# IN-SILICO MODEL OF LEFT ATRIAL APPENDAGE OCCLUSION: COMPARISON WITH IMPLANTATION IN 3D PRINTED PATIENT SPECIFIC GEOMETRY


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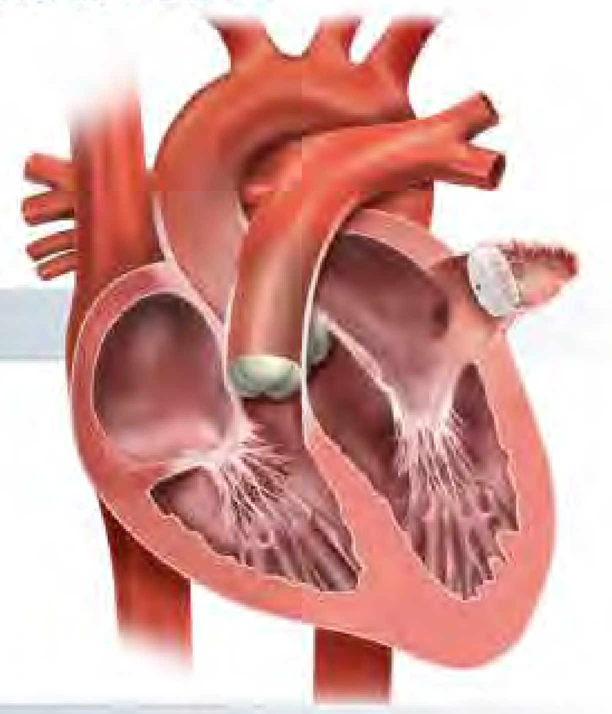


https://www.watchman.com

## INTRODUCTION

**Left atrial appendage (LAA)** is the most common site of thrombus formation for patients affected by non-valvular atrial fibrillation (AF). The standard treatment for AF is the administration of oral anticoagulation (OAC), but a significant number of patients could not be started on OAC because of severe complications, such as bleeding risk. For these patients **LAA occlusion** is a winning alternative: this minimally invasive procedure consists in the release through a catheter of a stented device, which closes permanently the LAA, preventing blood clot formation and migration. The pre-operative planning is fundamental to achieve a successful device implantation, but, due to the high variability of the LAA anatomies, it can become challenging. For this reason, in-silico models simulating the Watchman implantation in the patient-specific LAA anatomy could be a helpful tool for clinicians. This work aims to build and validate a **finite element model** of the **Watchman implantation procedure**. Moreover, deployment tests in 3D-printed patient-specific geometries were performed to assess the reliability of the model.

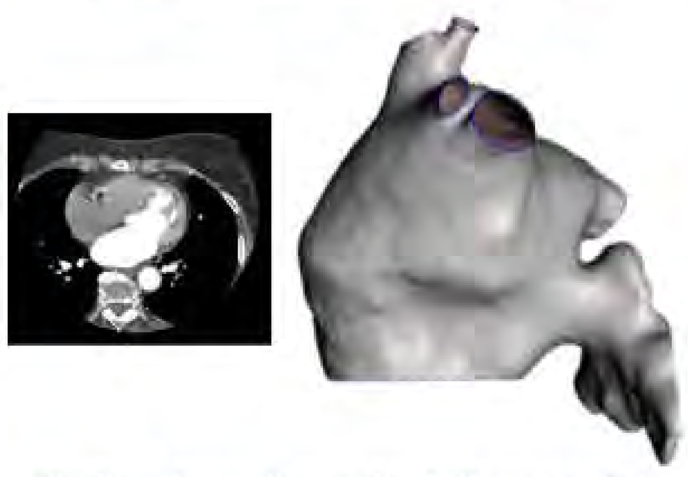
## MATERIALS AND METHODS

### PARAMETRIC DEVICE MODEL


**Geometry reconstruction:** Starting from **CT images** of the real device, the **3D CAD** of Watchman was realised in **Solidworks**..
**Mesh**: The mesh composed by beam elements was generated in **Hypermesh**. A **MATLAB** code was implemented to provide the correct beam orientation.

