Why human skin study is interesting for Mechanical Research?

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Objective:

An overview of the complex behavior of human skin in vivo through various studies on the mechanical and thermal behavior.

Outline:

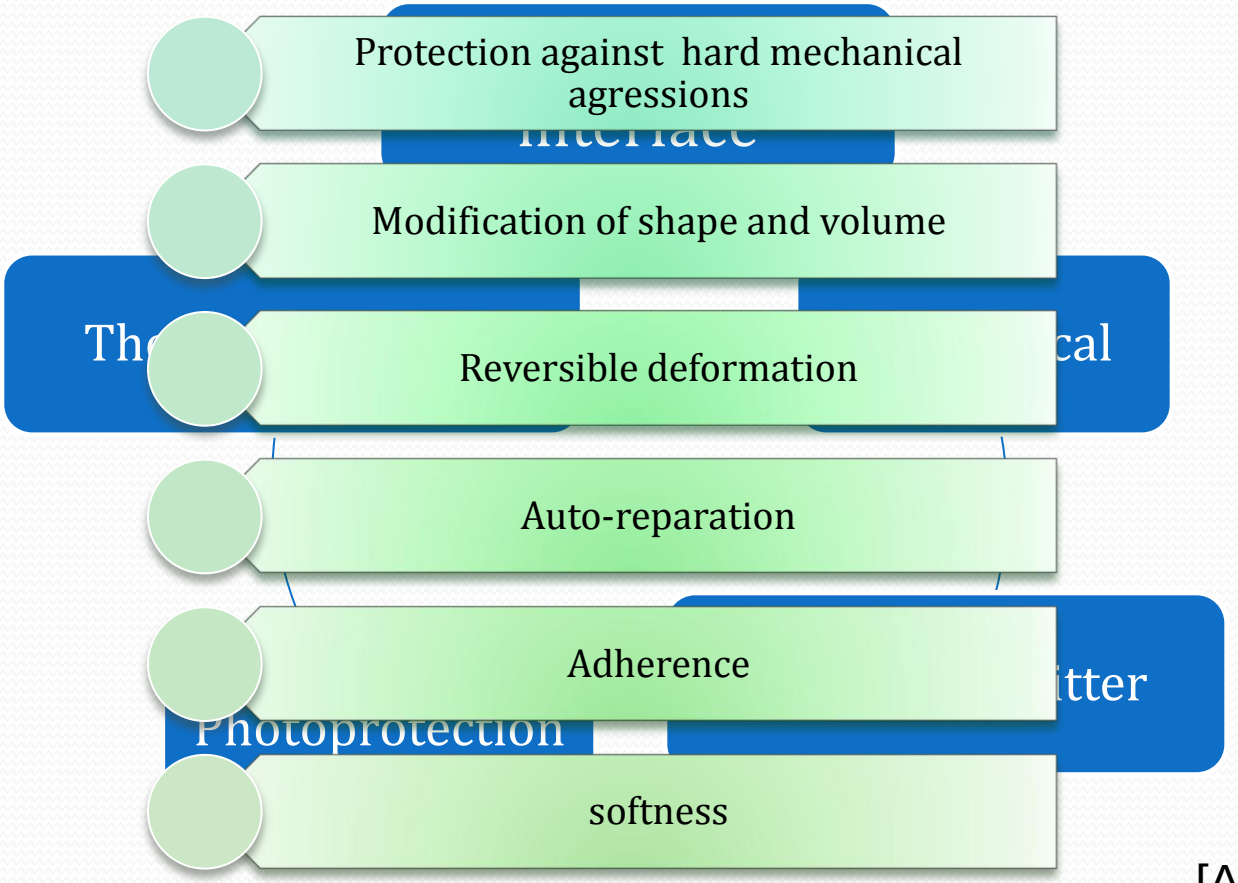
1. **The functions of the human skin**
2. **The different ways to study its behavior in vivo, in vitro, ex vivo. The multidisciplinary approach.**
3. **From a classical material science study to a specific device to identify natural stresses in vivo**

