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ADITIVE
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1st INTERNATIONAL CONGRESS ON ADDITIVE MANUFACTURING

BOOK OF ABSTRACTS

IWAM 22

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INSTITUTO POLITÉCNICO
DE BRAGANÇA

SEPTEMBER 30, 2022

1ST INTERNATIONAL CONGRESS

ON

ADDITIVE MANUFACTURING

BOOK OF ABSTRACTS

IWAM 22

Bragança - Portugal

September 2022

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Instituto Politécnico de Bragança 2022

Campus de Santa Apolónia

5300-253 Bragança - Portugal

ISBN: 978-972-745-310-8

http://hdl.handle.net/10198/23947

Book cover: Jorge Santos, Instituto Politécnico de Bragança

Technical Support: Clarisse Pais, Instituto Politécnico de Bragança

WELCOME

Additive manufacturing technologies are playing a decisive role in the laboratory environment, making a significant difference in STEAM education. Students use additive manufacturing to create physical models, topographic maps, biology artifacts, artwork, all types of engineering prototypes and solving mathematics challenges. By bringing additive manufacturing capabilities to the classroom, educators can raise interest in STEAM, introduce new concepts and capabilities, and help set the future for more skilled STEAM professionals.

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Additive manufacturing techniques for the fabrication of intracranial aneurysm biomodels

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ABSTRACT

The hemodynamics of intracranial aneurysm (IA) involves complex phenomena that influence its growth and rupture. The advancement of additive manufacturing techniques allowed the development of biomodels suitable for *in vitro* experimental tests. Thus, we present in this work the process of manufacturing flow biomodels, using different additive manufacturing techniques and materials. The biomodels obtained through these methods proved to be suitable for experiments using imaging techniques and for validation of numerical studies.

INTRODUCTION

Intracranial aneurysm (IA) is one of the most serious cerebrovascular diseases and it is associated with weakening of the arterial wall, which causes local dilation. This pathology has a mortality rate of 60% after rupture and a dependency rate of 40% (Amenta et al., 2012). The cause of the development and rupture of IAs is still not well understood, being related to simultaneous physical and biological factors (Tromp, Weinsheimer, Ronkainen, & Kuivaniemi, 2014). Therefore, to better understand IAs, it is important to analyze the local hemodynamic, and how it affects the vessel wall (Saqr et al., 2019).

As *in vivo* studies are expensive and difficult to perform, the *in vitro* study using flow biomodels proved to be a reliable method to study IA hemodynamic. In this work, the fabrication of phantom flow biomodels is presented, using two different additive manufacturing techniques: Fused Deposition Modeling (FDM) and Masked Stereolithography Apparatus (MSLA). 3D printing with the FDM technique builds parts layer by layer by depositing the filament (molten material) on a path, while MSLA printers use an LCD screen to project the image as an ultraviolet backlight that is cast as a shadow on the resin. This last technique has the advantage of curing the entire resin layer at once.

RESULTS

The two manufacturing processes of the biomodels (FDM and MSLA) are shown in Figures 1 and 2, respectively.

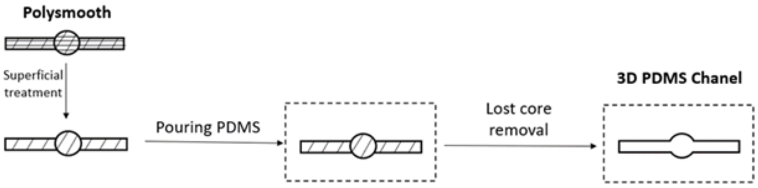

Figure 6: FDM manufacturing process.

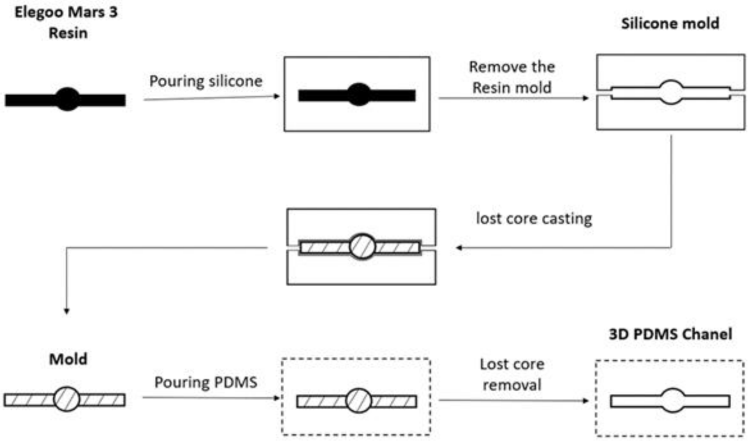

Figure 2: MSLA manufacturing process.