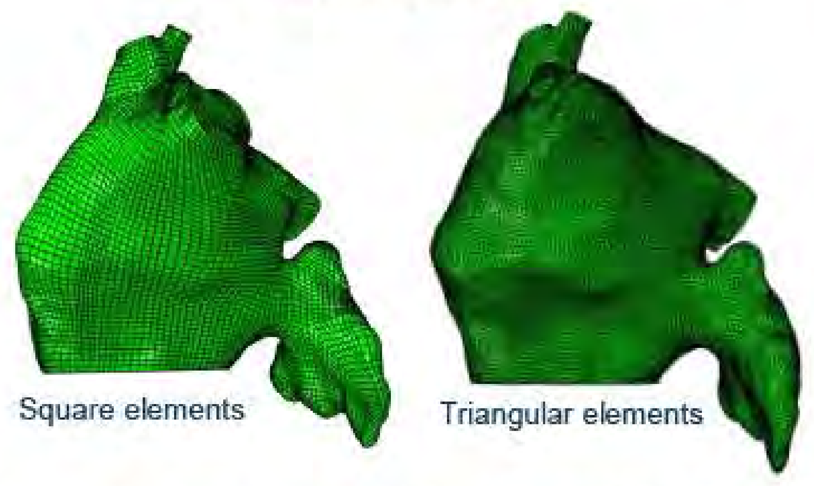
### PARAMETRIC PATIENT MODEL

**Generation of the 3D model**



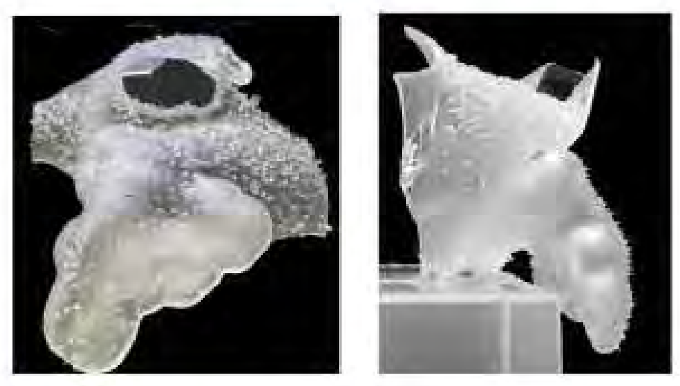
Starting from the patient thoracic **CT images** at 60% of the cardiac cycle, the **3D .stl format model** of the **LAA** and Left Atrium (LA) was generated through **3DSlicer.** Smoothing and refining of the model was obtained in **Meshmixer.**

**In-silico model**




The mesh was generated in **Hypermesh** (triangular element) and **ANSA** (square element through hexablocks meshing). After a element sensitivity analysis, triangular mesh guaranteed a adequate trade off between accuracy and effort in the model realisation.

**3D printed model**



LAA and **half LA** were printed using the Formlabs Form2 **SLA 3D printer**. The material used for the 3D printed geometry is **Elastic50A** with a **printing resolution of 0.1mm**

### IMPLANTATION PROCEDURE

Following the clinical technique, the LLAO was simulated using the solver **Abaqus** 2018. To validate the finite element model, the procedure was performed by the clinician on the 3D printed LAA. Fluoroscopic images were taken to compare the Watchman positioning in the in-silico and in-vitro models. Finally, the simulations were replicated by substituting the material properties of the 3D printed LAA with realistic patient-specific parameters.

***STEPS***

In all the steps the LA inlets and outlet were fixed in the three directions, while rotations were allowed.

- ***Crimping***: crimping of the device down a catheter of 12F diameter.
- ***Deployment:*** unsheating of the catheter, mantaining the device fixed.
- ***Guidewire removal*** to allow the device position adjustment.