Conclusion and outlooks

Part. 1

The functions of the human skin

Mechanical functions



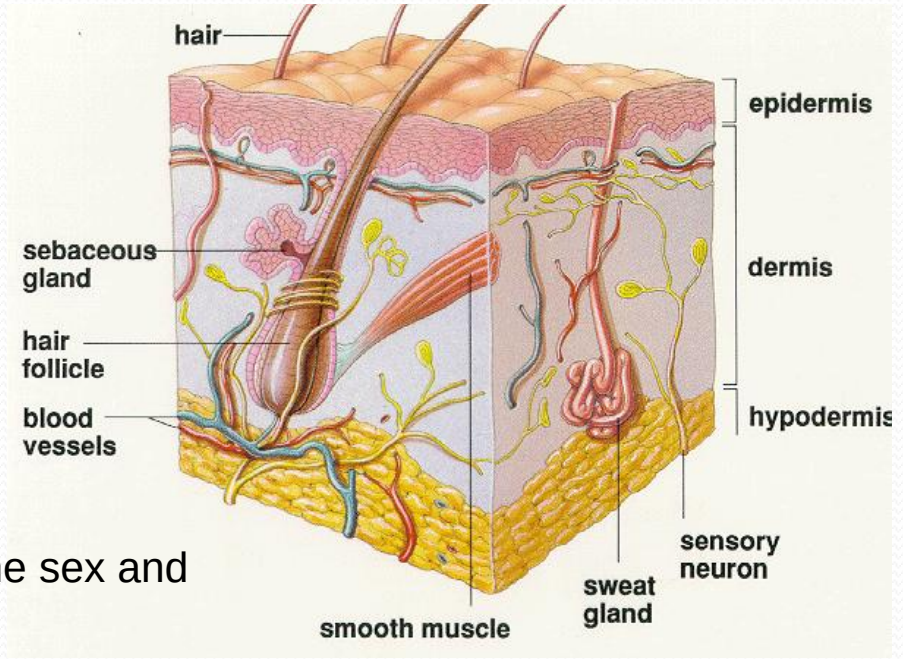
[Agache 2000]

Mechanical properties

- **Composite multilayers:** 3 layers with different thickness and mechanical properties [Agache 2000]

- **inhomogeneous**, **nonlinear**, **viscoelastic**, **anisotropic** material. [Fung 1973] [Silver 2003]

- subjected to **large deformations**. [Delalleau 2007]



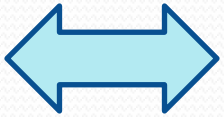
- **Variability**: mechanical properties highly dependent on the water content, the age, the sex and the localisation on the body. [Mofid 2006]

- **pre-stressed living tissue.** [Diridollou 2000]

Understand, Identify and predict the mechanical behaviour of human skin

Who:

- Doctors
- Surgeons,
- Cosmetologists
- Engineers



What:

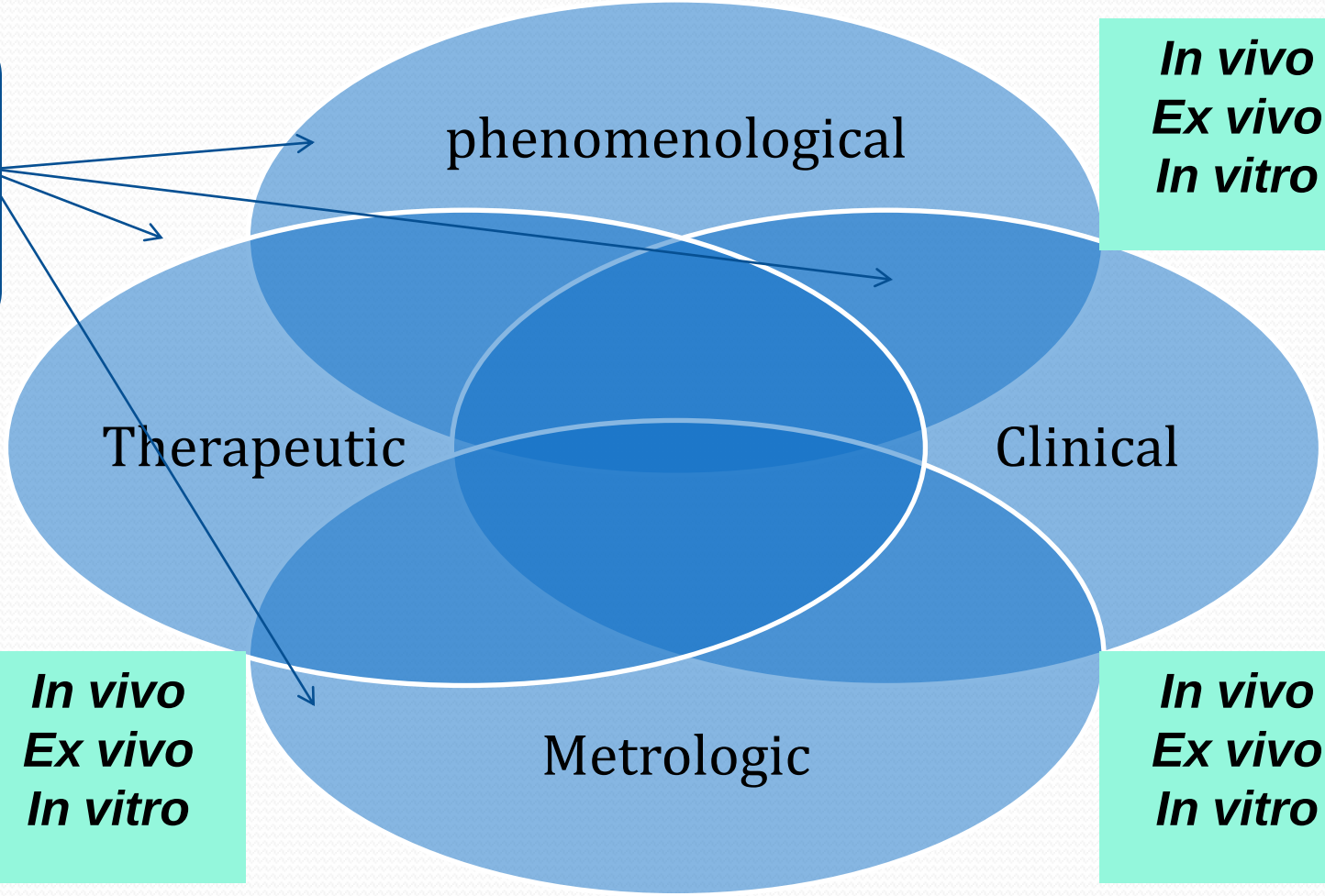
- **Diagnosis** aid and preparation for care
- Optimisation of **suture technics**
- Design of technical tissue or **subcutaneous tissue** as efficient as skin
- improvement of tissue repair (pressotherapy)
- Objective **qualification** of skin behavior
- Biomedical device **Design**

Part. 2

The different ways to study its behavior in vivo, in vitro, ex vivo. The multidisciplinary approach

Multidisciplinary study of DMA Femto-ST

surgeons
doctors
biologists
engineers



In vivo
Ex vivo
In vitro

In vivo
Ex vivo
In vitro

In vivo
Ex vivo
In vitro

The different skin samples

« in vivo »

- Real material
- environment
- Living property

« in vitro »

