Abstract Template

Title: 5D printing of nano-laden fibre aerogel

Foresti R[1, 2], Rossi S[1, 2]

[1]Department of Medicine and Surgery, University of Parma, Parma, Italy
[2]CERT, Center of Excellence for Toxicological Research, Parma, Italy

Keywords: 5D printing, Composite biomaterial, Bio-composite manufacturing process, Nanoparticles (NPs)

I. Abstract Body

The organs functionality and the related material mimicry properties (Kokkinis) are difficult to reproduce. The smart design and reconstruction processes (Avventuroso; Wu) requires the material functionalization and engineering. To overcame these problems, we merged the composite biomaterials (Guarino; Milazzo) properties with the bio-composite manufacturing processes (Foresti). In fact, the composite biomaterial can modulate its properties with nanoparticles and the resulted bio-ink can be used for the fabrication of the fibre, the adhesive interface and the coating matrix of a bio-composite material. For example, with a flexible fibre covered with an adhesive coating (impermeable and unable to improve the cells adherence, avoiding occlusion problems) it is possible to develop a functional vessel (Hajal).
We reconstructed a femoral peripheral artery bifurcation utilising a patient morphology CT, obtaining a full customisable 5D printed object (Gillaspie). The resulted digital model was used to realise, with a custom made RFP bioprinter (Ozbolat), a sodium alginate-based (enriched with green fluorescent NPs) coating balloon gelled with EtOH, dehydrated (nano-laden fibre aerogel) and tested *in-vitro*. Furthermore, *in-vivo* tests (Fig. 1) with the bio-composite device demonstrated the uniform gradual release and a very short dissolution time (~ 2/3 minutes).
Thus, digitalising the object we can realise 5D printed devices with hard and/or soft material (engineering parameters, functional activity and biological interaction). Moreover, using different bio-composite material, merged with the patient morphology, it is possible to implement a synthetic organ for preliminary tests and training.

II. Image:

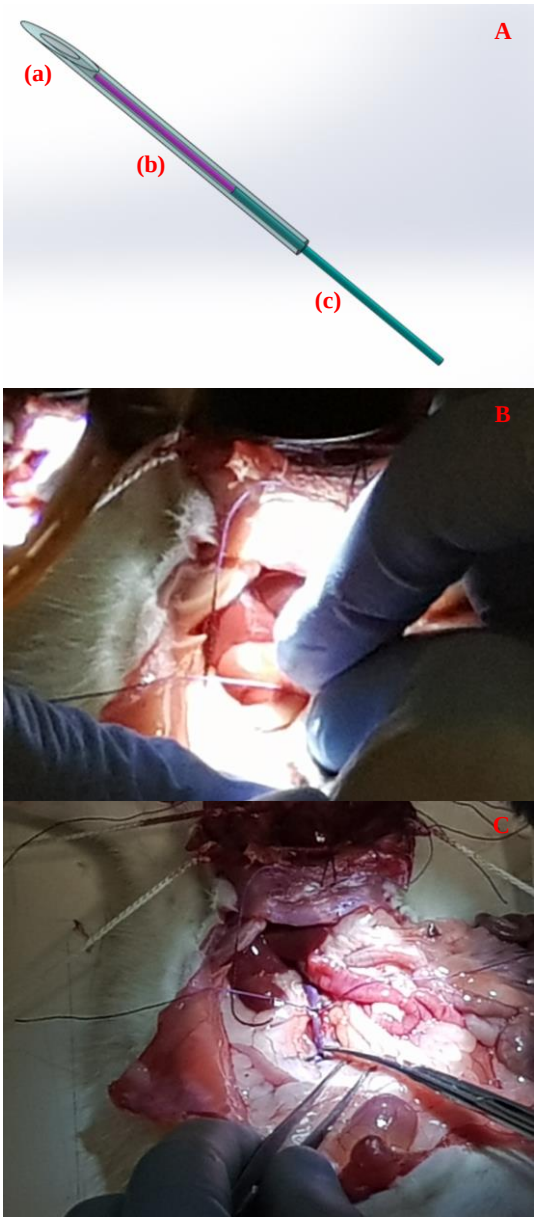


Figure 1: *In-vivo* operative process for nano-laden bioprinted device insertion. A: Mechanical devices for the insertion. (a): Angiocath 14G, 40mm length (transparent). (b): Nano-laden fibre aerogel (violet). (c): Piston for nano-laden aerogel insertion in vena cava (blue). B: Detail of vena cava clamping. C: Detail of vena cava section for the insertion of the nano-laden bioprinted device.

