ULST Timisoara

Multidisciplinary Conference on Sustainable Development

15-16 May, 2025

From 3D print to functional implant: Engineering a PLA-based trachea

D. Iakovou*, S. Matsia, A. Salifoglou

Laboratory of Inorganic Chemistry and Advanced Materials, School of Chemical Engineering, Aristotle University of Thessaloniki, Thessaloniki 54124, Greece

E-mail: iakovoud@cheng.auth.gr

Abstract: The trachea is essential for breathing, filtering, and warming air. Any damage to it can be life-threatening. While traditional surgical repairs are being implemented, complex cases often require reconstruction. Advances in 3D printing now allow for custom, patient-specific tracheal grafts. Polylactic acid (PLA) is a preferred material for such cases, due to its biocompatibility, biodegradability, and strength. Enhancing PLA scaffolds with natural biopolymer coatings improves their compatibility and function, rendering them more suitable for surgical implantation and integration with body tissue.

Introduction

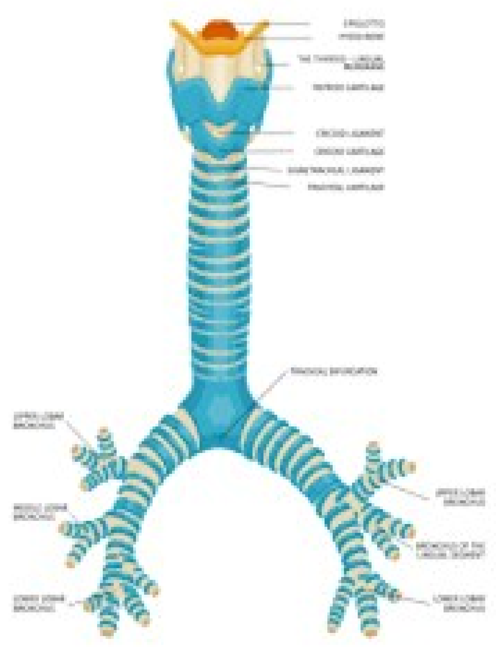


Fig. 1: Trachea Model

Trachea is a vital component of the respiratory system in all air-breathing organisms (**Fig. 1**). Positioned directly in front of the esophagus, it serves as the main conduit that conveys incoming air, while simultaneously warming and filtering it to protect delicate lung tissue. Without a fully functional trachea, the body cannot efficiently exchange gases, turning any disruption to its structure into a potentially life-threatening event.[1]

Pathological damage (**Fig. 2**) to trachea can arise in many forms, with two of the most serious ones involving tracheomalacia and tracheal stenosis.[2,3] Both conditions have seen a notable rise in incidence over recent years, requiring emergency intervention. Traditional surgical repair may involve segmental resection or stenting, but more complex or extensive damage sometimes requires reconstructive surgery to restore airway patency.[4] To that end, reliable trachea models and implants are needed, with 3D printing technologies (**Fig. 3**) playing a crucial role in the process.

