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Research Article

Thermoluminescence Dosimeters Holder Cassette Design and 3D Printing

Duygu TUNÇMAN[1,*], Fahrettin Fatih KESMEZACAR[2], Osman GÜNAY[3], Nami YEYİN [4], Özge DEMİR [5], Mustafa DEMIR[6], Baki AKKUŞ[7]

[1]Istanbul University, Science Faculty, Physics Department, 34134, Istanbul-Turkey
* **Corresponding Author** : **Email:** duygutuncman@gmail.com - **ORCID:** 0000-0002-0929-0441

[2]Istanbul University – Cerrahpasa, Vocational School of Health Services, Medical Imag. Tech. Program, Istanbul-Turkey
Email: okesmezacar@hotmail.com - **ORCID:** 0000-0001-5110-1184

[3] Yıldız Technical University, Faculty of Electrical & Electronics, Biomedical Engineering, 34220, Istanbul – Turkey.
Email: ogunay@yildiz.edu.tr - **ORCID:** 0000-0003-0760-554X

[4] Department of Nuclear Medicine, Cerrahpasa Faculty of Medicine, Istanbul University-Cerrahpasa, Istanbul, Turkey
Email: namiyeyin@gmail.com - **ORCID:** 0000-0003-0262-4020

[5] Istanbul University – Cerrahpasa, Faculty of Engineering, Department of Chemical Engineering, Department of Unit Operations and Thermodynamics, 34315, Istanbul – Turkey.
Email: ozge.demir@iuc.edu.tr - **ORCID:** 0000-0002-0342-5915

[6] Department of Nuclear Medicine, Cerrahpasa Faculty of Medicine, Istanbul University-Cerrahpasa, Istanbul, Turkey
Email: demirm@istanbul.edu.tr - **ORCID:** 0000-0002-9813-1628

[7]Istanbul University, Science Faculty, Physics Department, 34134, Istanbul-Turkey
E-mail: akkus@istanbul.edu.tr - **ORCID:** 0000-0002-9533-7671

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Abstract:
3-*dimensional* (3D) printing technology has been used in many fields and has taken a significant place in several applications. The ease of production, cheap cost, being able to produce the product most suitable for your needs, and easy accessibility of the 3D printer have enabled it to be used in many areas. This study emerged from the need for an apparatus to place thermoluminescence dosimeters (TLDs) during the calibration of TLDs to be used to determine organ doses in fluoroscopy applications. In the study, the TLD holder cassette that was specially designed in the SolidWorks program was printed from PLA material using the fused deposition modelling (FDM) technique with Creality Ender 3 S1 printer. With this 3D TLD holder cassette that was designed and printed in accordance with the needs, we aimed to show the usability of the 3D printing technique in almost every field of applied sciences.

1. Introduction

In recent years, there are many technologies available that make it possible to obtain a prototype of a designed product in a relatively short time. Among the variety of additive technologies (such as fused deposition modeling (FDM) and others), some are accessible to a wide range of users due to their simplicity and relative inexpensiveness [1,2]. The interest in 3D printing technology is increasing in almost every sub-branch in the fields of Health and Medicine. When it comes to 3D printing, the first thing that comes to mind is the general areas where this technique is used and the products known to be produced. The study is important in terms of emphasizing that 3D printing produces products suitable for the purpose. Various devices are used to detect the presence of ionizing radiation that cannot be detected by human sense organs and to measure its level. Thermoluminescent dosimeters (TLD) are routinely used for dose measurements due to their small size (Fig. 1), tissue equivalence, and high sensitivity [3]. TLD is a layer of solid crystals. After the ionizing radiation interacts with the crystal, the crystal is heated and the trapped electrons in the crystal emit a visible light photon with an energy equivalent to the energy of ionizing radiation. The emitted light photons are counted by means of photomultiplier tubes. Thus, the amount of radiation reaching the dosimeter is determined [4]. Before TLDs can measure doses, they must be prepared by going through a number of processes [5].

Figure 1. *Types of TLD dosimeters*

All dosimeters must be annealed under the manufacturer's instructions before making radiation measurements to standardize their sensitivity and natural background. Pre-irradiation annealing is especially important in order to eliminate the thermoluminescent radiation left over from previous irradiations, create thermoluminescence sensitivity, and eliminate unstable low-temperature radiation peaks. After annealing, it must be calibrated with a monoenergetic radiation source such as a gamma ray. For sensitive irradiation of TLDs, cassette holders suitable for TLD size are usually produced from hard-plexiglass or polymethylmethacrylate (PMMA) materials [6,7]. TLD irradiation apparatuses are produced by cutting in desired dimensions in special cutting machines. As an alternative to this conventional production technique, TLD irradiation and storage TLD holder cassette can be produced in accordance with the intended use of 3D printing technology. Apart from the ease of use of the TLD holder cassette, the choice of material before printing is important in terms of the backscattering of radiation during irradiation. Because TLDs are very sensitive dosimeters, it is necessary to minimize adverse environmental conditions during calibration in order to get the most accurate result from measurements.

