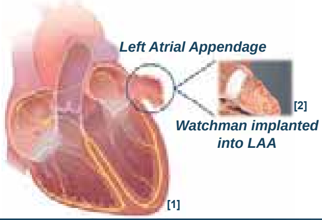
NUMERICAL MODEL OF A LEFT ATRIAL APPENDAGE OCCLUDER

F. Danielli[1], E. Gjini[1], A. Zaccaria[1], E. Gasparotti[2,3], B.M. Fanni[2,3], L. Petrini[4], S. Celi[3], G. Pennati[1]

1 LaBS, Department of Chemistry, Materials and Chemical Engineering, Politecnico di Milano, Milan, Italy
2 BioCardioLab, Bioengineering Unit, Fondazione Toscana Gabriele Monasterio, Massa, Italy
3 Department of Information Engineering, University of Pisa, Pisa, Italy
4 Department of Civil and Environmental Engineering, Politecnico di Milano, Milan, Italy

INTRODUCTION

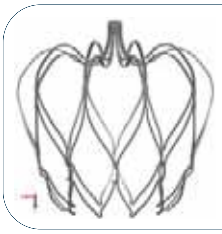


Left Atrial Appendage (**LAA**) is the common site of thrombus formation in patients affected by Non-Valvular Atrial Fibrillation (NVAF); the administration of oral anticoagulants may have several drawbacks such as intracerebral haemorrhage. **Left Atrial Appendage occluders** provide a valid alternative in the prevention of NVAF-induced strokes, avoiding blood clot migration. This work aims to calibrate the material parameters and validate a numerical model of **Watchman**, a CE-marked and FDA-approved LAA occluder made in **Nitinol**, through a comparison between **Finite Element Analysis** and **experimental tests**. Moreover, the **deployment** of the device in an idealised geometry was simulated.

Watchman

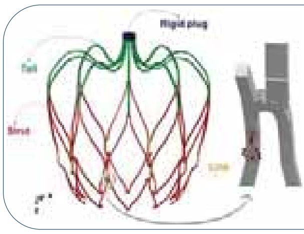
MATERIALS AND METHODS

1. 3D CAD of WATCHMAN



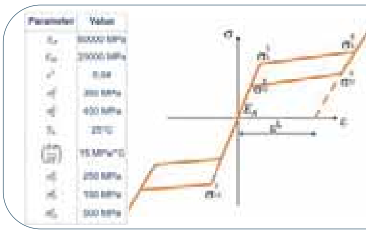
The **3D CAD** of Watchman was realised in **SOLIDWORKS** *(Dassault Systèmes, Vélizy-Villacoublay, France)*; the dimensions were taken from **micro-CT** images of the device itself.

2. MESH



The finite element model of the endoprosthesis is composed by mono-dimensional elements (**beam**), obtained using the software **HYPERMESH** (Altair Engineering, Troy, MI, USA). A **MATLAB** (MathWorks, Natick, MA, USA) code was used to give beam elements the proper orientation in 3D space.

3. MATERIAL MODEL

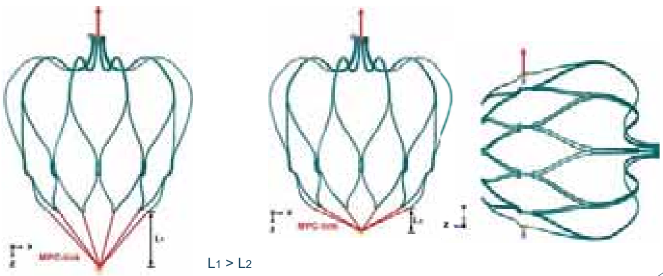


As regards the identification of Watchman's mechanical properties, the **superelastic material model** present in Abaqus was exploited (UMAT subroutine). The material was calibrated on the basis of experimental tests.

