frontiers | Frontiers in Medical Engineering

TYPE Specialty Grand Challenge
PUBLISHED 31 March 2023
DOI 10.3389/fmede.2023.1101299

OPEN ACCESS

EDITED AND REVIEWED BY
Dominique P. Pioletti,
Swiss Federal Institute of Technology Lausanne, Switzerland

*CORRESPONDENCE
Chiara Tonda-Turo,
chiara.tondaturo@polito.it

SPECIALTY SECTION
This article was submitted to Medical Engineering Technologies, a section of the journal Frontiers in Medical Engineering

RECEIVED 17 November 2022
ACCEPTED 04 January 2023
PUBLISHED 31 March 2023

CITATION
Tonda-Turo C (2023), Frontiers in medical engineering section in medical engineering technologies specialty grand challenge.
Front. Med. Eng. 1:1101299.
doi: 10.3389/fmede.2023.1101299

Frontiers in medical engineering section in medical engineering technologies specialty grand challenge

Chiara Tonda-Turo*

Politecnico di Torino, Turin, Italy

KEYWORDS

bioprinting, medical engineering technologies, organ-on-chip (OoC), nanomedicine, prosthesis, bioelectronic devices

Advanced technologies have been progressively introduced in medicine to tackle biological and clinical unmet needs thus improving pathologies outcomes and patient quality of life. In the last decades, medical engineering technologies have been rapidly grown showing a significant boom in both academia and industrial sector (CAGR 19% in 2021). Medical engineers, also called as biomedical engineers, deal with the design and development of several medical engineering technologies such prostheses, sensors and biosensors, nanocarriers, smart surfaces, fabrication processes, advanced therapies. Innovation in medical engineering technologies has been accelerated in the last years mainly thanks to the increased sharing of knowledge and expertise among researchers working in cutting-edge disciplines. Indeed, the intrinsic multidisciplinary nature of medical engineering technologies required trans-discipline and trans-sector approches to foster a step forward in developing breakthrough technologies.

Current trends in the design of medical engineering technologies aim to better understand biological mechanisms applying multiscale methodologies and to achieve personalized medicine and patient-tailor medical devices using advanced technologies.

Nowadays, Frontier biofabrication technologies and *in vitro* models as the Organ-On-Chip (OoC) have emerged for their capabilities in reassembling the structures, the microanatomy and the specific human biological milieus (Celikkin et al., 2021; Monteiro et al., 2022). In this scenario, additive manufacturing (AM) is recognized as a versatile technology to create complex tridimensional geometries for widespread applications. However, several constraints hinder AM applicability in the development of cellularised biomimetic structures. Indeed, the deposition of sequential layers is highly time-consuming, the design of bioinks is challenging due to the difficulties in combining biocompatibility with proper viscosity of the material and layerwise fabrication approaches reduced the design freedom, as it often requires support structures and consequently a post-process step for their removal, which can potentially alter the 3D structures and/or affect cell viability. Furthermore, despite many studies succeed in producing patient-tailor medical devices and 3D biomimetic structures, the translation of AM products from 'bench to bedside' has not been achieved yet.

Leveraging on novel technologies, drawbacks and limitations of traditional AM methods can be overcame to produce patient-tailor medical devices and 3D cellularized biomimetic structures in a fast and reproducible manner also reducing the gap to clinics.

Among others, tomographic volumetric additive manufacturing is potentially suitable for the ultrafast fabrication of advanced and functional constructs improving the similarities of artificial structures to anatomy and multicellular compositions of tissues and organs using a single step process (Loterie et al., 2020). Alternatively, tissues morphogenesis can be forced *in situ* through the recently proposed sound induced morphogenesis (SIM) which creates spatial patterns of cells or cell aggregates (organoids, spheroids) using acoustic waves, reaching a

physiologically-relevant tissue generation under contactless, fast and mild culture conditions (Petta et al., 2021).

Furthermore, another common issue which affects the development of novel strategies to treat organ impairments and pathological tissues is related to the validation models currently available. In this contest, animal models have been the gold standards to understand mechanism inducing pathologies progressions and to tests new drugs. However, these models showed low fidelity in reproducing human conditions and often fail in the reproduction of specific human biological milieus, with consequent incapability to predict human response. Human tissue experimental models hold great potential in achieving more effective mimesis of the human environment without posing ethic concerns. Models obtained with approaches borrowed from the tissue engineering field allow a superior replica of the *in vitro* 3D architecture, mechanical properties and composition of the *in vivo* microenvironment than 2D culture systems, heterotypic 3D spheroids and patient-derived organoids, which are currently the state-of-the-art for *in vitro* biological studies and drug testing described in the literature or available on the market.

Therefore, physiological *in vitro* experimental models and organ-on-chip (OoC) platforms have been recently introduced as an alternative to state-of-the-art approches. These platforms have the unique potential to combine the features of the experimental organ models with physiological or pathological stimuli and flow conditions, with the final goal of recapitulating the complex human physiology *in vitro* (Rodrigues et al., 2021; Leung et al., 2022). Unfortunately, a full exploitation of the potential of such a breakthrough technology is far from being achieved, and medium-scale production, real-time monitoring, reproducibility, and proper validation methods are still needed.

In clinics, a deeper understanding of the biological mechanisms influencing pathologies progression and therapeutic efficacy at multiscale level is pivotal for the identification of new biomarkers and the establishment of screening tests, in order to enable an earlier detection of pathological hallmarks thus improving the prognosis as well as to steer impairment repair in poorly regenerative tissues (e.g. cardiac tissue, neural tissues) which remains an unsolved clinical need, so far.