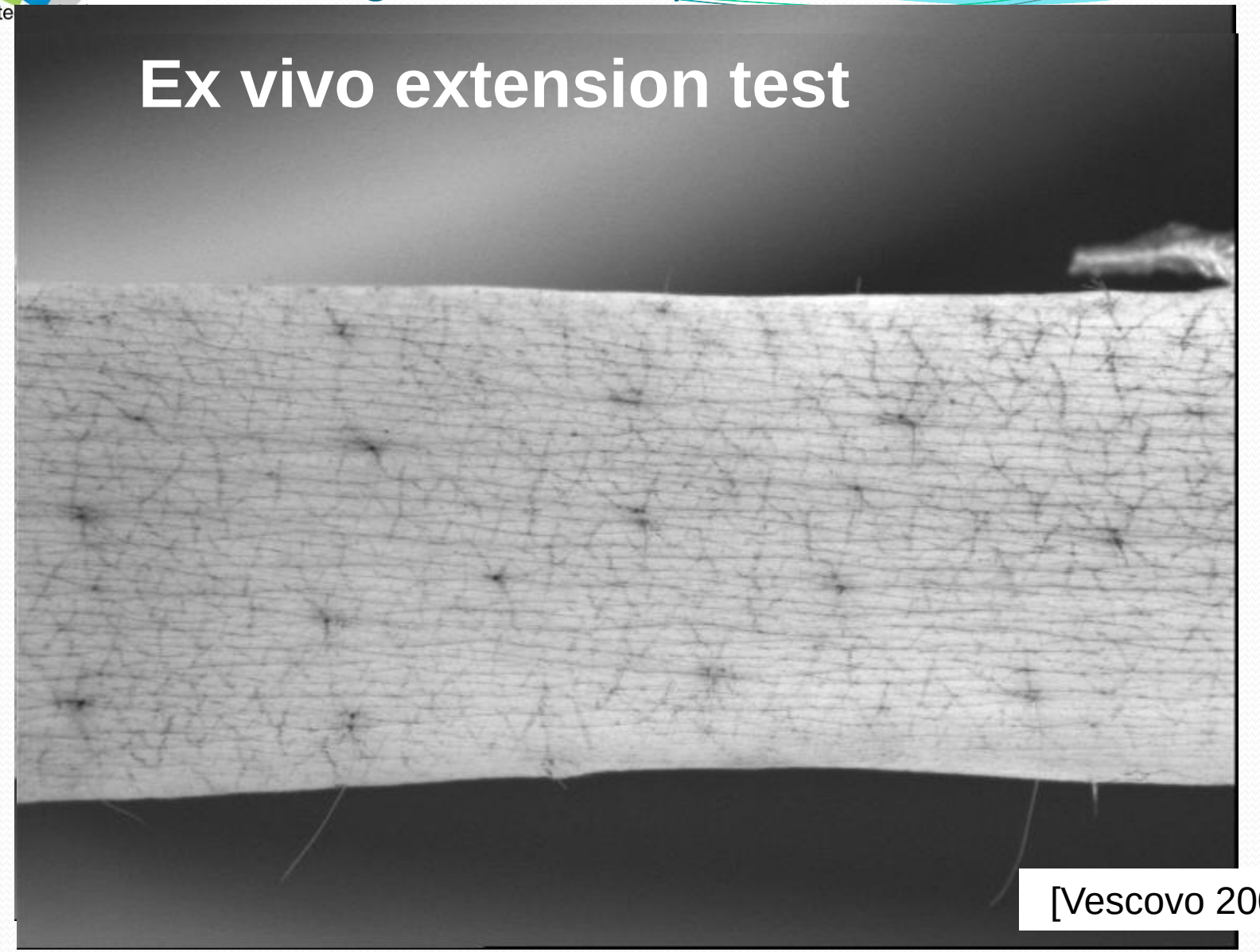
- A copy « man made material »
- environment
- Living or not living property

« ex vivo »

- basic model
- Similar material
- No in vivo environment

Part. 3

From a classical material science study to a specific device to identify natural stress in vivo



[Vescovo 2000]

Results

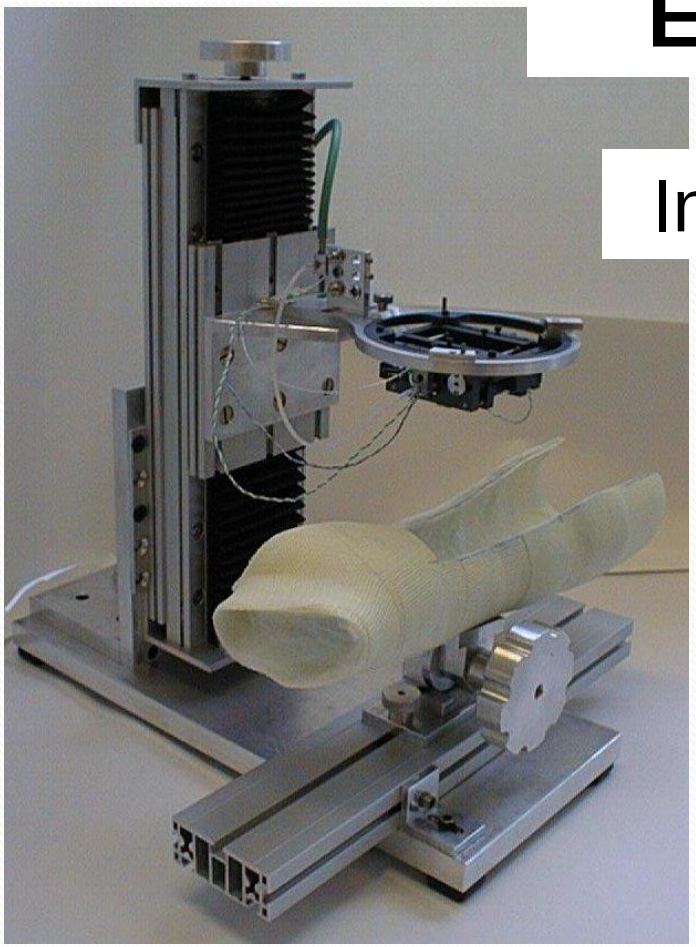
- Mechanical conditions of the test
- Behaviour easy to identify (anisotropy non linearity…)
- Easy of identification of the heterogeneity of the sample
- No ethical problem

