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LABORATORY OF INORGANIC CHEMISTRY AND ADVANCED MATERIALS

3D PRINTING IN ORGAN MODELLING AND HUMAN HEALTH

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ABSTRACT

3D Printing technology and advancements through the years have opened new avenues in biomedical engineering, particularly in the treatment of injuries and diseases revolving around invasive and non-invasive therapeutics related to trachea pathologies.[1] Tracheomalacia and stenosis of the human trachea are two of the main pathological conditions leading to breathing problems in humans.[2] An innovative solution to overcome these difficulties is the use of artificial substitutes to replace long-segment narrowed tracheas.[3] The methods used so far for solving such problems involve re-anastomosis leading to complications after surgery. Through tissue engineering and 3D-printing techniques, however, it is possible to design a customized tracheal model with a morphology suitable for patient support of biological and mechanical profiles. In this particular research effort, the design of 3D models of trachea is based on patient-specific tracheal characteristics, thereby producing a model with realistic tissue properties.[4] The approach employs geometrical features of the patient's tracheal structural profile, thus elevating numerical and materials data on those features as priority in the design process. To that end, the initial prototype developed in our Lab was based on data from an actual patient received through Magnetic Resonance Imaging (MRI). The 3D Slicer software program was used to create 3D models in a 3D printable file. Key considerations, such as resolution, layer thickness, and printing techniques, emerge as dominant factors and were taken into consideration in the implementation of the effort, and are discussed to exemplify the accuracy and reliability of the produced tracheal constructs. **4** Furthermore, selection and production of elastomer-like materials and/or embedded organic components was pursued in our Lab and led collectively to a well-configured structural model through 3D printing. Optimization and development of our 3D printed trachea provides a novel and useful tool in tissue engineering, meriting further entry into clinically adapted research for future use in surgical rectification of abnormalities, arisen as a result of tracheal stenotic processes.

INTRODUCTION

The development of this technological field moves at a rapid pace as it focuses on the design of the construct, the form of the material, the function of the cells, the process of the studied species, the planning of the analysis, and the experimental method of the in vivo test.

The trachea starts at the lower edge of the larynx (**Fig. 1**), connects to the left and right main stem bronchi, and is positioned in front of the esophagus. Its primary function is to facilitate the passage of air to and from the lungs. The trachea divides into the mainstem bronchi at a junction called the carina and is composed of 16 to 20 C-shaped cartilage rings, which keep it open. The trachea has four layers: the inner mucosal layer, with mucus-secreting goblet cells and cilia to trap and move debris, the submucosa containing nerves, blood vessels, elastin, and collagen fibers for support and elasticity; a layer of hyaline cartilage to prevent collapse during exhalation; and the outer adventitia that anchors trachea to adjacent tissues. The trachealis muscle allows the trachea to contract, aiding in coughing and swallowing by permitting the esophagus to expand.

This work aims to investigate recent surgical advancements in tracheal reconstruction by assessing the application of synthetic material fabrication for treating tracheomalacia and stenotic conditions, and discussing obstacles that impede these innovations.

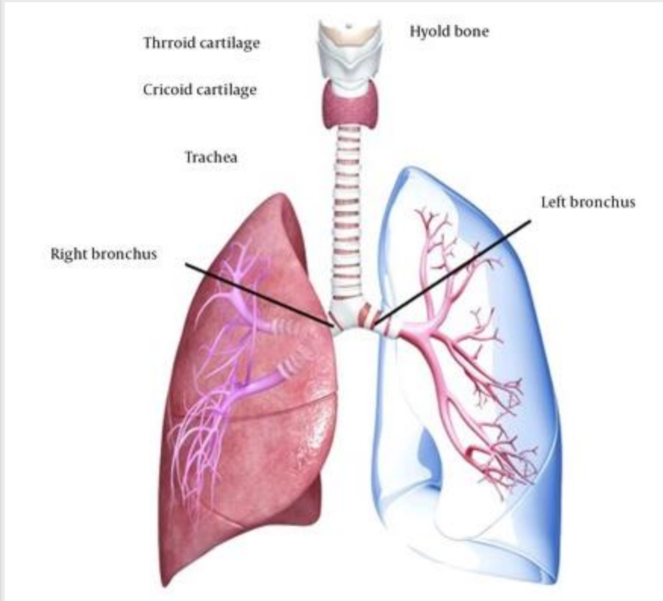
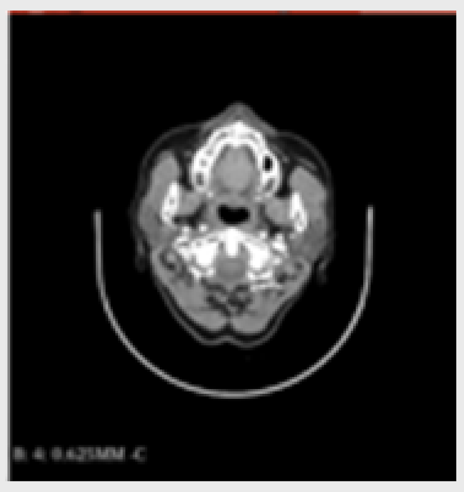


