TOWARD A NEW PRINTABLE AND CUSTOMIZABLE AIRWAY STENT

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Introduction

Tracheobronchial stents are tubular scaffolds used for enlarging a constricted airway. However, their placement is affected by several clinical problems. These prostheses should be easy to be inserted and eventually removed; they should avoid migration and be biocompatible [1]. Additionally, they should adapt to the airway and possibly be customizable to the patient [2]. In this sense, the three dimensional (3D) printing offers new opportunities that could help the clinics allowing rapid prototyping and fabrication of image-based and patient-specific anatomical shapes [1]. The goal of this work is to simulate and fabricate a new customizable and printable tracheobronchial prosthesis. With this aim, we proposed a parametric numerical tool capable of analysing the importance of each single parameter.

Methods

The baseline stent model created with the in-house tool is shown in Figure 1a and 1b. The outer surface of the tube was designed with an additional upward reinforcing structure that is similar to the typical X-pattern of the metallic stents. The geometry of the stent has been parameterized in order to study the effect of each single geometrical feature on the mechanical properties. Through modulating the different parameters in fact, the radial stiffness and the mechanical strength of the stent can be manipulated. Briefly, the inner radius, the stent thickness, the dimensions of the reinforcing fibres and their orientation can be changed. The in house code produces an input file for Ansys Mechanical (Ansys Inc., Canonsburg, PA, USA) in which the numerical analysis is carried out (Figure 1b).

Results

In Figure 1b, the stiffness of selected prosthesis configurations is compared. The plotted curves illustrate that different radial stiffness can be obtained, modulating the different parameters in which the prosthesis has been designed. For example, for a fixed configuration of the external fibres, the stiffness of the prosthesis with a thickness of 0.75 mm (black line with squares) can be obtained with a reduced thickness of 0.5 mm and a thicker fibre bottom width of 2 mm. Additionally, the same stiffness could be also obtained using a fibre bottom width of 3 mm and a ratio between upper and bottom fibre thickness of 0.5 (green line with triangles). The computational results were validated by means of a parallel experimental work that includes the production of selected stent configurations using the 3D printing technology (Figure 1c and 1d), their compressive test using an Advanced Digital Force Gauge (Mecmesin, Slinfold, UK) and their numerical simulation.

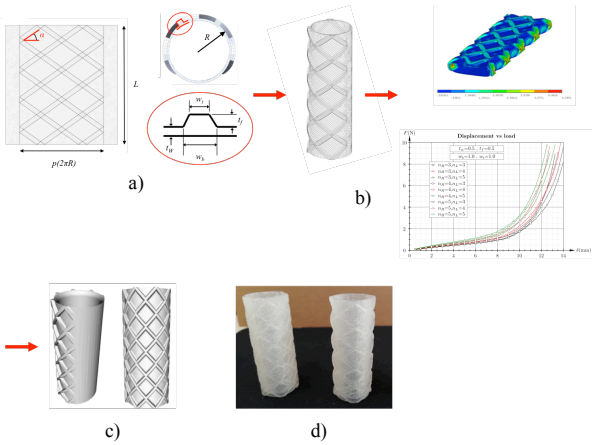

Figure 1: a) and b) baseline model and main parameters; b) numerical analysis for obtaining the mechanical properties; c) optimized geometrical models; d) 3D printed prostheses.

Discussion

Progress towards the customization of commercial airway stents has been made in the recent years. However, the offered personalization is related only to few dimensions under request to the fabricant. In many cases, the use of customized commercial prosthesis could be a good compromise, but frequently this is not sufficient [1]. The methodology proposed in this study offers the possibility of addressing some of these limitations. For instance, the thickness of the stent can be reduced by adequately increasing the external fibres thickness. This aspect has important applications to the stent design, as the obstruction and mucus plugging is one of the more frequent problems after the surgery and it is caused by the thickness of the prosthesis.

References

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Acknowledgements

The authors are supported by grant PID2021-125731OB-C31 from MCIN/AEI/10.13039/501100011033/ and FEDER ('A way to build Europe`).