Difficulties

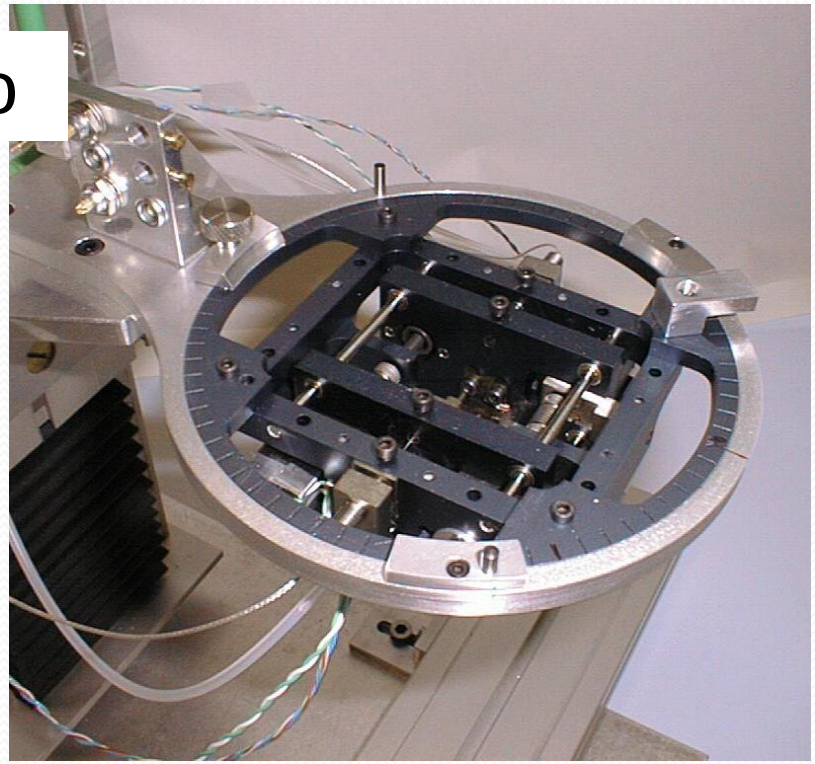
- Specific conditions of « ex vivo » tissue different from the in vivo ones
- Loading history
- No reproductibility
- Representative sample

