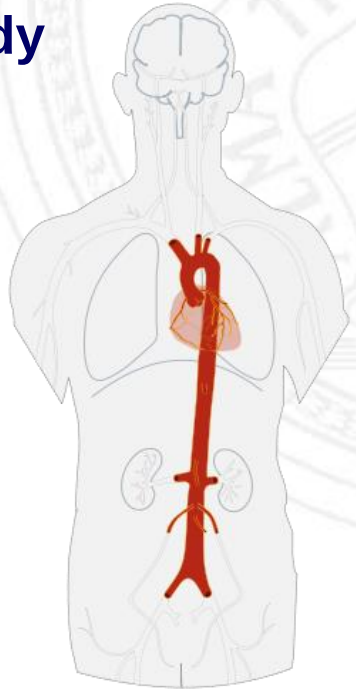
Progettazione e prototipazione di stampi per distretti vascolari in silicone

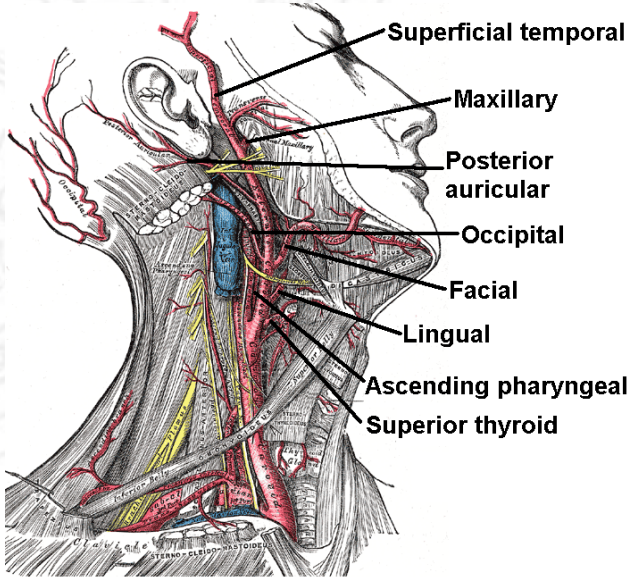
Laurea in Bioingegneria
A.A. 2012/2013

Presentazione di Tesi di laura di
Merli Stefano

Introduction to the problem

- **Bioengineers goals: obtain and evalutate data about human body**
- **Some body parts present hardly reachable structure and or positions**
- **It's very useful for us to recreate this body parts OUTSIDE the human body**





β-lab

Why creating a mock artery?

- **Simulations:**
  - **Not invasive analysis**
  - **Multiple analysis**
- **Surgical planning**
- **Provide didactic tool**
- **Reducing costs**
- **Possibility to work on patient specific files**

B-lab activities

So far we don't have patient specific models installed:

- **Connecting my mock arteries in the idraulic circuit.**

  → **More complex and realistic simulations.**

My job steps

1. Analysis of the mechanical characteristics of arteries
2. Searching for the right material
3. Mold design with Solidworks
4. Mold prototyping with 3D printing
5. Material pouring into the mold
6. Analysis and overcoming of main drawbacks
7. Preliminary analysis of patient-specific geometries

The perfect mock carotid artery:

Our model should satisfy these tipical properties of an human vessel:

Propriety	Biological artery	Sylgard184 artery
Non-linearity	yes	yes
Inhomogeneity	yes	no
Anisotropy	yes	no
Viscoelasticity	yes	yes
Incompressibility	yes	yes
Transparency	no	yes

- **An example:**

About 1000 euros

The choice of the right material

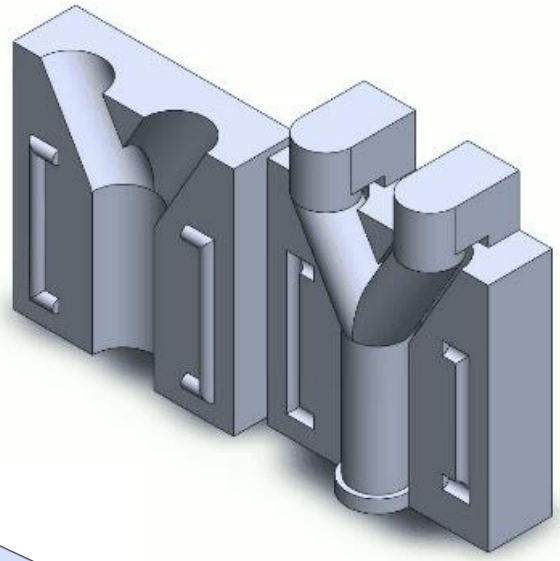
Sylgard 184 silicone :