This study arose from the need for an apparatus in which TLDs can be placed for dose measurements. In this sense, this study is aimed to introduce the 3D printing technique of a TLD holder cassette with 100 slots (10x10).

2. Material and Methods

The 3D printing process, which allows the transition from direct design to production, consists of the steps described below. In this study, the 3D model was created using the SolidWorks program (Fig. 2).

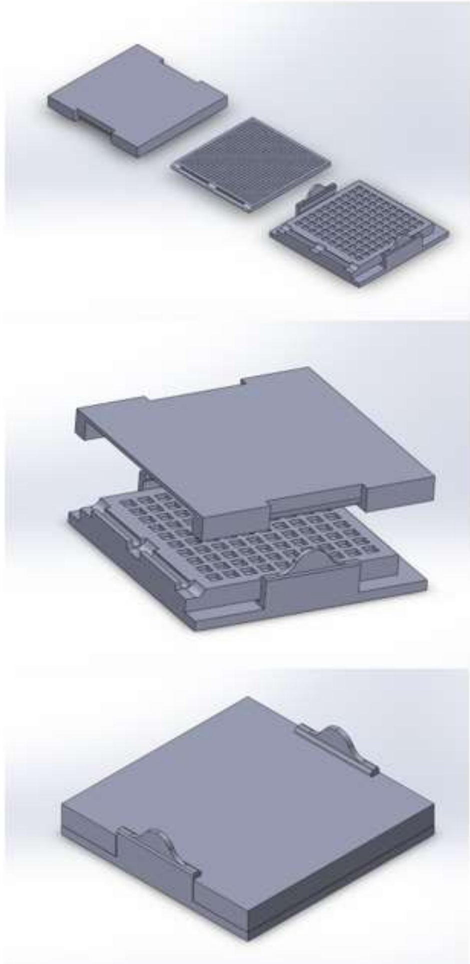

Figure 2. *Design of the TLD holder cassette in the SolidWorks 3D program*

TLD holder cassette is designed to consist of three basic parts as shown in Fig. 3. A top cover was designed to keep TLDs stable during irradiation (Fig. 3-A). Furthermore, the top cover is locked thanks to its latch structure on the side and ensures that the TLDs in the apparatus remain stable during irradiation. The intermediate plate that is shown in Fig. 3-B is produced for direct irradiation of TLDs even without a cover. There are 100 slots in the lower plate (Fig. 3-C). The slots shown in Fig. 3 - Detail A are designed to place TLDs in the apparatus (Fig. 3).

In order to take the output of the drawn model from the 3D printer, it is exported as a Standard Triangle Language (STL) file that the Ultimaker Cura software program will detect (Fig. 4). The TLD holder cassette was planned at a %30 infill ratio. Designed modes that are obtained as an STL file to slice software are divided into layers. After specifying the required variables such as fill, printing speed, and printing temperature with Ultimaker Cura, g. code extension output to 3D printer transferred.