Extensometer

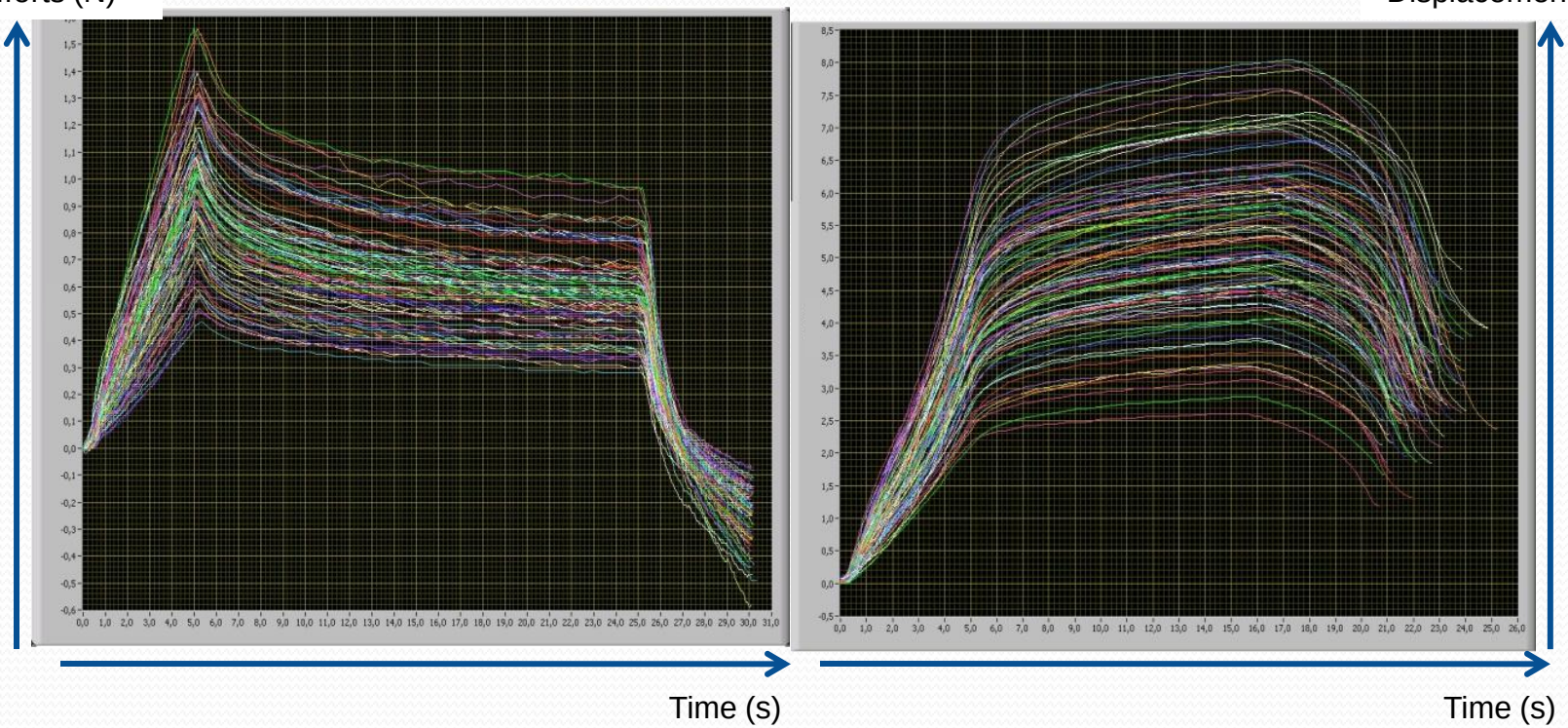
[Vescovo 2002]