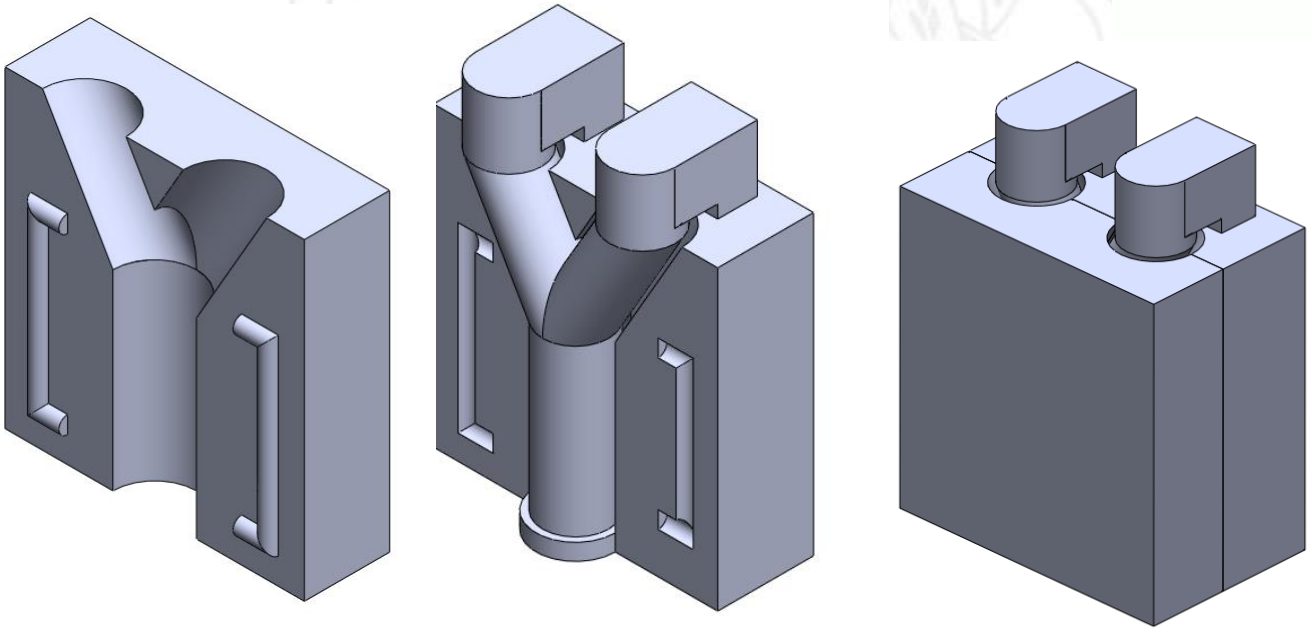
- **Composed by a base and a polymerizing agent**
- **Largely used in microfluids studies**
- **Great compatibility with artery's properties**
- **Possibility of controlling the mechanical properties**
- **Perfect transparency**

The mold design for carotid arteries

First attempt:

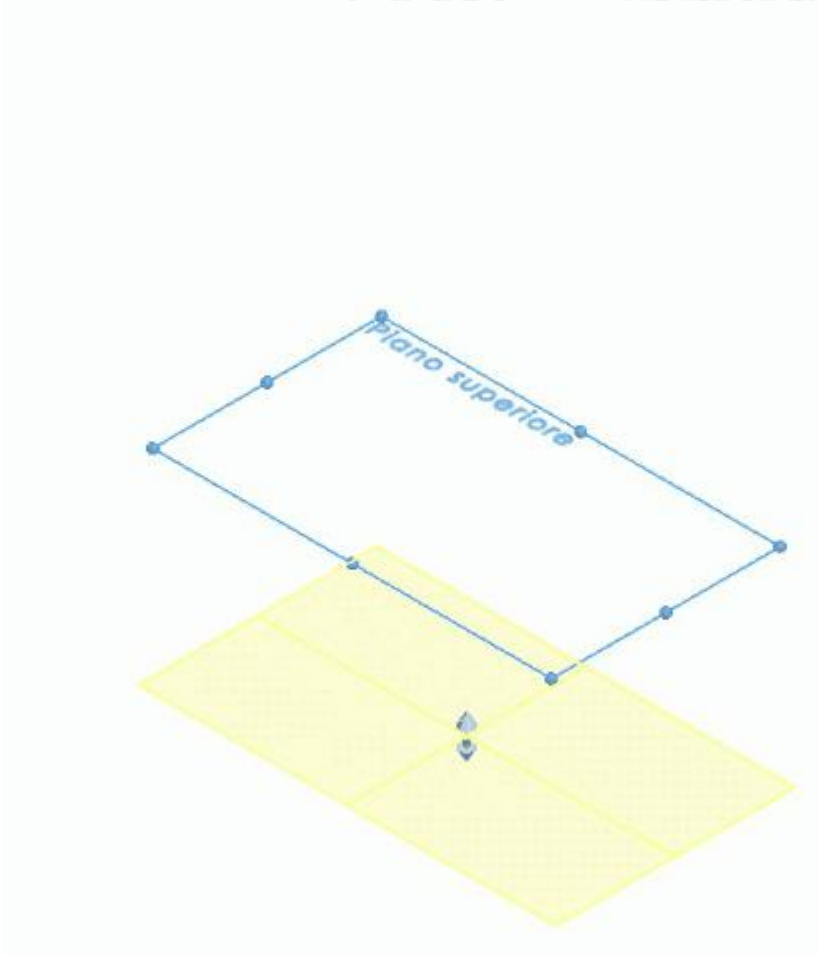
- **Sample geometry: bifurcation**
- **Assess the feasibility of the project**

