Development of a fused filament fabrication (FFF) 3D printed neck-thyroid phantom for multidisciplinary purposes.

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Purpose: Phantoms, devices that represent the human body, have been used in the fields of medical physics, physics and biomedical engineering since the beginning. The use of 3D printing and filaments commonly found commercially for the development of phantoms is being investigated recently. The application of this technique for the development of low-cost simulators requires a complex study of the interaction of printed materials with different types and qualities of radiation, as well as the characterization of print configurations. By making these measurements, it is possible to find methodologies so that they can correctly simulate human tissue. This study aims to describe the process of design and manufacture an anthropomorphic neck-thyroid phantom using a fused filament fabrication (FFF) 3D printer and tissue-equivalent materials for multidisciplinary purposes.

Materials and Methods: To this study, the commercial phantom ATOM MAX 711, from CIRS, was used as an anatomical reference for the 3D modeling base of the neck-thyroid phantom. Commercially available PLA and ABS XCT-A developed at IPEN were used in the 3D printing process in order to simulate soft and bone tissues respectively. It was used the RAISE3D PRO 2 FFF printer from IPEN. The usability validation of the phantom was performed through the analysis of images from a computed tomography (CT) acquisition. The Hounsfield Units (HU) numbers were compared between the 3D printed and the ATOM MAX 711 phantoms to each type of tissue represented. A thyroid accessory was also developed on the purpose of immobilization of radioactive material with epoxy resin.

Results: The modeling methodology of the 3D phantom of this study opens possibilities for using tomographic images of any objects, or even patients, to perform 3D prototyping of increasingly specific and customized simulators. The CT image analysis show great results on the analysis of the construction of the soft tissue with PLA filaments; construction of the bone tissues with ABS XCT-A; analysis of the construction of the thyroid accessory with epoxy resin; analysis of the spacing of the fit of the printed pieces; and analysis of image artifacts caused by the FFF technique.

Conclusions: The developed phantom presents the desirable characteristics for applications in radiation protection, measurements of radioisotopes incorporated in the thyroid (both contamination counters and nuclear medicine detectors) and training of techniques of acquisition of images with X rays. It is a viable alternative to a tissue-equivalent phantom; and low cost when compared to other commercially available options.

Keywords: 3D printing; 3D printed phantom; PLA; ABS.