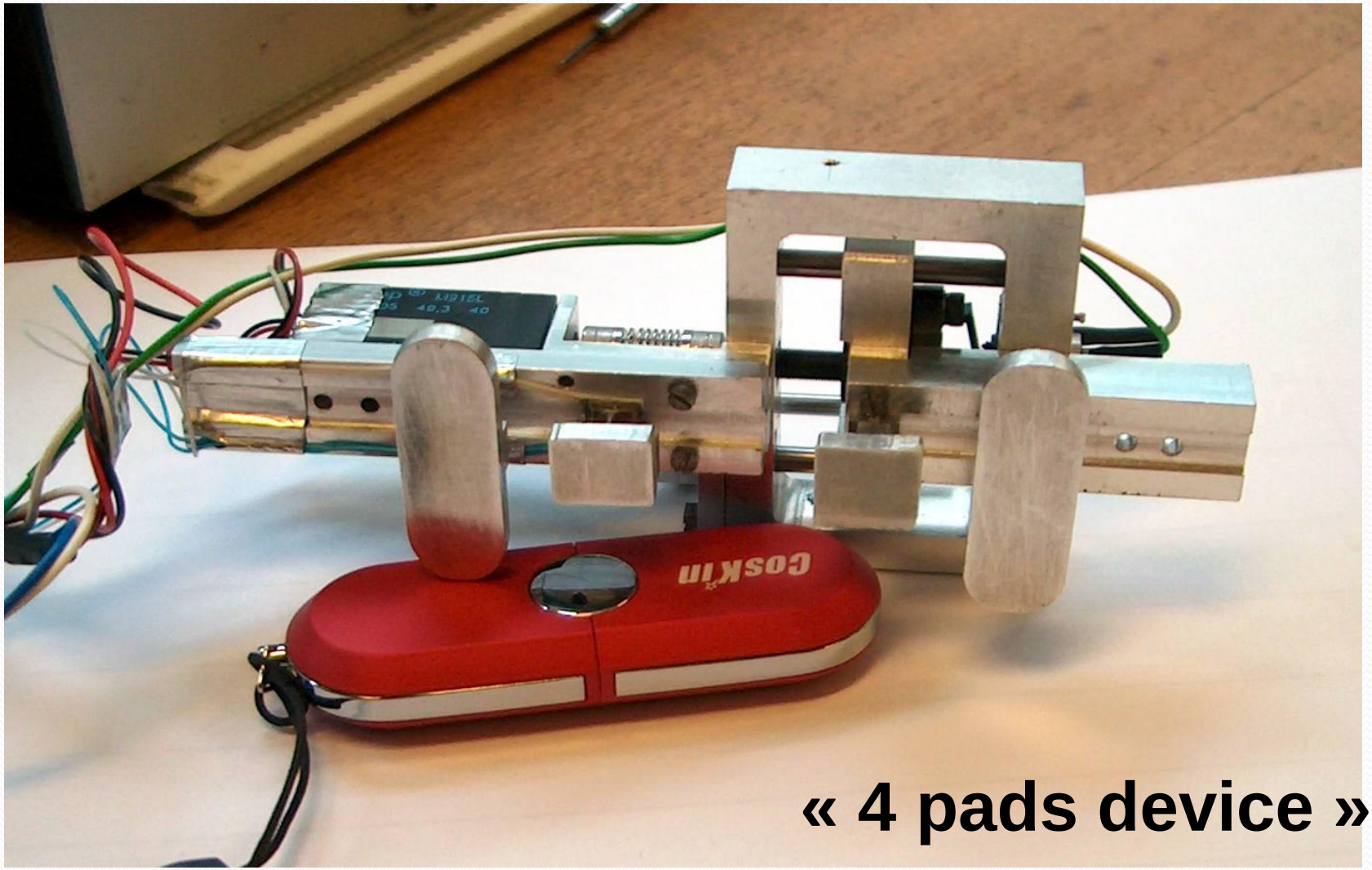
In vivo



Extensometer results - clinical tests relaxation and creep tests



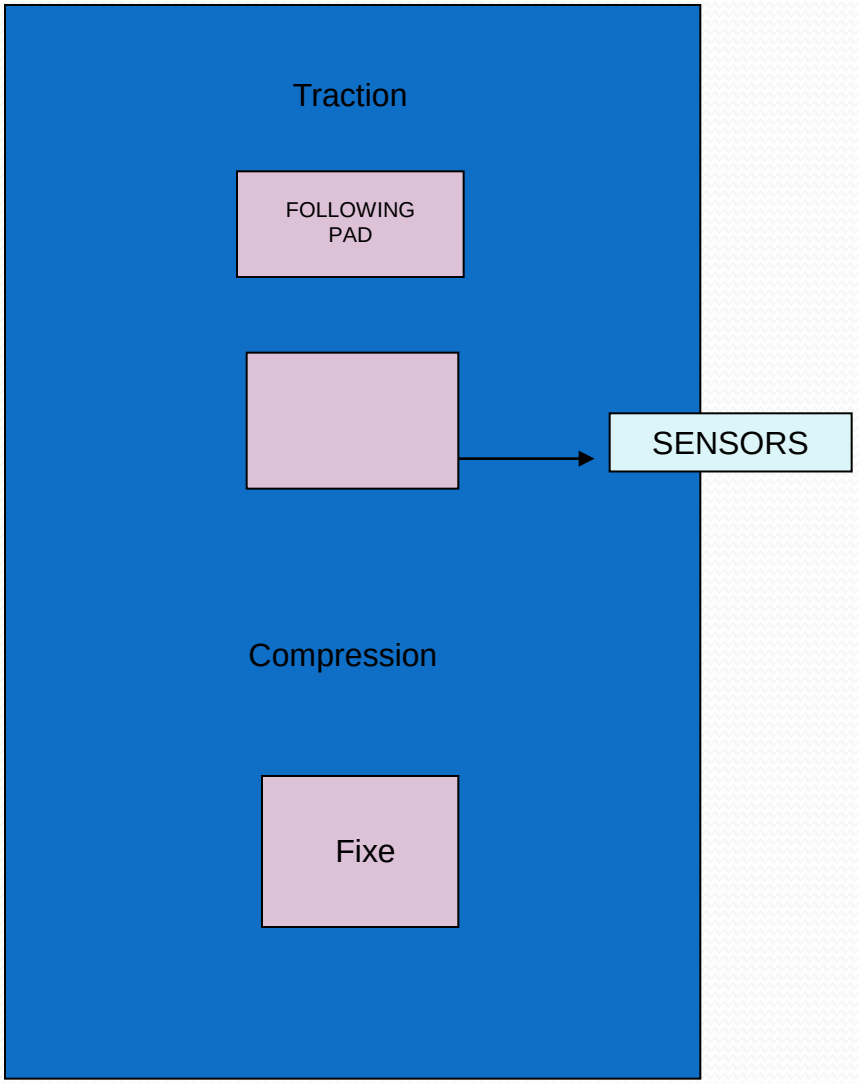
[Khatyr 2004]