***MATERIAL PROPERTIES***

- **Watchman device**: the superelastic **Ni-Ti** material properties calibrated in a previous work [1] were exploited for the device.
- **3D printed LA and LAA:** linear elastic material.
- **LA and LAA:** the linear elastic material properities of the patient specific atrium were idealised through CT-gated images.

*Watchman*

| | |
|---|---|
| EA | 60000 MPa |
| EM | 25000 MPa |
| ν | 0.3 |
| εL | 0.04 |
| σLS | 350 Mpa |
| σLE | 450 Mpa |
| σUS | 250 Mpa |
| σUE | 150 Mpa |
| σCLS | 500 MPa |
| T0 | 25 °C |
| δσ/δT | 15 MPa/°C |

*3D printed LA and LAA*

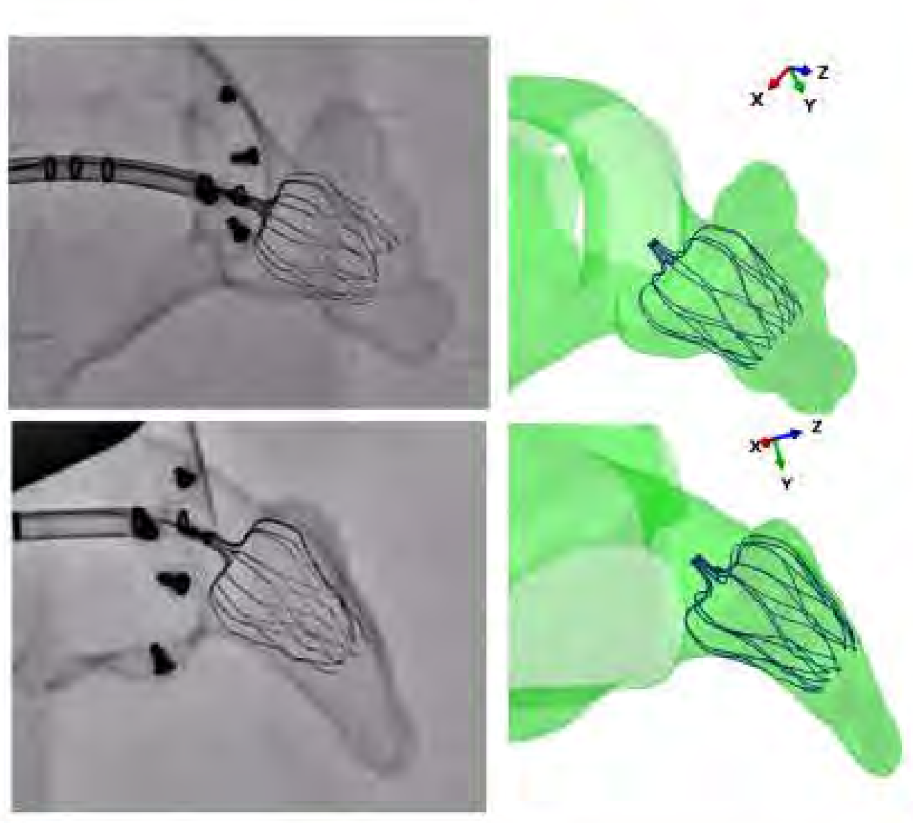
| | |
|---|---|
| E | 2.5 *MPa* |
| N | 0.45 |
| ρ | 1.15e-03 g/*mm*³ |
| S | 1.5 mm |

