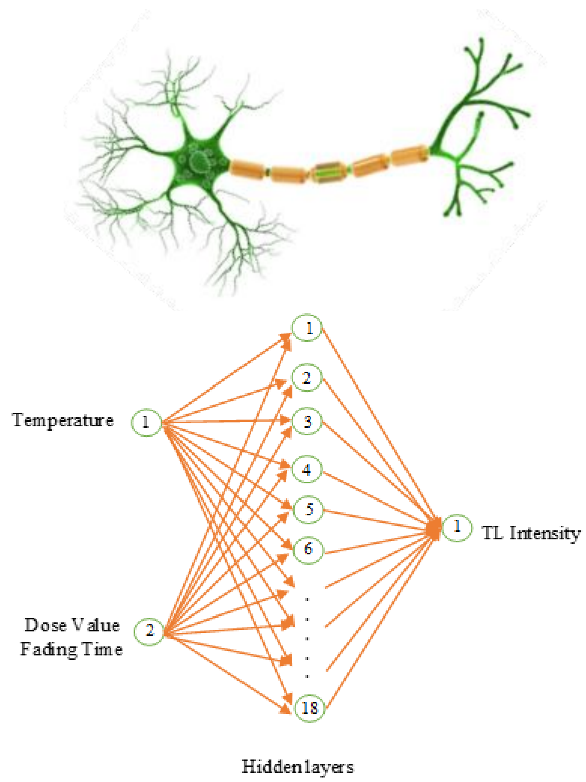

Figure 1. A neuron and its software model

up to 12, 24, 36, 72, 144, 288, 576, 2304, 3456 and 6912 Gy for dose estimation study and irradiated at fix dose value (36 Gy) and waited in a dark ambient from 1 hour to six weeks for fading time estimation study. In this study, Levenberg-Marquardt training algorithm of ANN model is used to estimate dose value and fading time of glass ceramics. Temperature, dose value and fading time are used for input and TL intensity used for output component. 18 neurons are used for hidden layer to analyze the proposed ANN model.

Results and Discussion

The glow curve which is TL intensity versus temperature variation of glass ceramic is shown in Figure 2 and when the dose increased the signal intensity also raised that is seen clearly. The TL glow curves for dental glass ceramic were characterized four dominant peaks extending from room temperature (RT) up to 400 °C. The visible peaks of the glow curves are characterized peak 1 (~175°C), peak 2

(~225°C), peak 3 (~275°C) and peak 4 (~350°C) for the indicated temperature interval for the dental glass ceramic sample. The simulated and experimental glow curves of six different dose values which are 12, 24, 72, 144, 2304 and 6912 Gy are shown in Figure 3. The simulation glow curve of model shows similar characteristics with the experimental glow curve of glass ceramic. Experimental and simulated glow curve are given in the same graph to compare the similarity. The similarity is obtained as 99 % between experimental and simulation results of glass ceramic. Mean square error (MSE) and coefficient of determination (R^2) values which are obtained from the proposed model are given in Table 1.

