Computed Tomography Imaging analysis of a fused filament fabrication (FFF) 3D printed neck-thyroid phantom for multidisciplinary purposes

D. Villani[1,2], M. Savi[3], O. Rodrigues Jr.[1], M.P.A. Potiens[1] and L. L. Campos[1]

Email: dvillani@ipen.br
[1]Instituto de Pesquisas Energéticas e Nucleares – IPEN/USP. Prof. Lineu Prestes Avenue 2242, São Paulo, Brazil,
[2]Photo Injector Test Facility – PITZ, Deutsches Elektronen-Synchrotron DESY. Platanenallee 6, 15738 Zeuthen, Germany.
[3]Instituto Federal de Educação, Ciência e Tecnologia de Santa Catarina – IFSC. Mauro Ramos Avenue 950, Florianópolis, Brazil.

Introduction

The application of the 3D printing technique for the development of low-cost phantoms is being investigated recently and requires a complex study of the interaction of printed materials with different types and qualities of radiation, as well as the characterization of printing filaments to correctly simulate human tissue. This study aims to present the Computed Tomography (CT) Imaging analysis of a fused filament fabrication (FFF) 3D printed anthropomorphic neck-thyroid phantom.

Methods

In 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 validated 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 imaging study of the phantom was performed through the analysis of images from a CT acquisition, comparing the Hounsfield Units (HU) numbers of the tissues between both phantoms.

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 is a feasible alternative to a tissue-equivalent phantom and 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.

Step-by-step of 3D printing a head-and-neck phantom: proposal of a methodology using fused filament fabrication (FFF) technology

M. Savi[1], D. Villani[2,3], M.A.B Andrade[1], F.A.P Soares[1], O. Rodrigues Jr.[2], L. L. Campos[2] and M.P.A. Potiens[2]

Email: Matheus.savi@ifsc.edu.br
[1]Instituto Federal de Educação, Ciência e Tecnologia de Santa Catarina – IFSC. Mauro Ramos Avenue 950, Florianópolis, Brazil.
[2]Instituto de Pesquisas Energéticas e Nucleares – IPEN/USP. Prof. Lineu Prestes Avenue 2242, São Paulo, Brazil,
[3]Photo Injector Test Facility – PITZ, Deutsches Elektronen-Synchrotron DESY. Platanenallee 6, 15738 Zeuthen, Germany.

Introduction

3D printing has developed and become popular very quickly in the last 10 years. Its use in the health and biomedical applications. Phantoms that mimic the interaction of radiation with the human body have been manufactured for many years with various technologies with great demand in use, however, its availability is restricted, and its cost is high for considering importation taxes and exchange rates in Brazil. Thus, this paper aims to share the step-by-step of 3D printing a head-and-neck phantom using of a fused filament fabrication (FFF) technology.

Methods

For this study, a CIRS 711 Atom Max phantom CT image was used as a basis for the segmentation of the phantom. Radiopaque FFF filaments XCT-0, XCT-A and XCT-C were used to build soft tissue, bone, and dental enamel respectively. The phantom's design and segmentation were performed using the "3D Slicer Software", as 58 different 3D models of the slabs of phantom and it was used a GTMaX Pro Core H4 3D printer accoupled with a Mosaic Pallet multimaterial and Simplify3D software to print the phantom. An imaging analysis was then performed in order to compare the original CIRS 711 Atom phantom and the 3D printed.

Results

The proposed methodology of this study shows possibility of use of tomographic images of any objects, or even patients, to perform 3D prototyping of increasingly specific and customized phantoms. The phantom imaging comparison show great results on using FFF filaments to mimic the main human tissues of the head-and-neck region.

Conclusions

This methodology represents a feasible alternative to develop CT tissue-equivalent phantoms with the desirable characteristics for radiation technology and biomedical applications. In addition, the developed phantom is cost-effective and can be obtained with around 10% of the budget of a commercially available phantom.