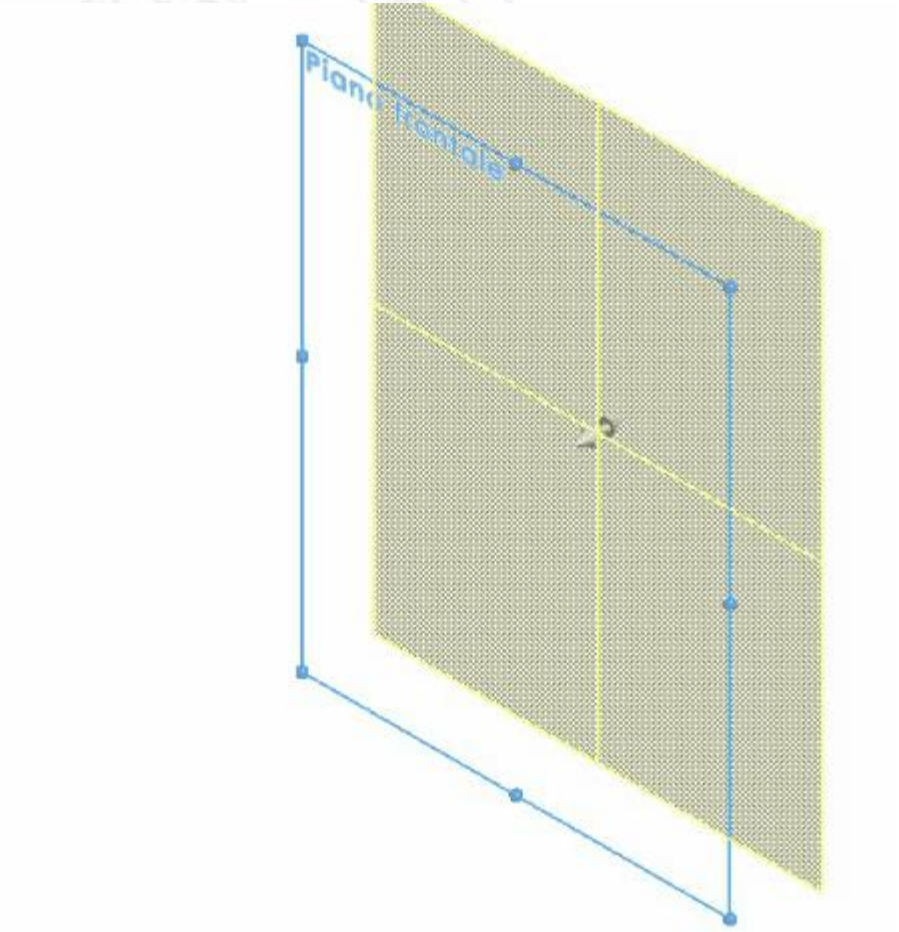




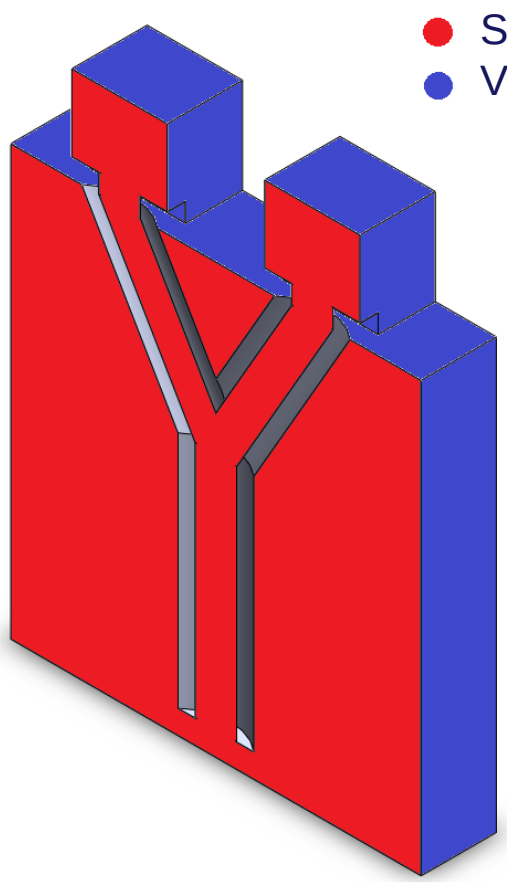
The mold design for carotid arteries

Use of boolean operators to assess the perfect negative geometry.





The mold design for carotid arteries



The printer uses 2 materials:
- **VeroWhite (rigid) and**
- **Support (friable)**

“hollow function”

- **Reducing printing costs**
- **Same performances**
- **Useful for inner lumen extraction**

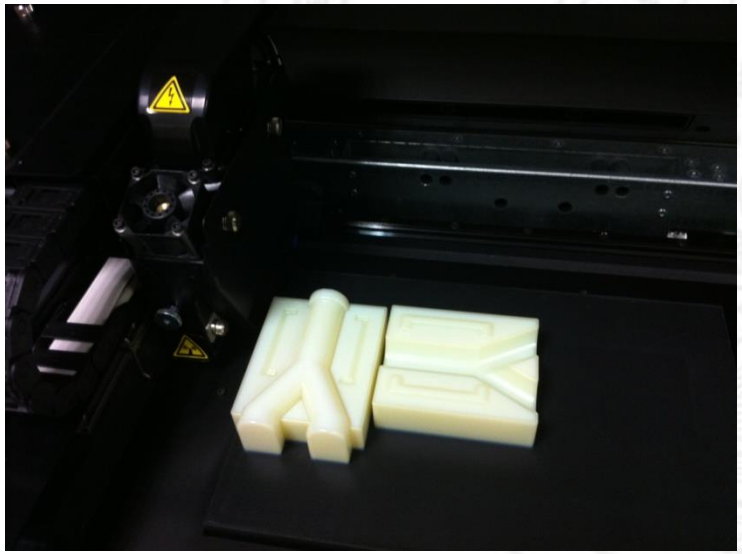
The printing process

The next step is the printing process and the following cleaning operations.

The printing process

Perfect replica of the CAD model.

High level of detail (28 micron).



The pouring

- Silicone pouring
- Wait for 48h at room temperature (as suggested in datasheets)

After 48h :

-incomplete polymerization

-strong adherence to the mold

The extraction of our geometry

The main steps of the extraction of the mock artery:

1. Disjunction of the 2 parts
2. Rupture of the inner part with a milling machine
3. Removal of fragments

Main problems occurred

Drawbacks:

- Lack of precision in the mixture of the two components
- A too low room temperature
- The presence of macro and micro bubbles in the silicone
- Too strong adhesion to the mold