*LA and LAA*

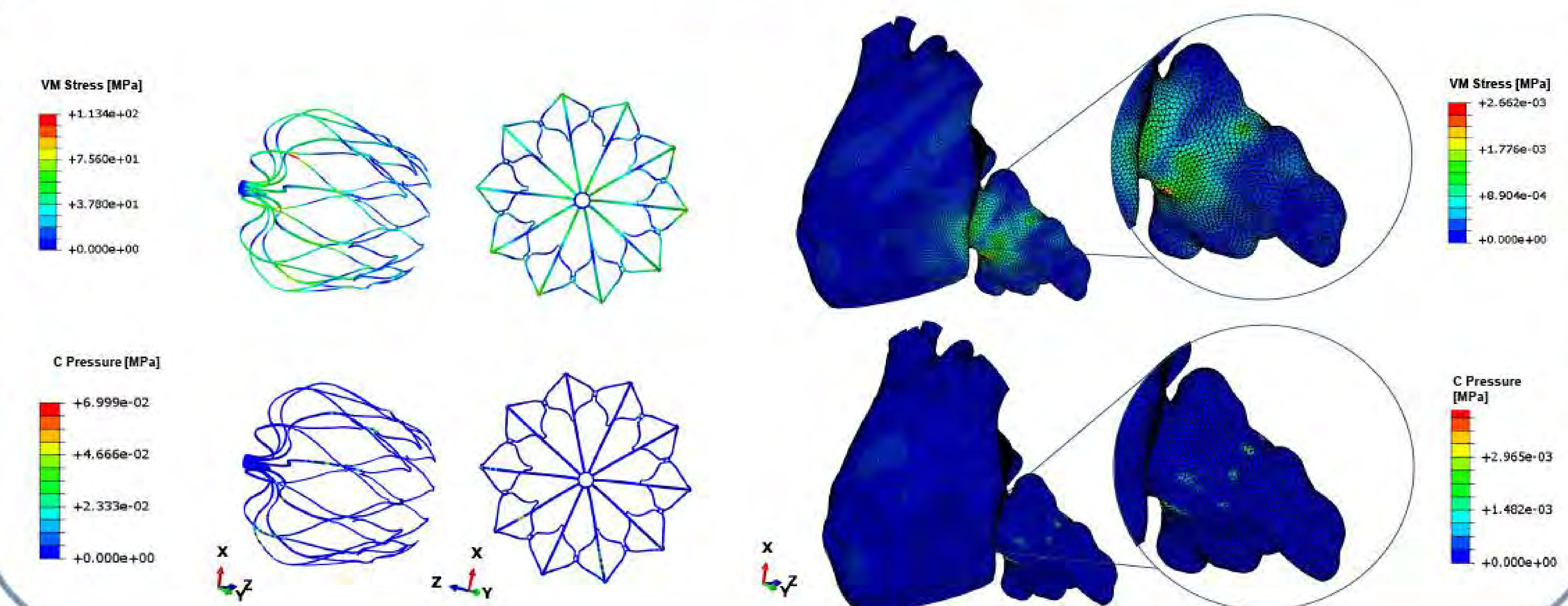
| | |
|---|---|
| E | 0.005 *MPa* |
| ν | 0.45 |
| ρ | 1e-03 g/*mm*³ |
| s | 2 mm |

## RESULTS


### VALIDATION OF THE MODEL: SIMULATION WITH RESIN MATERIAL PROPERTIES



### SIMULATION WITH LAA MATERIAL PROPERTIES




## CONCLUSIONS

**Up to now**

- The finite element model of LAA was developed
- The deployment was simulated in one Left Atrial Appendage using different positions and depths
- Validation of the implant procedure simulation throughout the comparison between the 3D-printed experimental tests' results and the in-silico model's results
- Implant outcome prediction in patient-specific geometry imposing realistic material properties

**Next steps**

- Evaluate the stability, anchoring and correct sizing of the device for different deployment positions and depths
- Introduction of a curved catheter
- Replicate the study on more patient-specific LAAs

**Limitations:**

- The wall atrium pressurization is not considered in this study
- Static boundary conditions were used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[1] Zaccaria et al. " Left atrial appendage occlusion device: Development and validation of a finite element model." Medical Engineering & Physics (2020).