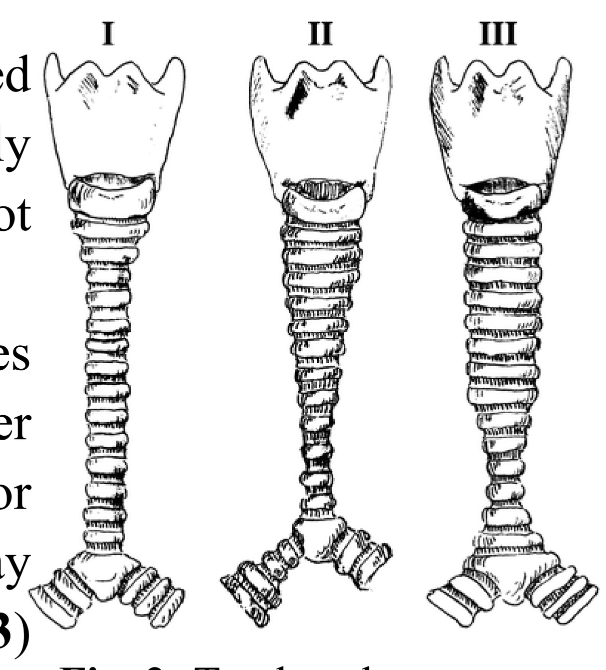


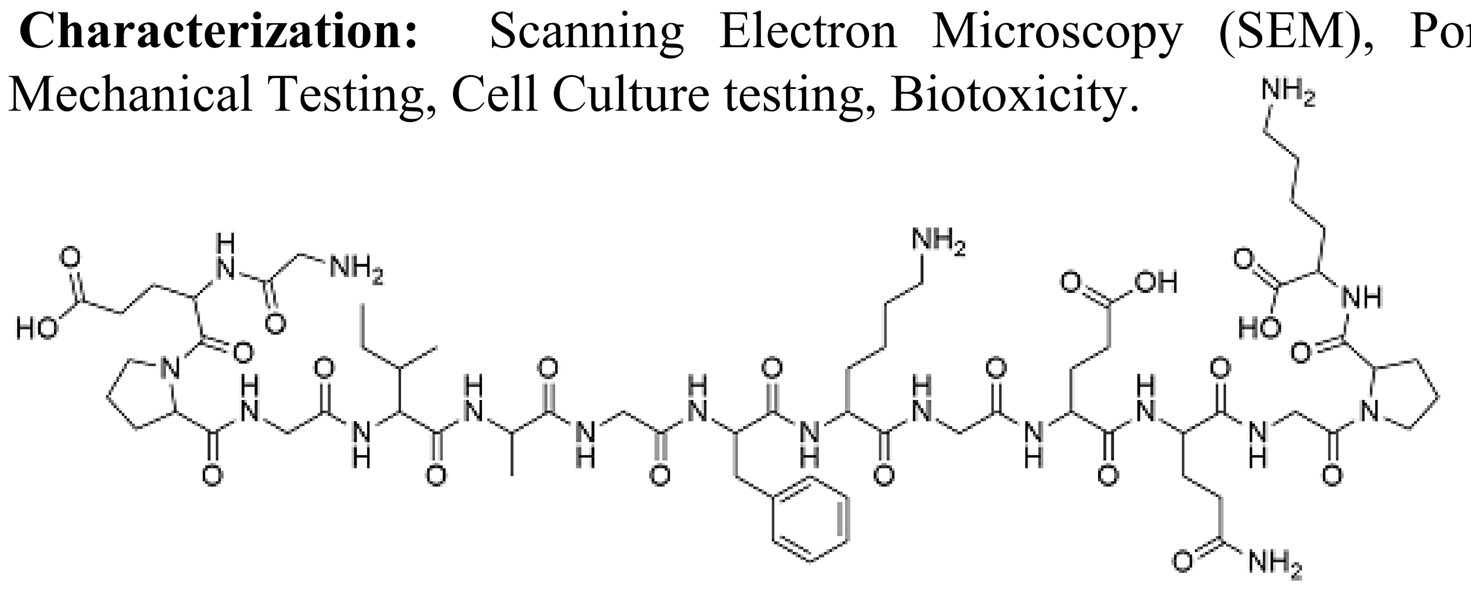
Fig. 2: Trachea damage

Materials and methods

Materials: Polylactic acid (PLA), Chitosan, Collagen.

Printing technique: 3D printing (FDM).

Scaffold Characterization: Scanning Electron Microscopy (SEM), Pore Siz analysis, Mechanical Testing, Cell Culture testing, Biotoxicity.



Collagen

Chitosan

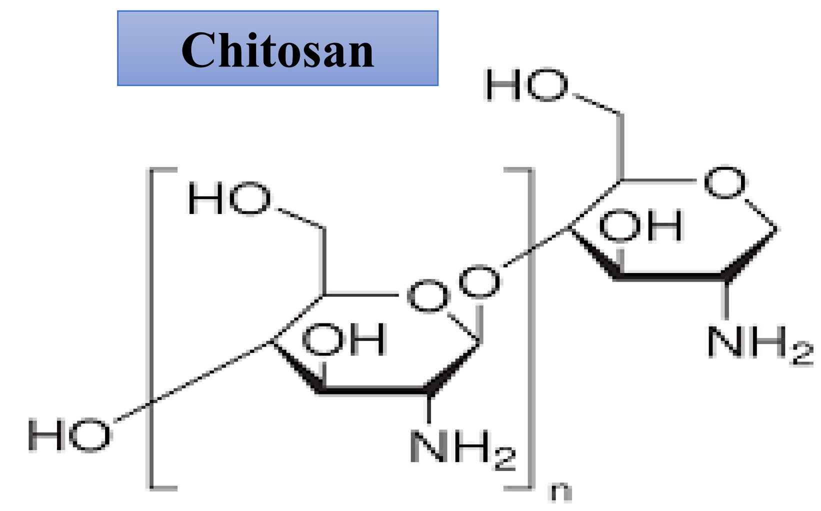


Fig. 3: "Creality Ender V2. Neo" 3D printer

Discussion and Flow Diagram of Trachea Printing

Three-dimensional (3D) printing has matured from a rapid-prototyping tool into a powerful method for producing industrial and biomedical components. By depositing material layer by layer directly from digital blueprints, 3D printing can generate highly intricate structures that perfectly match a patient's unique anatomy. This capability is especially valuable in tracheal reconstruction.[5]