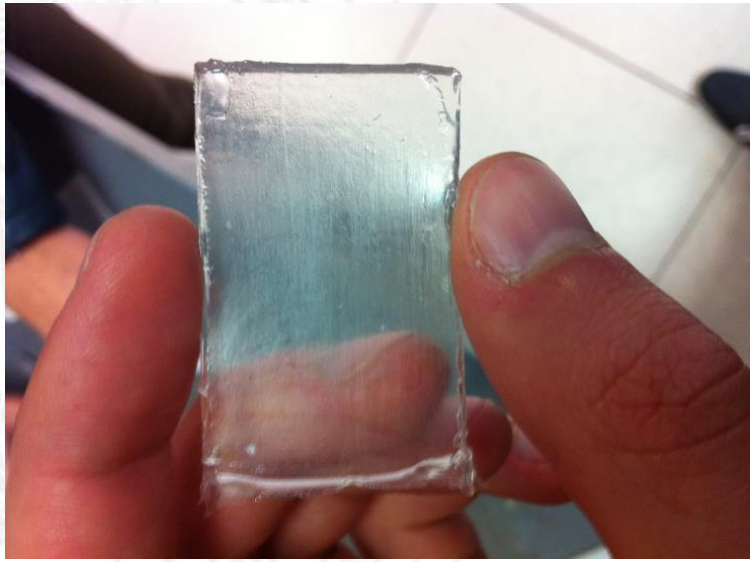
Future precautions:

- Use of a precision balance
- Use of an automatic mixture machine
- Experimentation of anti-adherent agents
- Use of a vacuum chamber to remove bubbles
- Use of an industrial oven set at 65° C
- Need for a less invasive extraction method
- Need to move to a 3 parts mold

Study of anti-adherent agents

Anti-adherent agents:

1. ~~S[illegible] based [illegible]~~
2. ~~Ordi[illegible]~~
3. ~~T[illegible]n based lub[illegible]pray~~
4. **Spray plasticizer**
5. **Spray plasticizer + liquid wax**
6. **Control**



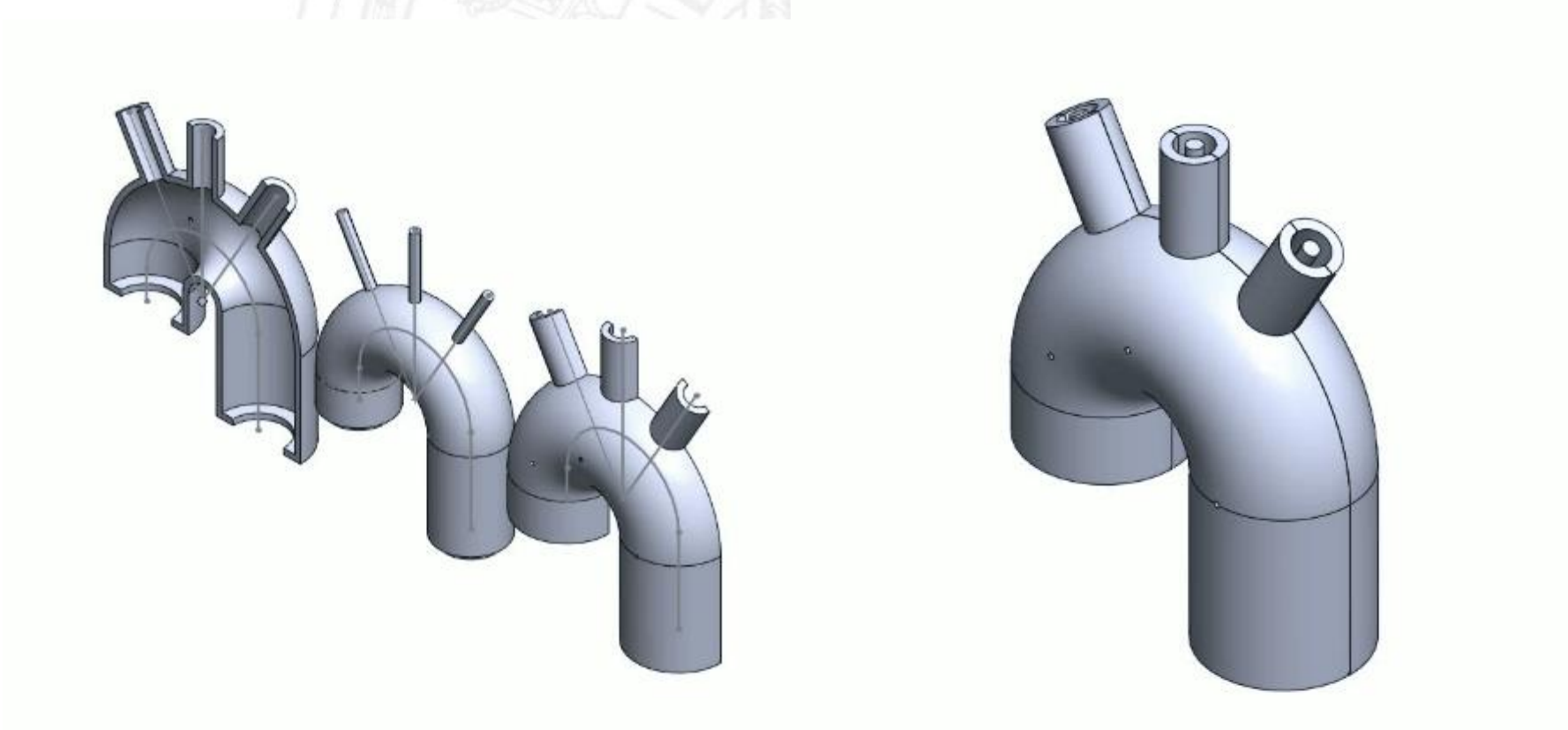
Tests 1, 2, 3 : Corrupted polymerizations.