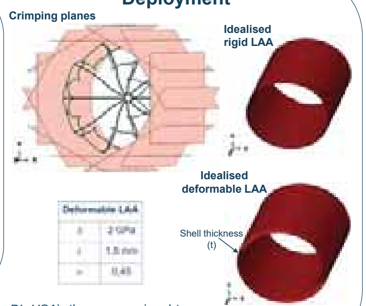
4. EXPERIMENTAL TESTS + SIMULATIONS

Experimental tests

Calibration **Validation**



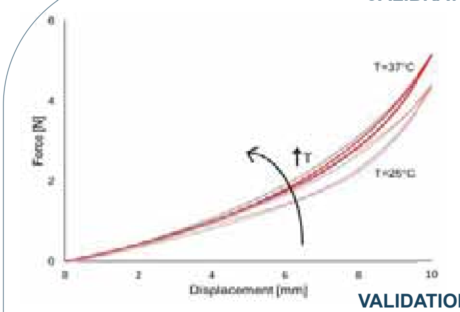
Deployment

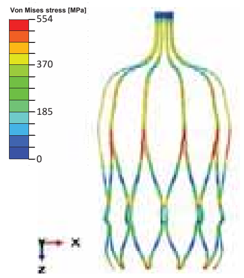


In order to **calibrate** the material parameters and **validate** the numerical model of Watchman, simulations of **traction** were implemented in **ABAQUS 2018** *(Dassault Systemes Simulia, Providence, RI, USA)*; these ones aimed to replicate the experimental tests conducted using the electromechanical testing machine **MTS SYNERGIE** (100N full scale). Secondly, the **crimping** and the **expansion** of the device were simulated in order to investigate the effects of the deployment on both rigid **[3]** and deformable **[4]** idealised LAAs; a cylinder with an ellipsoidal section (11,5mm x 10mm) was adopted to simplify the geometry of the anatomical site.

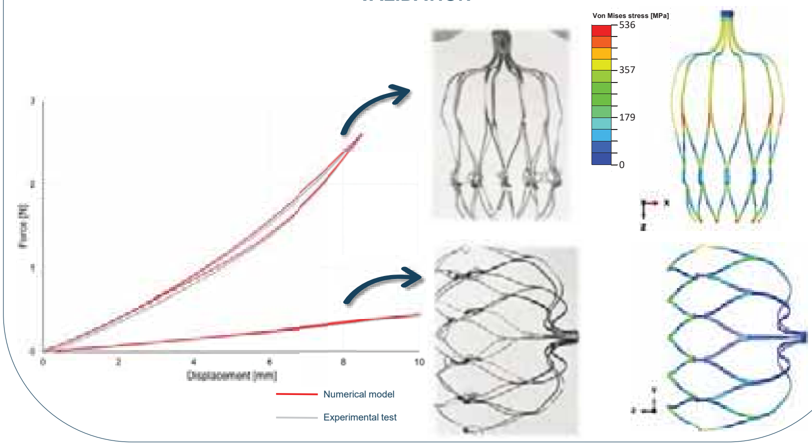
RESULTS

CALIBRATION



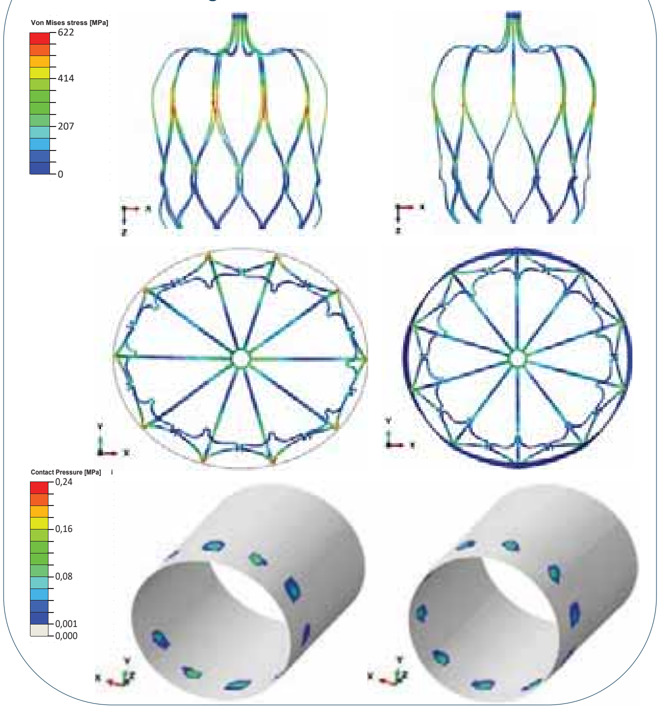


VALIDATION



DEPLOYMENT

Rigid LAA **Deformable LAA**



Force-displacement curves and deformed configurations of the device were taken into consideration, aiming to compare properly numerical simulations and experimental tests.

CONCLUSIONS

Up to now

- The material was correctly calibrated both at room and body temperature. ✓
- The finite element model of Watchman fitted well experimental data from different tensile tests. ✓
- *Limitation*: the deployment was simulated in only one and oversimplified Left Atrial Appendage. ~

Next steps

- Simulate the deployment of the device in patient-specific LAAs.
- Validate the deployment throughout experimental tests, that might be performed in 3D-printed more realistic LAA models.

Contact address:
francesca.danielli@mail.polimi.it, ereza.gjini@mail.polimi.it, alissa.zaccaria@polimi.it

References:
[1] http://electrophysiology.onlinejacc.org/content/5/4/407
[2] http://www.watchman.com/
[3] A. M. Bavo, et al., "Validation of a computational model aiming to optimize preprocedural planning in percutaneous left atrial appendage closure", Journal of cardiovascular computed tomography (2019).
[4] A. Caimi et al., "Prediction of stenting related adverse events through patient-specific finite element modelling" Journal of Biomechanics (2018)