In this scenario, the availability of new platforms able to emulate the biological environments *in vitro* have a direct impact on the development of patient-tailor medical devices and personalized treatments introducing a novel paradigm in the pipeline of preclinical screening and a more efficient designed of prosthesis and drug carriers. For instance, the use of engineering technologies at the nanoscale for diagnosis, delivery, sensing or actuation purposes in a living organism has led to nanomedicine and nanotheranostic. These new approaches rely on both well-established biological knowledge and biologically-relevant platforms to tailor nanoscale systems, thus testing their ability to trigger specific pathways inside the cells for achieving the clinical purposes (Lee et al., 2020).

In the last years, several engineering technologies have contributed to improve the cure and the prevention of diseases reaching novel insights in medicine. Indeed, concerning diagnosis, highly sensitive biosensors can improve biomarkers detection in order to enable an earlier detection of pathological situations thus improving the prognosis (Haleem et al., 2021).

Moreover, progresses in miniaturization and low-weight materials have encouraged the development of wearable, implantable, and the ingestible bioelectronic devices which are becoming key technologies to enhance rehabilitation fostering localized tissue stimulation (Demolder et al., 2021) as well as allowing an *in-situ* pathology monitoring (Wang et al., 2022). In addition, bioelectronics devices can be integrated inside prothesis, implantable devices and experimental *in vitro* models to improve their biomimicky by reproducing the electrical cues found in tissues and organs (Soares dos Santos and Bernardo, 2022). Alongside, the integration of biosensors and actuators within cell culture systems have contributed to technological progress in bioreactors design satisfying the needs of long-term culture, clinical-grade cell expansion and efficient tissue maturation *ex vivo* (Massai et al., 2020; Wang et al., 2020).

It is now clear that progresses in medicine are strongly committed to progresses in technical disciplines which provide new tools and complementary knowledge. For these reasons, current research focusing on advanced medical engineering technologies are strongly encouraged as novel insights in medicine can be achieved by means of technological breakthroughs to make a step forward in prognosis outcomes and patient quality of life.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Celikkin, N., Presutti, D., Maiullari, F., Fornetti, E., Agarwal, T., Paradiso, A., et al. (2021). Tackling current biomedical challenges with frontier biofabrication and organ-on-A-chip technologies. *Front. Bioeng. Biotechnol.* 9, 732130. doi:10.3389/fbioe.2021.732130

Demolder, C., Molina, A., Hammond, F. L., and Yeo, W. H. (2021). Recent advances in wearable biosensing gloves and sensory feedback biosystems for enhancing rehabilitation, prostheses, healthcare, and virtual reality. *Biosens. Bioelectron.* 190, 113443. doi:10.1016/j.bios.2021.113443

Haleem, A., Javaid, M., Singh, R. P., Suman, R., and Rab, S. (2021). Biosensors applications in medical field: A brief review. *Sensors Int.* 2, 100100. doi:10.1016/j.sintl.2021.100100

Lee, S. W. L., Campisi, M., Osaki, T., Possenti, L., Mattu, C., Adriani, G., et al. (2020). Modeling nanocarrier transport across a 3D *in vitro* human blood-brain–barrier microvasculature. *Adv. Healthc. Mater.* 9, 1901486. doi:10.1002/adhm.201901486

Leung, C. M., de Haan, P., Ronaldson-Bouchard, K., Kim, G. A., Ko, J., Rho, H. S., et al. (2022). A guide to the organ-on-a-chip. *Nat. Rev. Methods Prim.* 2, 33. doi:10.1038/s43586-022-00118-6

Loterie, D., Delrot, P., and Moser, C. (2020). High-resolution tomographic volumetric additive manufacturing. *Nat. Commun.* 11, 852. doi:10.1038/s41467-020-14630-4

Massai, D., Pisani, G., Isu, G., Rodriguez Ruiz, A., Cerino, G., Galluzzi, R., et al. (2020). Bioreactor platform for biomimetic culture and *in situ* monitoring of the mechanical response of *in vitro* engineered models of cardiac tissue. *Front. Bioeng. Biotechnol.* 8, 733. doi:10.3389/fbioe.2020.00733

Monteiro, M. v., Ferreira, L. P., Rocha, M., Gaspar, V. M., and Mano, J. F. (2022). Advances in bioengineering pancreatic tumor-stroma physiomimetic Biomodels. *Biomaterials* 287. doi:10.1016/j.biomaterials.2022.121653

Petta, D., Basoli, V., Pellicciotta, D., Tognato, R., Barcik, J., Arrigoni, C., et al. (2021). Sound-induced morphogenesis of multicellular systems for rapid orchestration of vascular networks. *Biofabrication* 13, 015004. doi:10.1088/1758-5090/abbb9c

Rodrigues, J., Heinrich, M. A., Teixeira, L. M., and Prakash, J. (2021). 3D *in vitro* model (R)evolution: Unveiling tumor–stroma interactions. *Trends Cancer* 7, 249–264. doi:10.1016/j.trecan.2020.10.009

Soares dos Santos, M. P., and Bernardo, R. M. C. (2022). Bioelectronic multifunctional bone implants: Recent trends. *Bioelectron. Med.* 8, 15. doi:10.1186/s42234-022-00097-9

Wang, B., Wang, Z., Chen, T., and Zhao, X. (2020). Development of novel bioreactor control systems based on smart sensors and actuators. *Front. Bioeng. Biotechnol.* 8, 7. doi:10.3389/fbioe.2020.00007

Wang, M., Yang, Y., Min, J., Song, Y., Tu, J., Mukasa, D., et al. (2022). A wearable electrochemical biosensor for the monitoring of metabolites and nutrients. *Nat. Biomed. Eng.* 6, 1225–1235. doi:10.1038/s41551-022-00916-z