Table 1. MSE and R^2 values of the proposed ANN model for dose value

	MSE	R^2
Training	1.26212	0.99838
Testing	4.53604	0.97231

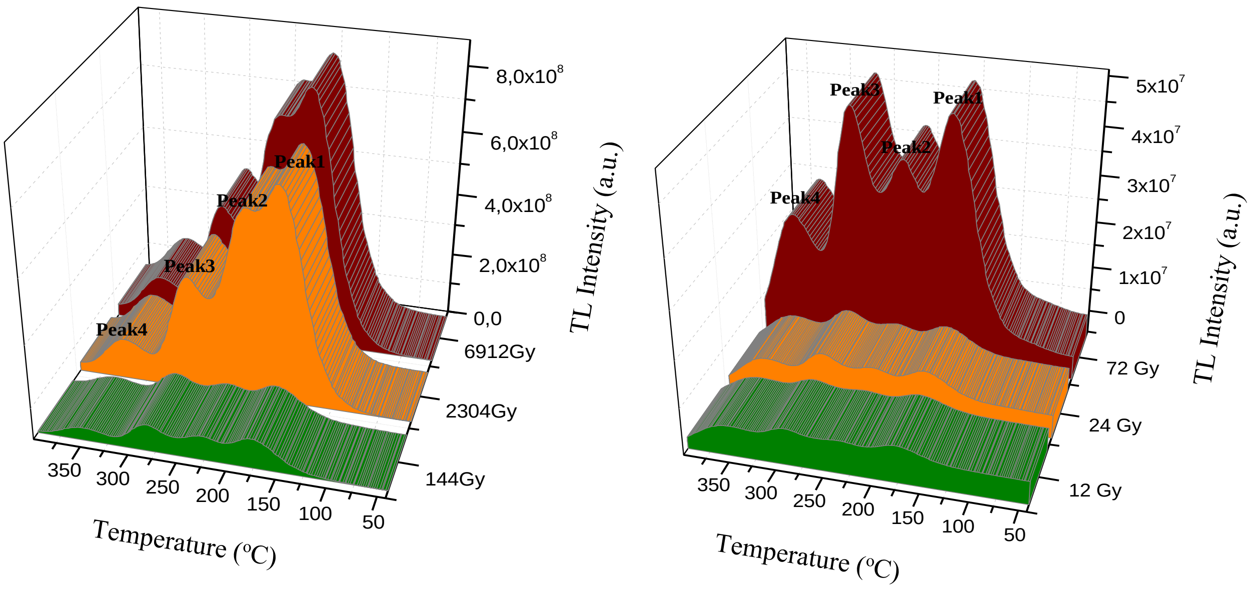

Figure 2. The TL glow curve of glass ceramic as a function of dose response irradiated with β-source for 12, 24, 72, 144, 2304 and 6912 Gy at room temperature

Fading is identified to decrease luminescence signal as a result of irradiated ceramics waiting under different environments. The trapped carriers within the sample can be stimulate by heat, light or by any other means. The period of 6 weeks was assessed for fading of dental glass ceramics in this study. The samples readout by using the TLD reader at different storage times (1, 4, 24, 168 and 1008 hours). The glow curve of glass ceramics as a function of fading is shown in Figure 4. After 1 hour storage, all the TL peaks have a major decreasing about 60% in luminescence intensity this observation demonstrates that all TL peaks were unstable. The TL glow peak labeled at 175°C faded completely for the dental glass ceramic after 1 week storage. The simulated and experimental glow curves of six different fading time which are 0, 1, 4, 24, 168 and 1008 hours are shown in Figure 5. The simulation glow curve of model shows similar characteristics with the experimental glow curve of glass ceramic as a function of fading time. Experimental and simulated glow curve are given in the same graph to compare the similarity. The similarity is obtained as 99 % between experimental and simulation results of glass ceramic. Mean square error (MSE) and coefficient of determination (R^2) values which are obtained from the proposed model are given in Table 2.