Using the FDM technique, the model used as the lost core was printed on the Ultimaker 3 printer with PolySmooth filament. After obtaining the model, it was positioned in the Polysher machine to perform a surface treatment with isopropyl alcohol. With the surface treatment completed, the model was placed in an acetate box and then the PDMS was poured by gravity over the model. PDMS was prepared in a ratio of 10:1 and its curing process took place in 48 hours. After the PDMS had completely cured, the lost core material was removed with isopropyl alcohol. The final PDMS biomodel is shown in Figure 3 (a).

In the manufacturing process using the MSLA technique, the Elegoo MARS 3 printer was used. Initially, the mold was produced in resin. It was then used for the manufacture of the bipartite silicone mold, which is used to model the lost core material (glycerin-based soap). After obtaining the lost core in glycerin soap, it was placed in the acetate box, and the PDMS was then poured by gravity over the lost core. After PDMS cured, the lost core was removed with water. The final biomodel image is shown in Figure 3 (b).

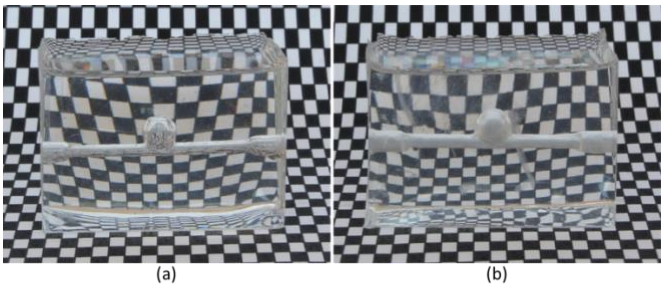
(a) (b)

Figure 7: Final biomodels in PDMS, using the MA techniques: (a) FDM and (b) MSLA.

To validate the biomodels, a flow visualization test was performed. The system used was an inverted microscope (IX71, Olympus, Japan), a high-speed camera (Photron

FASTCAM SA3) and an objective lens (ZEISS, 2.5 ×). The fluid used in the tests was a mixture of 61% glycerol and 39% distilled water (w/w) and 0.1% suspended particles of Polymethylmethacrylate (PMMA). Figure 4 shows visualization of the fluid in the biomodel obtained by FMD printing technique.

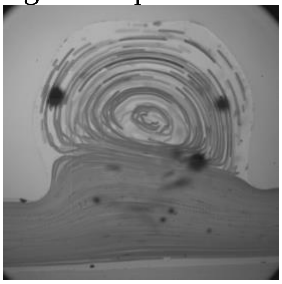

Figura 4: Flow test – 10 ml/min.

CONCLUSIONS

In this study, the results obtained demonstrate that the PolySmooth material using the FDM printing technique proved to be suitable for the manufacture of biomodels, with good dimension accuracy, roughness, good visualization and ease of removal of the material from the lumen. The MSLA technique using resin and glycerin soap, although presenting the same advantages as the previous technique, has the disadvantage of requiring manual work during its manufacturing process.

ACKNOWLEDGMENTS

The authors acknowledge the financial support provided by Fundação para a Ciência e a Tecnologia (FCT), through the projects EXPL/EME-EME/0732/2021, PTDC/EEI-EEE/2846/2021, funded by NORTE 2020, PORTUGAL2020, and FEDER. This work was also supported by Fundação para a Ciência e a Tecnologia (FCT) under the strategic grants UIDB/04077/2020, UIDB/00690/2020, UIDB/04436/2020 and UIDB/00532/2020. Andrews Souza acknowledges the PhD scholarship 2021.07961.BD attributed by FCT. Partial support from the Junta de Extremadura through Grants No. GR21091 and IB20105 (partially financed by FEDER funds) is gratefully acknowledged.

REFERENCES

Amenta, P. S., Yadla, S., Campbell, P. G., Maltenfort, M. G., Dey, S., Ghosh, S., … Jabbour, P. M. (2012). Analysis of nonmodifiable risk factors for intracranial aneurysm rupture in a large, retrospective cohort. *Neurosurgery*, *70*(3), 693–701. https://doi.org/10.1227/neu.0b013e3182354d68

Saqr, K. M., Rashad, S., Tupin, S., Niizuma, K., Hassan, T., Tominaga, T., & Ohta, M. (2019). What does computational fluid dynamics tell us about intracranial aneurysms? A meta-analysis and critical review. *Journal of Cerebral Blood Flow and Metabolism*, *40*(5), 1021–1039. https://doi.org/10.1177/0271678X19854640

Tromp, G., Weinsheimer, S., Ronkainen, A., & Kuivaniemi, H. (2014). Molecular basis and genetic predisposition to intracranial aneurysm. *Annals of Medicine*, *46*(8), 597–606. https://doi.org/10.3109/07853890.2014.949299