Tests 4 and 5: Great polymerizations and transparency.

Test 5 gave the best results.

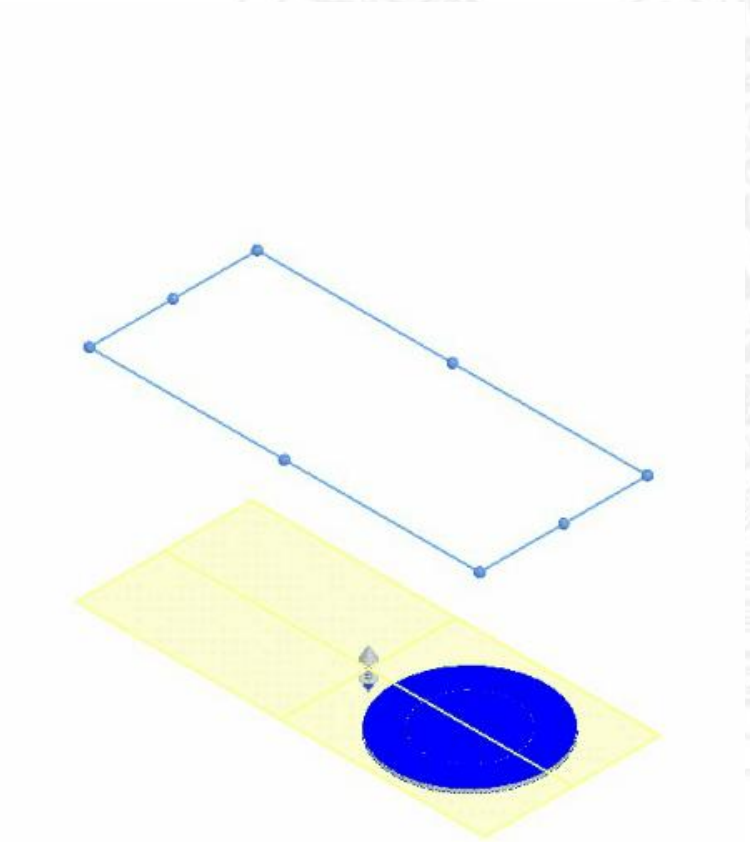
The mold design for aortic arch

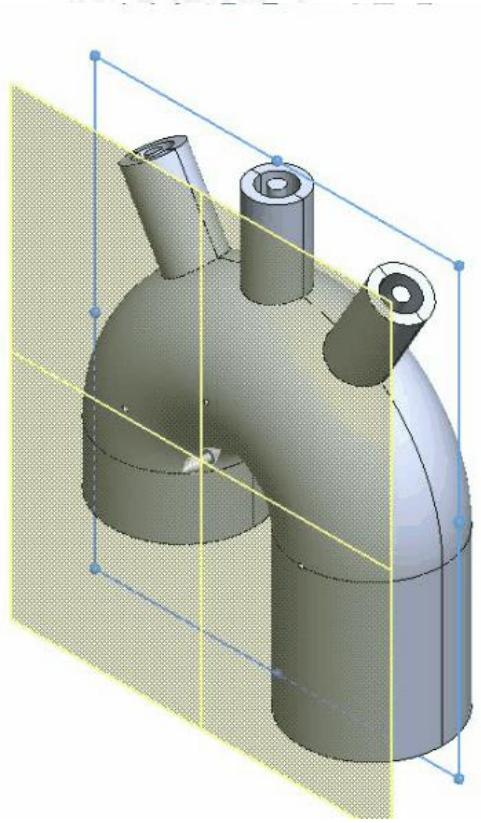
- Due to laboratory priorities we decided to proceed with the creation of a replica of the human aortic arch.
- The three parts are fixed with glue on the bottom.