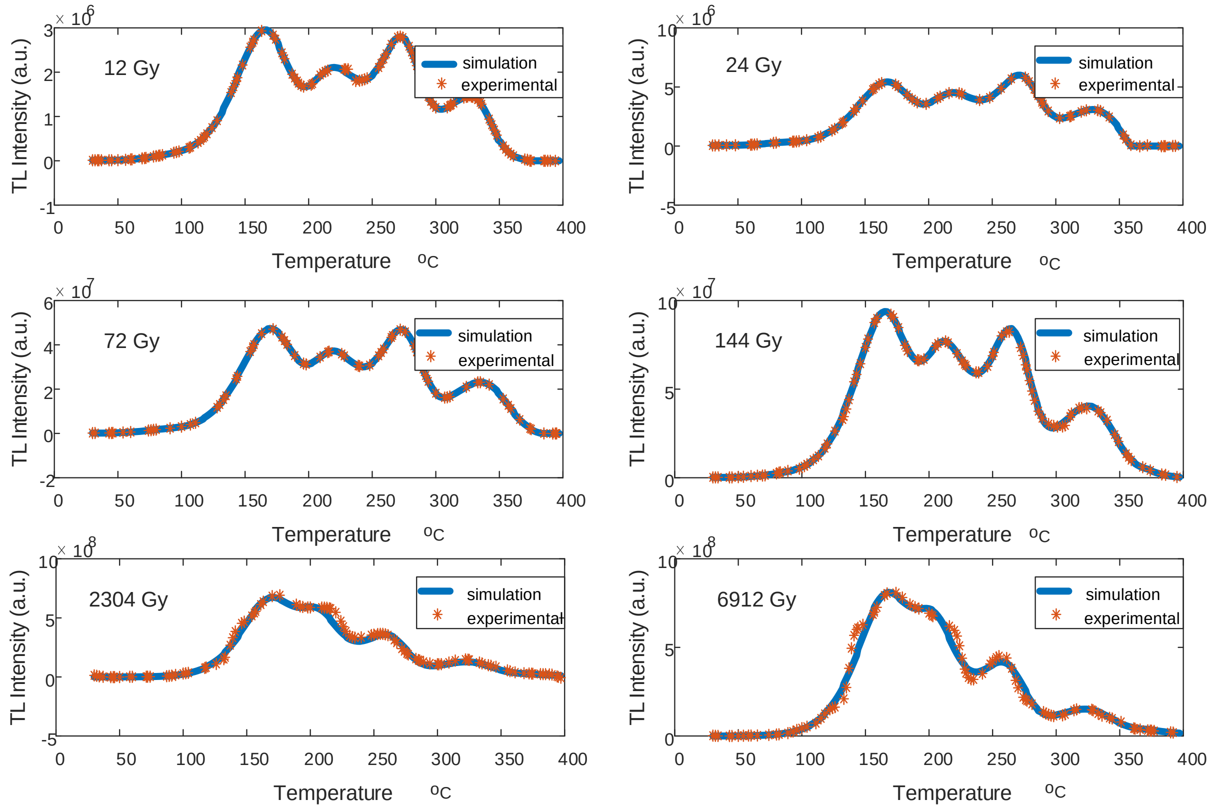

Figure 3. The TL glow curve of simulation and experimental results of glass ceramic as a function of dose response irradiated with β-source for 12, 24, 72, 144, 2304 and 6912 Gy at room temperature

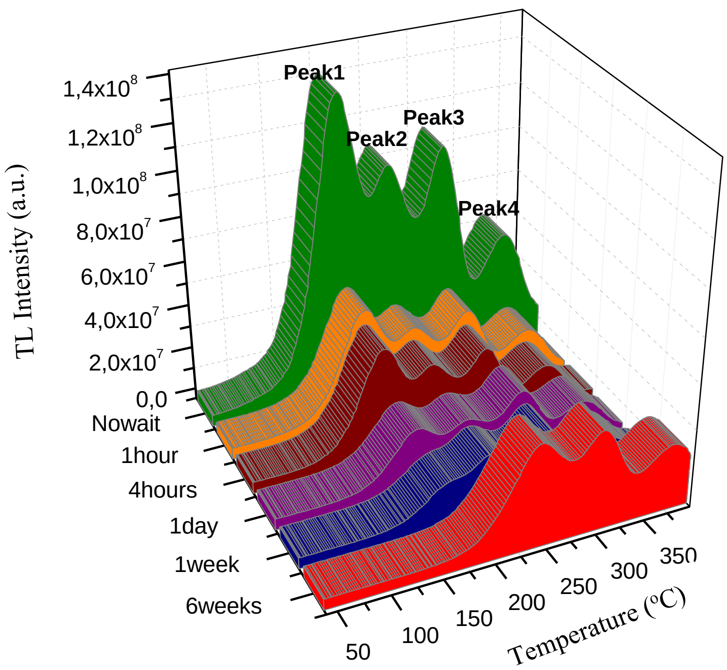

Figure 4. The TL glow curve for dental glass ceramic with respect to the fading.

