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A novel 3D additive manufacturing machine to biodegradable stents

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Abstract

Biodegradable stents offer the potential to improve long-term patency rates by providing support just long enough for the artery to heal. However, design a biodegradable structure for an intended period of support is rather difficult. Nowadays in the stent industry the manufacture process par excellence is the laser micro cutting. Nevertheless in the case of polymeric stents, the 3D additive manufacturing techniques could be a more economical solution.

This work aim to design and implement a novel 3D Additive Manufacturing Machine to Biodegradable Stent Manufacture. The effects of nozzle temperature, fluid flow, and printing speed over the polycaprolactone stent's precision is studied. Results have shown the strong influence of temperature and flow rate over the printing precision. Printing speed did not had a clear tendency. The results allow us to believe that the novel technology presented in this paper will be an interesting future research line.

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Keywords: Additive Manufacturing, Cylindrical, 3D Printing, Biodegradable Stent, Polymer

1. Introduction

Although metallic stents are effective in preventing acute occlusion and reducing late restenosis after coronary angioplasty, many concern still remain. The role of stenting is temporary and is limited to the intervention and shortly thereafter, until healing and re-endothelialization are obtained. Bioresorbable stents (BRS) were introduced to overcome these limitations with important advantages: complete bioresorption, mechanical flexibility, does not produce imaging artefacts in non-invasive imaging modalities, etc. [1]

Biodegradable stents offer the potential to improve long-term patency rates by providing support just long enough for the artery to heal, offering the potential to establish a vibrant market. However, design a biodegradable structure for an intended period of support is rather difficult. Nowadays in the stent industry the manufacture process par

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excellence is the laser micro cutting. Nevertheless in the case of polymeric stents, the 3D additive manufacturing techniques could be a more economical solution [2].

Recently, three-dimensional (3D) printing, a specific technique in the biomedical field, has emerged as an alternative system for producing biomaterials. The 3D printing system, applied to rapid prototyping in structural fabrication can easily manufacture biomaterials, such as BRS, better than other devices. Additionally, 3D-printing offers a more efficient process for assembling all of the necessary components, such as the vascular artificial scaffold. For the past decade, biomedical stents have received much attention for their prevention of coronary thrombosis. Conventionally used BMS, such as stainless steel and titanium, can cause after effects, as they remain in situ even after vascular repair. Thus, there is a need for residue-free alternatives [2].

Some authors have been focused their research in the field of stent manufacture. Stepak et al. [3] presented the impact of the KrF excimer laser irradiation above the ablation threshold on physicochemical properties of biodegradable PLLA. It could be concluded that usage of the 248 nm wavelength resulted in simultaneous ablation at the surface and photo degradation within the entire irradiated volume due to high penetration depth. Stepak et al. [4] fabricated a polymer-based biodegradable stent using a CO2 laser.

Nevertheless, with the best author's knowledge, the use of cylindrical 3D printing for stent purpose have been never reported before. This work aim to design and implement a novel 3D Additive Manufacturing Machine to Biodegradable Stent Manufacture. The effects of nozzle temperature, fluid flow, and printing speed over the stent's precision is studied and compared with the laser cutting technology.

2. Material and method

2.1. 3D Printer machine

The 3D Additive Manufacturing Machine developed is based in the Fused Filament Fabrication (FFF) and the 3-axis 3D printing technologies. The filament is melted into the extruder nozzle, which deposited the material onto a heated computer-controlled rotatory Cartesian platform (Fig. 1). The machine developed is based in the Fused Filament Fabrication (FFF) method and the 3-axis 3D printing technology. The filament is melted into the extruder nozzle, which deposited the material onto a computer-controlled rotatory platform. The machine provides a precision of 0.9375 µm in the X axis, 0.028125º in the W axis, 0.3125 in the Z axis, and 0.028125º in the extruder. The nozzle provides 0.4 mm of diameter.

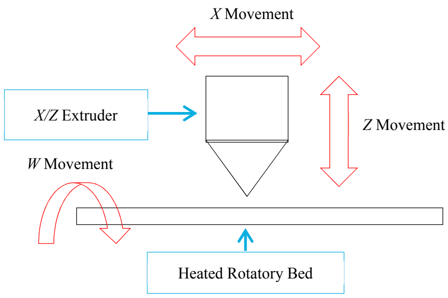

Fig. 1. 3D Machine methodology.

2.2. Material and geometry

Polycaprolactone (PCL) Capa 6500® supplied by Perstorp was used as material. PCL is a biodegradable polyester with a low melting point (60ºC) and a glass transition of -60ºC. PCL degradation is produced by hydrolysis of its ester linkages in physiological conditions and has therefore received a great deal of attention for using it as an implantable biomaterial, such stents, because of their properties (Table 1).