2021 International Nuclear Atlantic Conference – INAC 2021
Virtual meeting, Brazil, November 29 – December 2, 2021

ISBN: 978-65-594-1256-3

Development of a 3D printed anthropomorphic skull phantom for clinical photons beam dosimetry

*S.B. Almeida(1), D. Villani(2) and L. L. Campos(1)

(1, 2) Radiation Metrology Center, Instituto de Pesquisas Energéticas e Nucleares, Av. Prof. Lineu Prestes, 2242 – Cidade Universitária, São Paulo – SP, Brazil.
Email address: sbipen@usp.br

1. Introduction

Rapid prototyping, or as it is better known as 3D printing, is a method of constructing three-dimensional objects using materials such as plastic for a digital model [1]. It is a modality that has the ability to build geometries with great complexity, being made possible by its flexibility in these three-dimensional constructions. The 3D FFF printing technique is the most used in additive manufacturing for having a relatively low cost and for having easier access to the materials used for this type of technique. Developed by the American Company Stratasys, the technique is an innovation that has gained great prominence in technological, industrial and scientific development, due to the great possibilities of producing three-dimensional objects [2].

The 3D printing has been gaining a great deal of space in the medical field due to the possibility of developing phantoms that allow an assessment of the prescribed dose, as they can simulate real conditions of a dose measurement procedure at certain points of interest. This study will enable the development of accessible dosimetric methodologies for quality control related to measurements with clinical photon beams in radiotherapy services, in addition to enabling the evaluation of thermoluminescent detectors for clinical application.

2. Methodology

For this study commercially available Polylactic Acid (PLA) that simulates soft tissue (100% infill) and Acrylonitrile Butadiene Styrene (ABS) type XCT-A developed at IPEN, that simulates bone tissue (45% infill) filaments were used for 3D printer. The printer used in this study was a 3D UP MODEL RAISE 3D - PRO2. For the construction of the skull phantom, a CT scan of the CIRS 711-HN phantom was performed as a reference. The 3D Slicer® drawing programs for geometric construction (Fig. 1) and development of insertion of anatomical regions and the Simplify 3D® which serves as a connection to the printer and has the slicer objective to print the object in parts or print the object at once were also used.

The choice of this phantom as a reference was based on the detailed anatomical characteristics that include: brain, bone regions, larynx, trachea, sinuses, nasal cavities and teeth. To use the model proposed by the CIRS (711-HN), the 3D printed phantom was adapted with accessories that allow a fitting in the brain region (cranial vault) for positioning the thermoluminescent dosimeters for clinical dosimetry of photon beams. Aiming at geometric dimensions, the phantom was printed in fourteen segments (parts). The segmented pieces were about 2.0 cm high with an average printing time of 20 hours each piece.

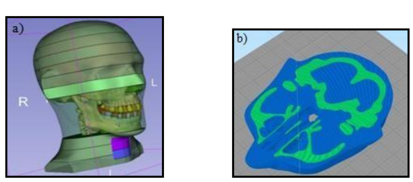

Figure 1: a) 3D *Slicer* segmentation software and b) software *Simplify* 3D for object printing.

3. Results and Discussion

The skull phantom was printed in fourteen subsequent axial layers due to the size and geometry of the piece (about 18 cm x 26 cm) and the materials used. Even taking into account the printing process, some factors influenced the printing of the pieces. The biggest impact factor regarding the printing of the phantom was the "warp" effect (Fig. 2), being caused by several parameters that directly interfere in the printing process, such as the printing made with a 100% infill filling, the side walls that serve as a base to sustain the print and the first layer does not adhere to the print platform. The “warp” effect causes a warp or slanting of the outer edges of the parts being printed, which occurs when there is no adherence of the part on the printer platform. Generally 3D printed phantoms are made to be filled with water, making printing easier. Objects printed with internal filling using tissue-equivalent materials give the phantom advantages for having anatomical details similar to a human body (Fig. 3). Even with the cited reports and the difficulties in assembling the phantom, it had a great advantage because it was printed with fill using materials that simulate soft tissue (PLA) and bone (ABS), accurately representing the anatomy of an individual, obtaining greater validity as a model for various clinical and research applications.

For validation of the printed phantom a tomography was performed to analyze the radiological density of the skull phantom. The results demonstrate a close equivalence to human tissue, but ABS that simulated bone parts presented a more radiopaque response compared to human bone tissue.

Figure 2: Phantom part featuring warp inthe frontal region.

Figure 3: 3D Printed Skull phanton.

4. Conclusions

Despite the potential impacts that occurred in the development of the phantom, none of these consequences are significant for the use of the phantoms, especially applications using clinical photon beams.

Acknowledgements

FAPESP Proc. No. 2018/05982-0 and CNPq Proc. No. 426513/2018-5

References

[1] B. Evans, *Practical 3D printers. The science and Art of 3D printing*. Apress. New York & USA (2012).

[2] A. F. Zier, A. D. N. F. Lemos, E. de Melo Volpato, I. de Campos Fatuch, R. P. de Oliveira, & A. M. dos Santos, Estudo de prototipagem rápida por meio da impressão 3D e seu efeito na redução de custos e prazos dos projetos de produção. *Memorial TCC Caderno da Gradução*, v. 5, n. 1, p. 301-318, (2019).