III. Reference:

1. Kokkinis, D., Schaffner, M., Studart, A.R., 2015. Multimaterial magnetically assisted 3D printing of composite materials. Nat. Commun. 6. https://doi.org/10.1038/ncomms9643

2. Avventuroso, G., Foresti, R., Silvestri, M., Frazzon, E.M., 2018. Production paradigms for additive manufacturing systems: A simulation-based analysis, in: 2017 International Conference on Engineering, Technology and Innovation: Engineering, Technology and Innovation Management Beyond 2020: New Challenges, New Approaches, ICE/ITMC 2017 - Proceedings. https://doi.org/10.1109/ICE.2017.8279987

3. Wu, Z., Su, X., Xu, Y., Kong, B., Sun, W., Mi, S., 2016. Bioprinting three-dimensional cell-laden tissue constructs with controllable degradation. Sci. Rep. 6. https://doi.org/10.1038/srep24474

4. Guarino, V., Scaglione, S., Sandri, M., Sprio, S., Tampieri, A., Ambrosio, L., 2019. Composite scaffolds for bone and osteochondral defects, Materials for Biomedical Engineering. Elsevier Inc. https://doi.org/10.1016/b978-0-12-816901-8.00010-9

5. Milazzo, M., Contessi Negrini, N., Scialla, S., Marelli, B., Farè, S., Danti, S., Buehler, M.J., 2019. Additive Manufacturing Approaches for Hydroxyapatite-Reinforced Composites. Adv. Funct. Mater. 1903055, 1–26. https://doi.org/10.1002/adfm.201903055

6. Foresti, R., Rossi, S., Selleri, S., n.d. Bio-composite materials : nano-functionalization of 4D bio-engineered scaffold, in: The 4th International Conference on Biophotonics - BioPhotonics 2019. Taipei, Taiwan., p. Paper T4.3.

7. Hajal, C., Campisi, M., Mattu, C., Chiono, V., Kamm, R.D., 2018. In vitro models of molecular and nano-particle transport across the blood-brain barrier. Biomicrofluidics 12. https://doi.org/10.1063/1.5027118

8. Gillaspie, E.A., Matsumoto, J.S., Morris, N.E., Downey, R.J., Shen, K.R., Allen, M.S., Blackmon, S.H., 2016. From 3-Dimensional Printing to 5-Dimensional Printing: Enhancing Thoracic Surgical Planning and Resection of Complex Tumors. Ann. Thorac. Surg. 101, 1958–1962. https://doi.org/10.1016/j.athoracsur.2015.12.075

9. Ozbolat, I.T., Hospodiuk, M., 2016. Current advances and future perspectives in extrusion-based bioprinting. Biomaterials 76, 321–343. https://doi.org/10.1016/j.biomaterials.2015.10.076

Biography:

Ph.D. Ruben Foresti Postdoctoral Researcher in applied medical technical sciences at University of Parma. Research field addressed in 3D, 4D and 5D processes for digital fabrication of biomedical devices and customized scaffolds. PhD in Industrial Engineering at University of Parma. Design and implementation of additive manufacturing systems for biomedical and food applications, including software and 3D model design. Expertise in rapid prototyping of automated systems with remote control including the design and the software development, electrical parts and mobile application. MSc. in Engineering Management and BSc. in Electronics Engineering. Co-founders of M3datek, academic spinoff.

Ph.D. Stefano Rossi. He obtained is Ph.D in 2006 at University of Parma and he spent one year at the CVRTI, University of Utah. Dr. Rossi' expertise is focused on in-vivo cardiac physiology and arrhythmia. He currently collaborates in several project, in particular related to nanotoxicology and nanomedice. He is author of 31 indexed publication, h index=13 and reviewer for several international journal. He was awarded with the Kenichi Harumi Young Investigator's Award 2006 at the International Congress on Electrocardiology. He is member of the Italian Society of Cardiovascular Research, European Society of Cardiology (WG in cellular electrophysiology).

IV. Presenting author details



Full Name: Ruben Foresti
Contact number: +39 3472476425
E-mail: ruben.foresti@gmail.com
LinkedIn account: https://www.linkedin.com/in/ruben-foresti-b110b3a4/
Session name/ number: Applications of 3D Printing in Health Care & Medicine
Category: Oral presentation

V. Acknowledgments

We do thank CSEIA (Center for Studies in European and International Affairs), University of Parma, for the award assigned to R.F and S.R: CSEIA 2018 Open-Up Outgoing Publications grant.