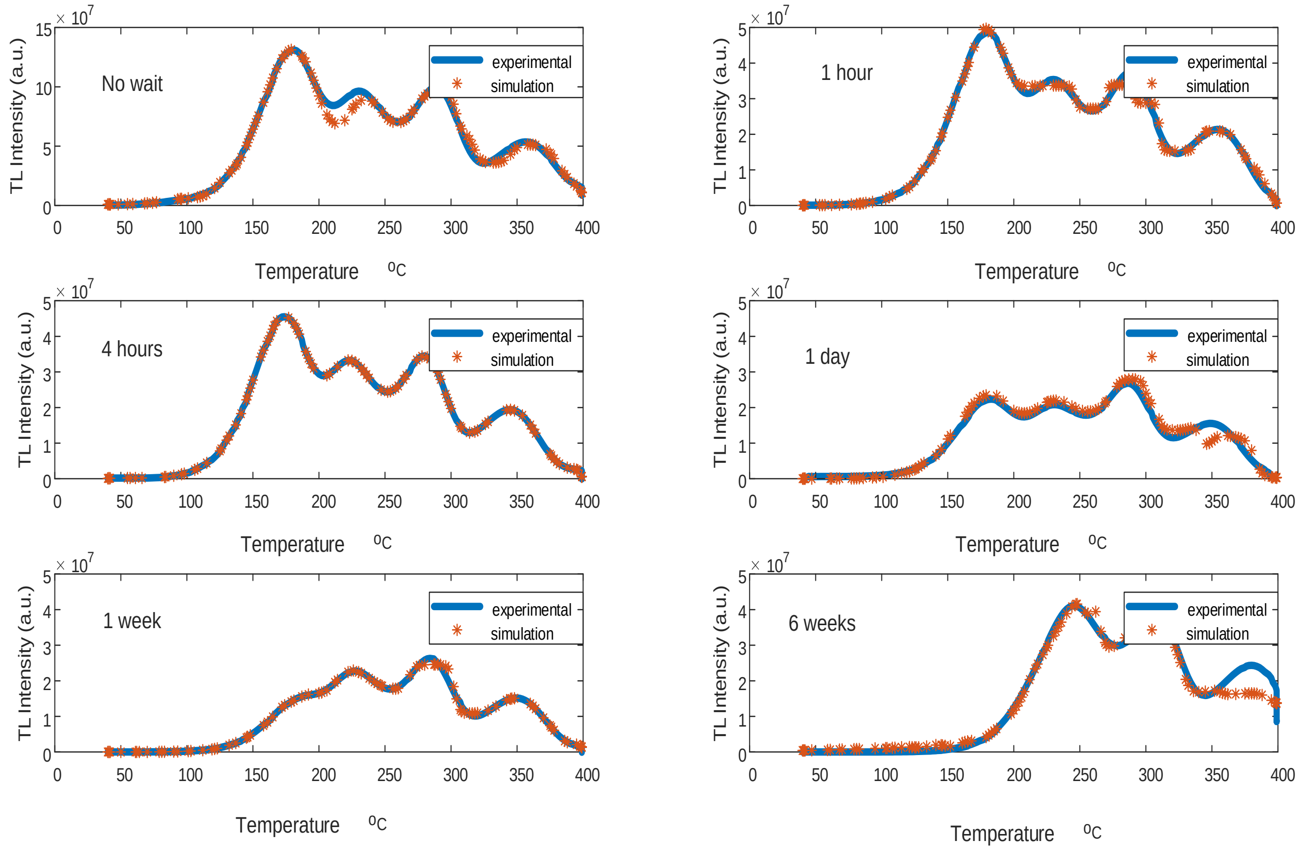

Figure 5. The variation of TL intensity versus temperature of simulation and experimental results of glass ceramic as a function of fading.

Table 2. MSE and R^2 values of the proposed ANN model

	MSE	R^2
Training	1.25895	0.99125
Testing	4.43568	0.98952

Conclusions

When the applied dose increased, the intensity of TL peak increased for both the experimental and simulated glow curves. Similarity of these glow curves is obtained about 99 % for all dose value and fading time of glass ceramic. By using this ANN model, dose and fading time estimation are successfully done and also the other parameters such as kinetic parameters can be predicted in the future.

References

[1] E. Isik and H. Toktamis, "TLD characteristic of glass, feldspathic and lithium disilicate ceramics," *Luminescence*, vol. 34, no. 2, pp. 272–279, 2019.

