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Density comparison of 3D printing materials and the human body

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ABSTRACT

Introduction: Phantoms are commonly used for teaching and radiation dosimetry as a simulator of the human body in order that no individual be exposed to radiation during training and research. Some are the properties that can be used as a measurement parameter in a phantom: density, energy compatibility, attenuation and scattering of the radiation, anthropomorphism, among others. 3D printing has revolutionized many areas of knowledge, including those that make use of radiations. In this context, this study aims to evaluate the density of various materials applied in 3D printing and compare found values with human body density in ICRP 110. Methods: Cubes with 2cm edges were printed on 12 materials of different compositions with internal filling of 60 %, 80% and 100%, weighed on a precision balance and measured with a caliper. Results: The densities found ranged from 0,575 g/cm³ to 2,624 g/cm³ for 60% infill, 0,686 g/cm³ to 3,091 g/cm³ for 80% and 0,794 g/cm³ to 3,572 g/cm³ for 100%. Densities related to teeth, bones, muscles, fat, among others, could be created from specific infill variations. Conclusion: All analyzed materials have the capacity to mimic the structures described in ICRP 110 when the percentage of filling are varied. However, even achieving human tissue density the materials may be not adequate for attenuation and require further experiments.

Keywords: Radiologic Phantom, 3D Printing, Radiation Protection.

1. INTRODUCTION

Phantoms are commonly used for teaching and radiation dosimetry as a simulator of the human body in order that no individual be exposed to radiation during training and research. Some are the properties that can be used as a measurement parameter in a phantom: density, energy compatibility, attenuation and scattering of the radiation, anthropomorphism, among others. 3D printing has revolutionized many areas of knowledge, including those that make use of radiations. In this context, this study aims to evaluate the density of various materials applied in 3D printing and compare found values with human body density in ICRP 110.

2. MATERIALS AND METODS

Cubes with 2 cm edges were printed at a Flashforge Creator Pro by means of Simplify 3D printing software, with rectilinear pattern and infill of 60 %, 80% and 100%. After that, the cubes were weighed on a precision balance and measured with a caliper. A total of 12 materials with different compositions were evaluated to find, with a maximum error of 5%, which one could mimic the density of fat, brain, muscle, blood, teeth cortical bone and marrow bone.

3. RESULTS E DISCUSSION

The densities found (Table 1) ranged from 0,575 g/cm³ to 2,624 g/cm³ for 60% infill, 0,686 g/cm³ to 3,091 g/cm³ for 80% and 0,794 g/cm³ to 3,572 g/cm³ for 100%.

Table 1: Material Densities

	Materials tested											
Infill	**ABS**	**Al**	**BRO**	**Cu**	**HIPS**	**PETG**	**PLA**	**PVA**	**SILK**	**TPE**	**W**	**WOOD**
60%	0,684	0,803	0,857	0,779	0,666	0,772	0,759	0,778	0,861	0,575	2,624	0,807
80%	0,798	0,859	1,040	0,947	0,794	0,915	0,920	0,912	1,046	0,686	3,091	0,967
100%	0,911	0,987	1,197	1,127	0,926	1,057	1,184	1,050	1,184	0,794	3,587	1,076

Al:ABS+Aluminum; Bi:ABS+Bismuth, BRO:ABS+Bronze; Cu:ABS+Copper; W:ABS+Tungsten

When compared with the main common tissues of ICRP 110, it is possible to affirm that the materials could imitate almost perfectly the density of the tissues, except for cortical bone (Table 2). However, although the value of the cortical bone was not found with the studied percentages, it can be achieved by creating the curve equation of density, which makes the value of 31% of tungsten infill represents the required bone value of 1,922 g/cm^3.

Table 2: Best mimic density results

Tissue	Comparison				
	Material	**Infill (%)**	**Error (%)**	**Material Density (g/cm³)**	**Tissue Density (g/cm³)**
Blood	PETG	100	1	1,057	1,060
Liver	PVA	100	1	1,050	1,050
Brain	PVA	100	1	1,050	1,050
Muscle	PVA	100	1	1,050	1,050
Fat	Copper	80	1	0,95	0,947
Teeth	Tungsten	60	5	2,624	2,750
Cortical Bone	-	-	-	-	1,920
Marrow Bone	Aluminum	100	1	0,980	0,987

4. CONCLUSION

All analyzed materials have the capacity to mimic the structures described in ICRP 110 when the percentage of filling are varied. Densities related to teeth, bones, muscles, fat, among others, could be created from specific infill variations. However, even achieving human tissue density the materials may be not adequate for x-ray attenuation and require further experiments.

5. ACKNOWLEDGMENT

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REFERENCES

1. ICRP - International Commission on Radiological Protection. **Publication 110: Adult Reference Computational Phantoms**. Vol. 39, Is. 2, p 1-1668, 2009.