Among the various polymers explored for 3D-printed biomedical scaffolds, polylactic acid (PLA) stands out for its exceptional biocompatibility, ability to biodegrade, and suitability for 3D printing process.[6] 3D-printed PLA scaffolds provide the necessary mechanical strength and anatomical conformity for tracheal replacement.[7] To enhance the biocompatibility and functionality of a 3D-printed PLA-based tracheal graft, a dual-coating strategy is employed, employing natural biopolymers. Collectively, this dual-coating approach (**Fig. 4**) aims to produce a fully biodegradable, biofunctional tracheal graft suitable for surgical implantation, offering improved compatibility with host tissues and enhanced potential for successful in vivo integration.[8]

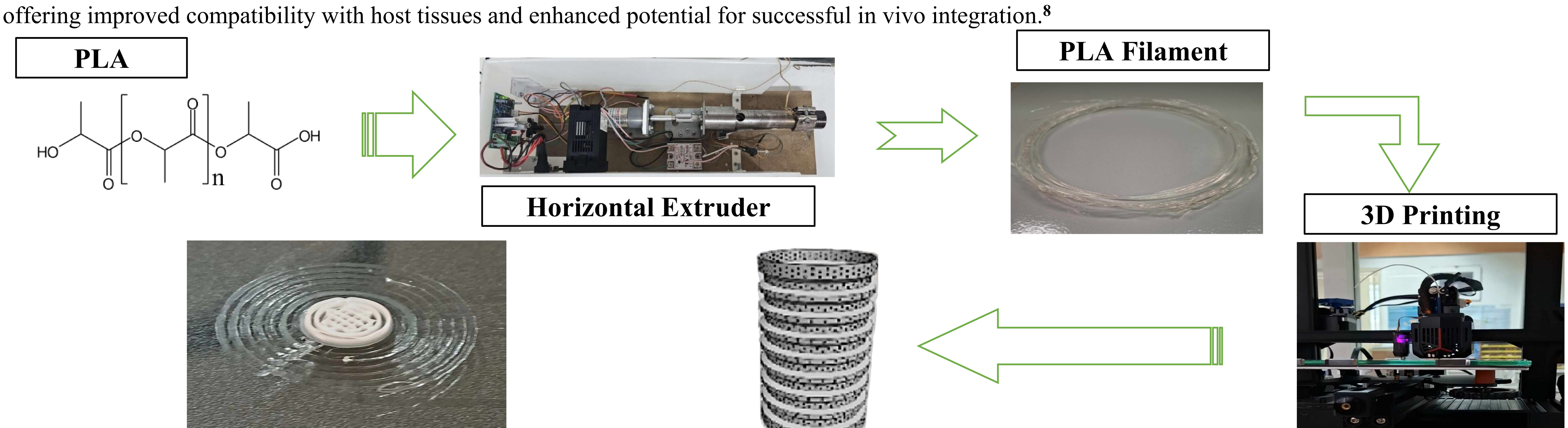


Fig. 4: PLA 3D-Printed scaffold

Conclusions

- 3D Printing enables personalized and precise approaches in airway reconstruction.
- Biodegradable materials can support both function and safety in medical implants.
- PLA offers a sustainable option for creating functional, temporary implants.

Literature

[1]. Forlow P.W., Mathisen J.D., Ann. Cardiothorac Surg. 7(2) (2018), 255-260.
[2]. Blair G.K., Cohen R., Filler R.M., J. Pediatric Surg. 21(9) (1986), 781-785.
[3]. Feng Y.G., Tao S.L., Mei L.Y., et al., Cardiothorac Surg. 18(1) (2023), 293.
[4]. Özdemir C., Kocatürk C.I., et al., Ann. Thorac. Cardiovasc. Surg. 24(6) (2018), 288.
[5]. Bozkurt Y., Karayel E., J. of Mat. Res.Technology, 14 (2021), 1430-1450.
[6]. Alavi M.S., Memarpour S., Pazhohan-Nezhad H., Moghbeli M., Shadmanfar S., Saburi E. Artif. Organs. 47(9) (2023), 1423-1430.
[7]. Khalid T., Soriano L., Lemoine M., et al. Front. Bioeng. Biotechnol. (11) (2023).
[8]. Jalageri M.D., Kanth S., Shetty S.C. J. Polym. Environ. 33(2025), 1216–1231.