[2] E. Isik and H. Toktamis, and I. Isik, "Analysis of thermoluminescence characteristics of a lithium disilicate glass ceramic using a nonlinear autoregressive with exogenous input model," *Luminescence*, vol. 35, no. 6, pp. 827–834, 2020.

[3] D. Banerjee, L. Bùtter-jensen, and A. S. Murray, "Retrospective dosimetry : estimation of the dose to quartz using the single-aliquot regenerative-dose protocol," *Appl Radiat Isot.*, vol. 52, pp. 831–844, 2000.

[4] H. Oks et al., "Assessment of thermoluminescence peaks in porcelain

for use in retrospective dosimetry," *Radiat. Meas.*, vol. 46, no. 12, pp. 1873–1877, 2011.

[5] I. Veronese, A. Galli, M. C. Cantone, M. Martini, F. Vernizzi, and G. Guzzi, "Study of TSL and OSL properties of dental ceramics for accidental dosimetry applications," *Radiat. Meas.*, vol. 45, no. 1, pp. 35–41, 2010.

[6] I. K. Bailiff and S. Road, "The use of luminescence techniques with ceramic materials for retrospective dosimetry," *The International Nuclear Information System*, pp. 985–994.

[7] W. Höland, V. Rheinberger, M. Schweiger, K. F. Kelton, and B. R. Haywood, "Control of nucleation in glass ceramics," *Philos. Trans. R. Soc. A Math. Phys. Eng. Sci.*, vol. 361, no. 1804, pp. 575–589, 2003.

[8] N. Kristianpoller, D. Weiss, and R. Chen, "Optical and dosimetric properties of zircon," *Radiat. Prot. Dosimetry*, vol. 119, no. 1–4, pp. 267–270, 2006.

[9] D. Ekendahl, L. Judas, and L. Sukupova, "OSL and TL retrospective dosimetry with a fl uorapatite glass-ceramic used for dental restorations," *Radiat. Meas.*, vol. 58, pp. 138–144, 2013.

[10] K. Bailiff et al., "Luminescence characteristics of dental ceramics for retrospective dosimetry: a preliminary study ," *Radiat. Prot. Dosimetry*, vol. 101, pp. 519–524, 2002.

[11] A. Pascu, A. Timar-Gabor, and V. Simon, "Retrospective accident dosimetry using dental ceramics," *Rom. Reports Phys.*, vol. 68, pp. 658–666, 2015.

[12] I. Veronese, G. Guzzi, A. Giussani, M. C. Cantone, and D. Ripamonti, "Determination of dose rates from natural radionuclides in dental materials," *J. Environ. Radioact.*, vol. 91, no. 1–2, pp. 15–26, 2006.

[13] R. K. Tamrakar, D. P. Bisen, K. Upadhyay, and I. P. Sahu, "Comparative study of thermoluminescence behaviour of Gd2O3phosphor synthesized by solid state reaction and combustion method with different exposure," *Radiat. Meas.*, vol. 84, pp. 41–54, 2016.

[14] F. Rosenblatt, "Perceptrons and the Theory of Brain Mechanics," *Cornell Aeronaut. Lab inc buffalo NY.*, VG-1196-G, p. 621, 1961.

[15] B. N. Network, R. Hecht-nielsen, S. Diego, and L. Jolla, "The Backpropagation Neural Network," *Processing*, pp. 593–605.

[16] M. Y. Rafiq, G. Bugmann, and D. J. Easterbrook, "Neural network design for engineering applications," *Comput. Struct.*, vol. 79, no. 17, pp. 1541–1552, 2001.

[17] I. B. Topçu and M. Saridemir, "Prediction of compressive strength of concrete containing fly ash using artificial neural networks and fuzzy logic," *Comput. Mater. Sci.*, vol. 41, no. 3, pp. 305–311, 2008.

[18] N. Kucuk and I. Kucuk, "Computational modeling of thermoluminescence glow curves of zinc borate crystals," *J. Inequalities Appl.*, pp. 1–7, 2013.