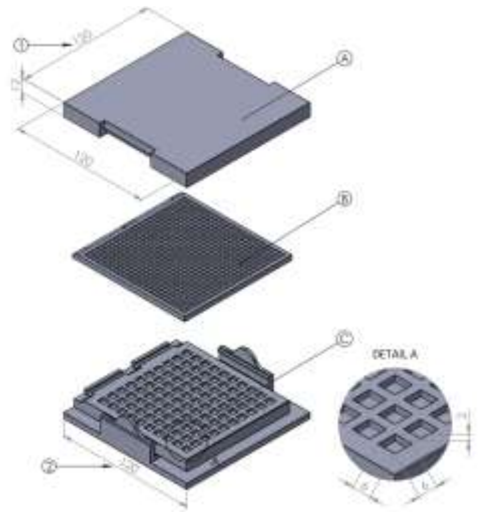

Figure 3. *The scaled version of the TLD holder cassette in the design program*

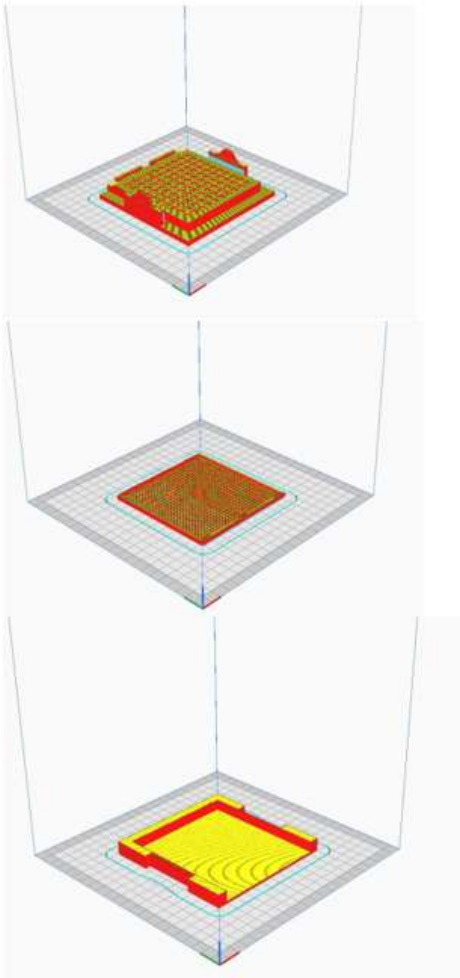

Figure 4. *The image of the TLD holder cassette in the Ultimaker Cura program*

3. Results and Discussions

Creality Ender 3 S1 printer was used for the output of the 3D model (Fig. 5). FDM technique was used while printing the TLD holder cassette.

Figure 5. *Creality Ender 3 S1 printer*

Table 1. *Creality Ender 3 S1 printer product **parameters***

Molding Technology	**FDM**
Printer Size	487x453x622 mm
Build Size	220 x 220 x 270 mm
Package Size	540 x 510x 260 mm
Supported Filaments	PLA/TPU/ PETG/ABS
Nozzle Diameter	0.4 mm
Maximum Nozzle Temperature	260°C
Printing Speed	Maximum 160mm /s
Maximum Heatbed Temperature	100°C

The technical features of the Creality Ender 3 S1 3D printer that is used for printing are given in table 1 [8]. Material selection is important since the produced TLD holder cassette will be used in radiation irradiation. Porima PLA (Polylactic acid) filament was used in this study. Because this material has much better mechanical properties than materials such as polyurethane, polypropylene and plastic. Therefore, it is the most preferred filament type. PLA filament parameters are given in table 2

[9]. Fig. 6 shows the 3D printing of the model created for the TLDs.

Table 2. *Technical properties of PLA material*

Density	1.24 g/cm^3
Coefficient of Thermal Expansion	68μm/m-°C
Tensile Strength	65 MPa
Maximum Operating Temperature	52 °C
Nozzle	200 – 230 °C
Bed	60- 75 °C

Figure 6. *A printed version of the TLD holder cassette*

When the printed material is examined visually, it is seen that it is exactly compatible with the designed model. Fig. 6 shows TLDs placed in the printing TLD holder for irradiation.

As shown in detail A in Fig. 2, each slot is manufactured in accordance with the TLD size. Chip-type TLDs are embedded in Fig. 5. However, the TLD holder cassette is also suitable for the placement of rod and powder-type TLDs.

In Fig. 6, markings on the plates are placed to orient them during the calibration of the TLDs. The printed TLD holder cassette has been used and tested in the calibration of TLDs.

There are many publications in the literature on the use of 3D printing applications in different fields and for specific purposes. When time and cost calculations are made, products produced with 3D printing are more advantageous.

One of the most common areas where 3D printing technologies are used for professional purposes in the production of functional parts is the biomedical sector.

In the literature, there are TLD holder apparatus made from various materials used during the storage and irradiation of TLDs. In Toossi et. al study, TLDs were set in a PMMA plate, which had slots for putting TLDs [10]. In Suleiman et.al study, the PMMA slab was used to accommodate the TLD chips in an array of slots 10x10 [6]. In Aksözen et. al study, TLDs were calibrated on a 30 cm x 30 cm rigid plexiglass holder cassette [11].

In our study, PLA material, which is a 3D printer material, was used for the TLD cassette holder, unlike the materials in the literature. The production processes of cassette holders that were produced with plexiglass and PMMA materials are more time-consuming and costly than 3D printing. Thanks to 3D design and printing technology, it can be used for calibration and storing TLDs by creating holes on the cassette holder according to the TLD type to be used. At the same time, the loss of TLDs can be prevented by producing a top cover for the cassette holder exactly as in our study.

4. Conclusions

3D design and printing technology have a wide range of applications in the health sector, from patient-specific designs to special production of device parts. Thanks to its 3D printing technique, easy design, fast production, and low cost solves the problems or deficiencies. In this study, for TLD irradiation, an apparatus has been designed to be used in calibration and readings of TLD dosimeters and it has been proven that it can be printed with 3D printing technique.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have

appeared to influence the work reported in this paper

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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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