Fig. 1. Anatomy of human trachea

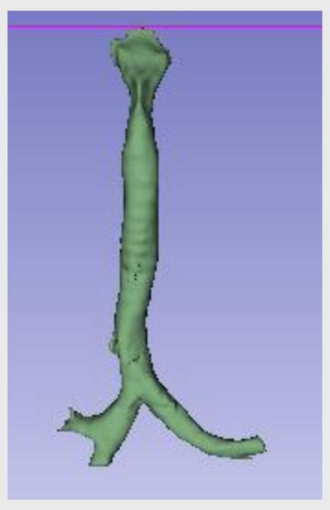
FLOW DIAGRAM OF REAL TRACHEA PRINTING

CT Chest → 3D Slicer → 3D Airway Model → Silicon Conversion



Import CT data into the slicer program

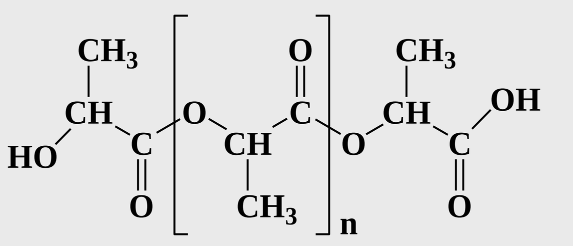
Tool selection with the slicer program



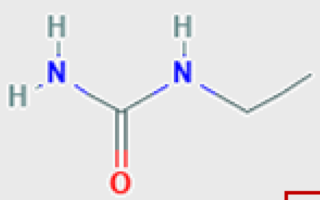
Segmentation of the printed model CT scan

Creating a 3D model with the 3D printing printer

RESULTS

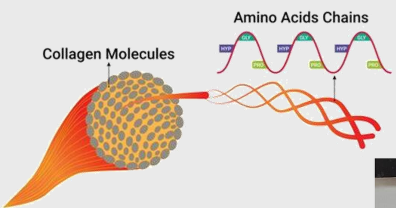


PLA



TPU

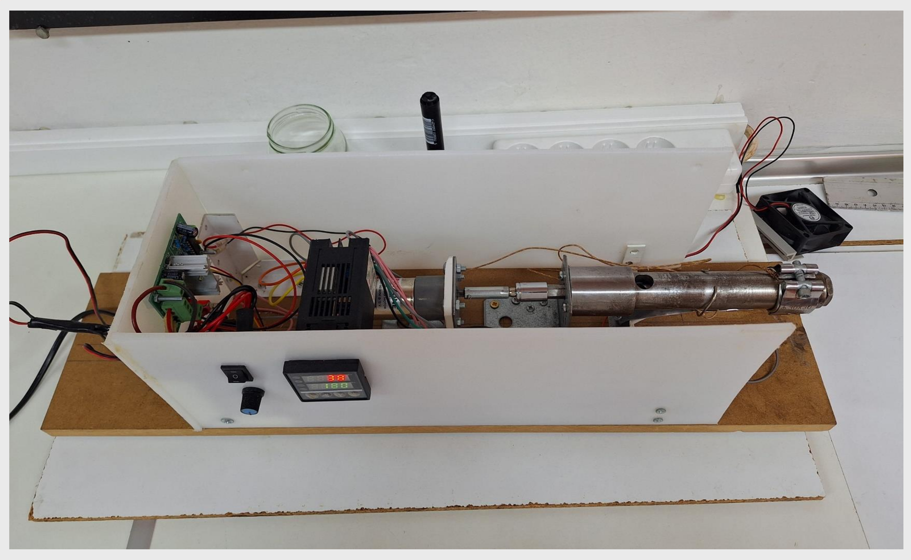
They are printed both alone and together



Enrichment with collagen and castor oil

Solvent casting method

Films



Horizontal extruder

PLA Filament

CONCLUSIONS - FUTURE GOALS

Fabrication of synthetic materials has shown encouraging results in initial studies with small animals. However, to fully explore the applicability of these innovations, research must advance to clinical trials. These trials will evaluate the anatomical and physiological effects on the human body, providing a thorough assessment of post-operative outcomes and any potential complications related to the materials or cells implanted in the trachea.

Enhanced Biocompatibility: Developing materials that are even more biocompatible, reducing the risk of immune reactions and ensuring better integration with the patient's body.

Improved Mechanical Properties: Creating 3D printed tracheas with mechanical properties that closely mimic natural tracheal tissue, ensuring they are strong, flexible, and durable enough to function effectively in the body.

By achieving these goals, 3D printing of tracheas could revolutionize the treatment of tracheal diseases and injuries, providing patients with safer, more effective, and personalized therapeutic options.

REFERENCES

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3. Francik R, Kryczyk J, Krośniak M, Berköz M, Sanocka I, Francik S. (2014). *Scientific World J.* 2014, 847368.
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