The mold design for aortic arch

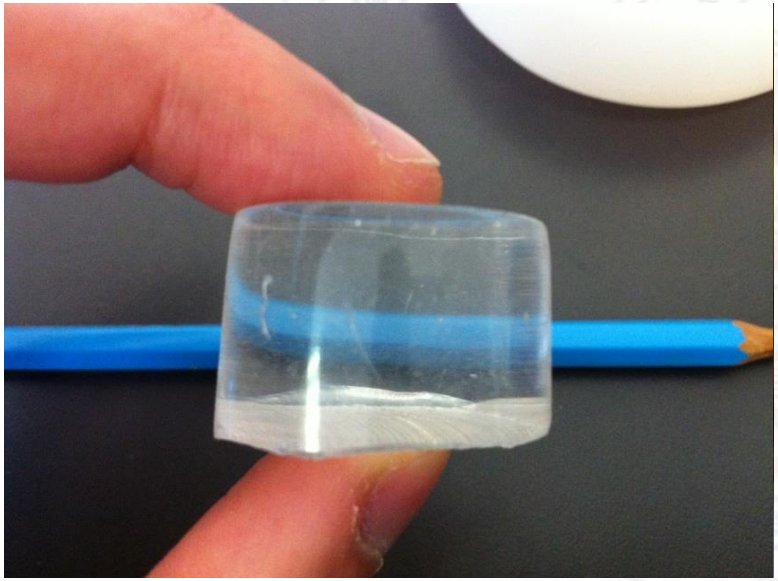
Use of boolean operators to assess the perfect negative geometry.





Anti-bubble procedures

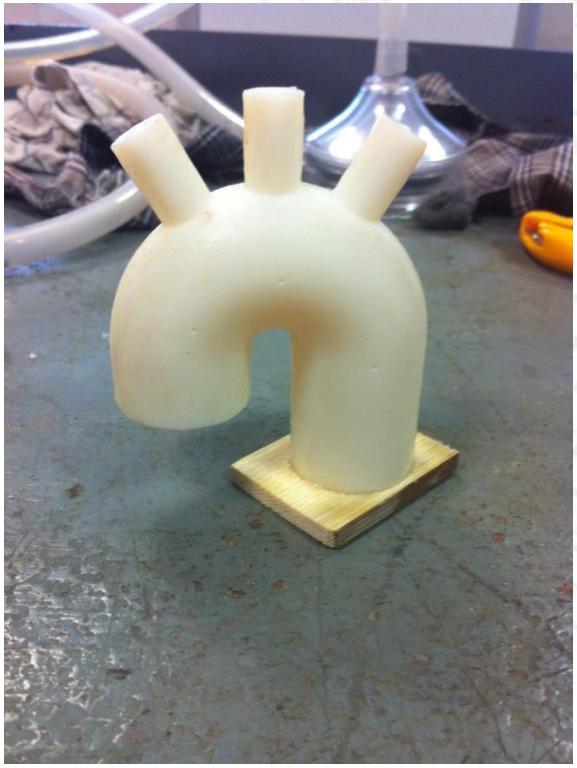
The combined action of a vacuum chamber and the application of wax and spray gives us the possibility to obtain perfectly trasparent objects.

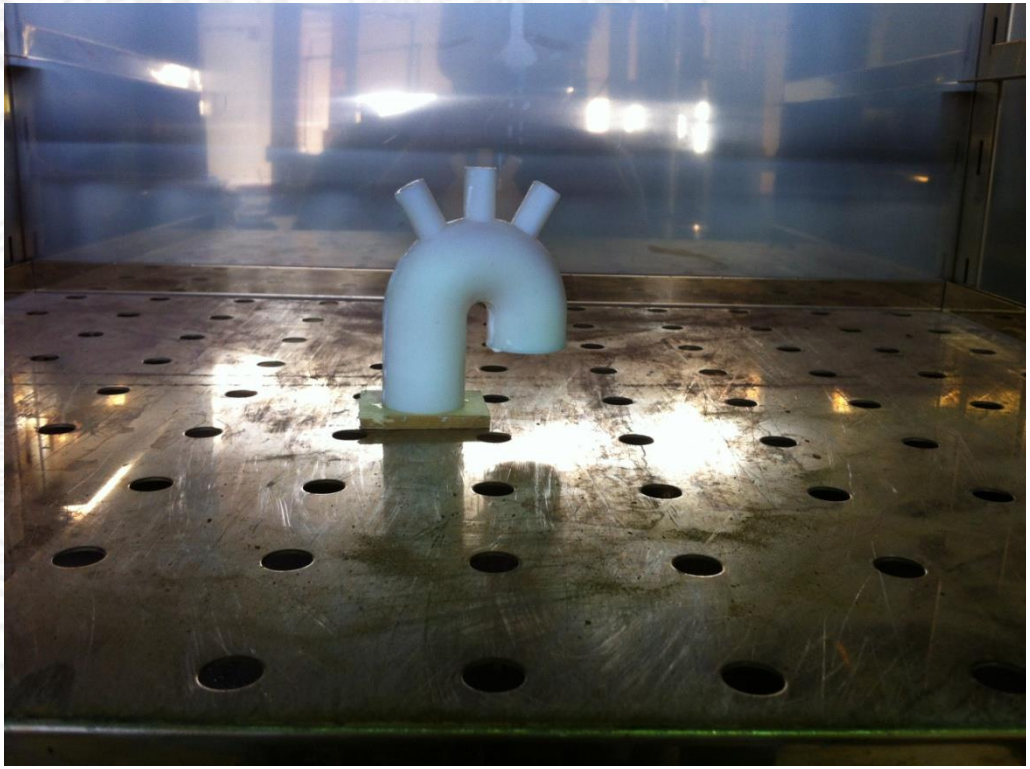


Degassing facilities at dip. of Chemestry, Prof.Dario Pasini Unipv

The polimerization process

- Silicone pouring
- Wait for 72 hours at 65° c





The extraction of our geometry

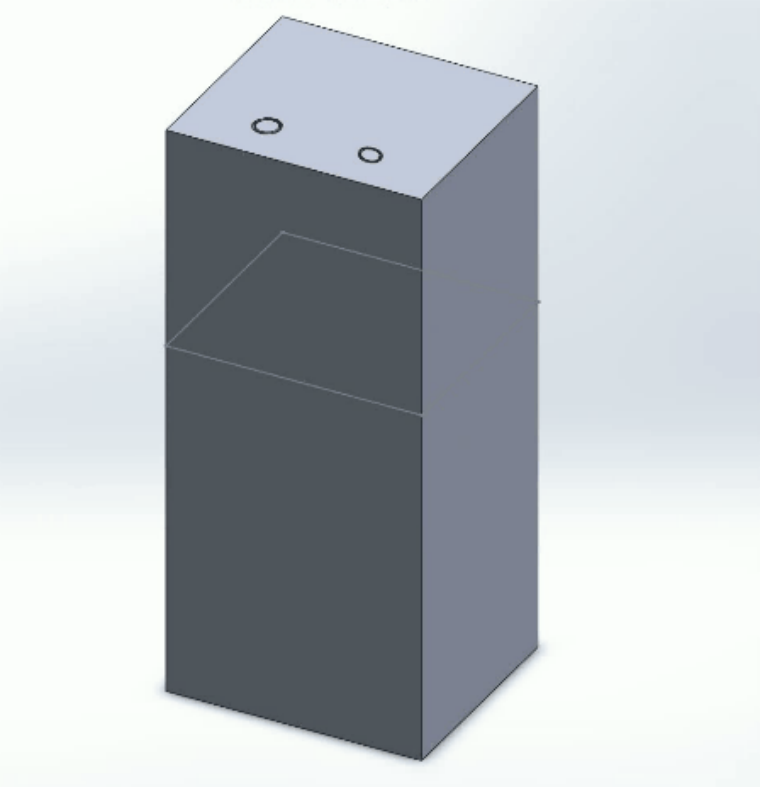
- **Compressed air jet to remove the silicone from the mold**

→ **minimize damages**

Future developements

Move to patient specific geometries:

- **Design of proper mold.**
- **Evalutation of a proper extraction method.**



Thanks for your attention

Un sentito ringraziamento a tutto il personale del B-lab in particolare: Prof. Ferdinando Auricchio, Ing.Michele Conti, Ing.Stefania Marconi, Prof.Dario Pasini.

Stefano Merli 2014

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