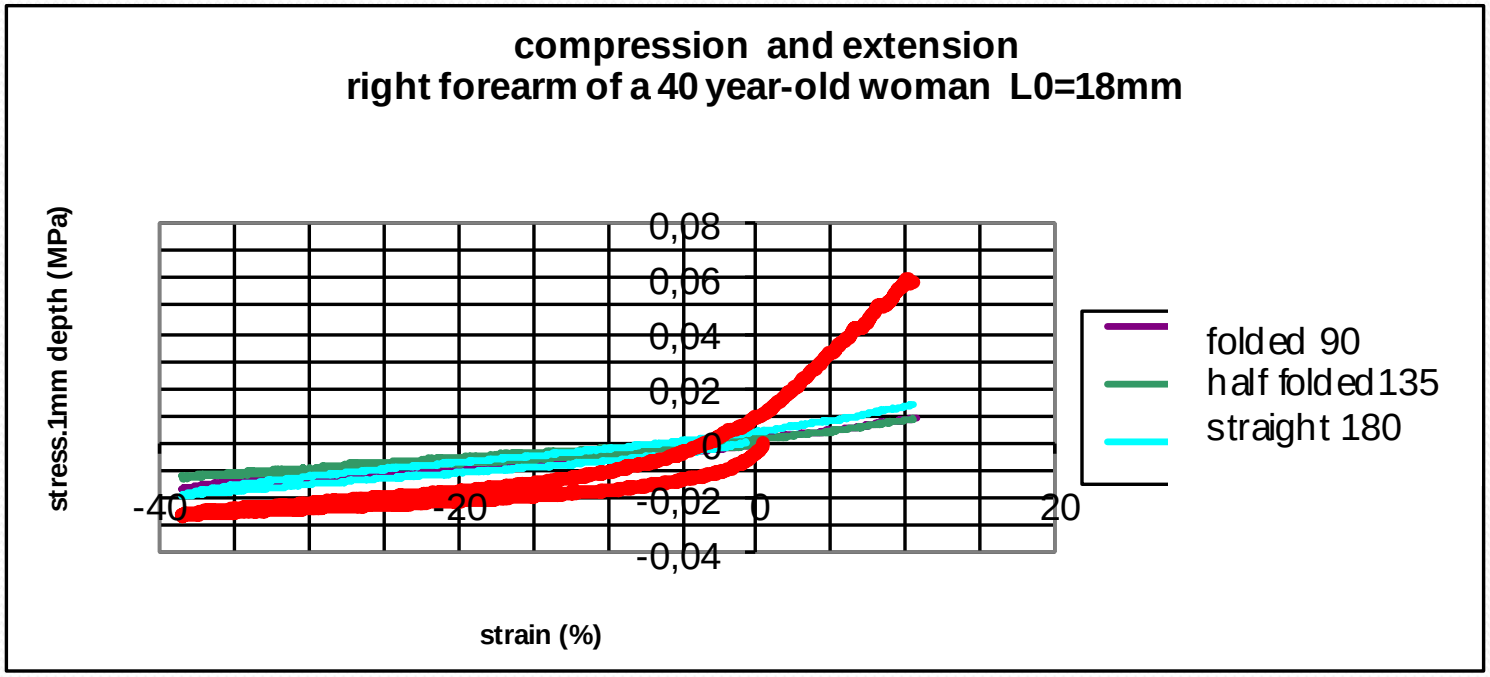
« 4 pads device »

[Jacquet 2006]

4 pads device diagram

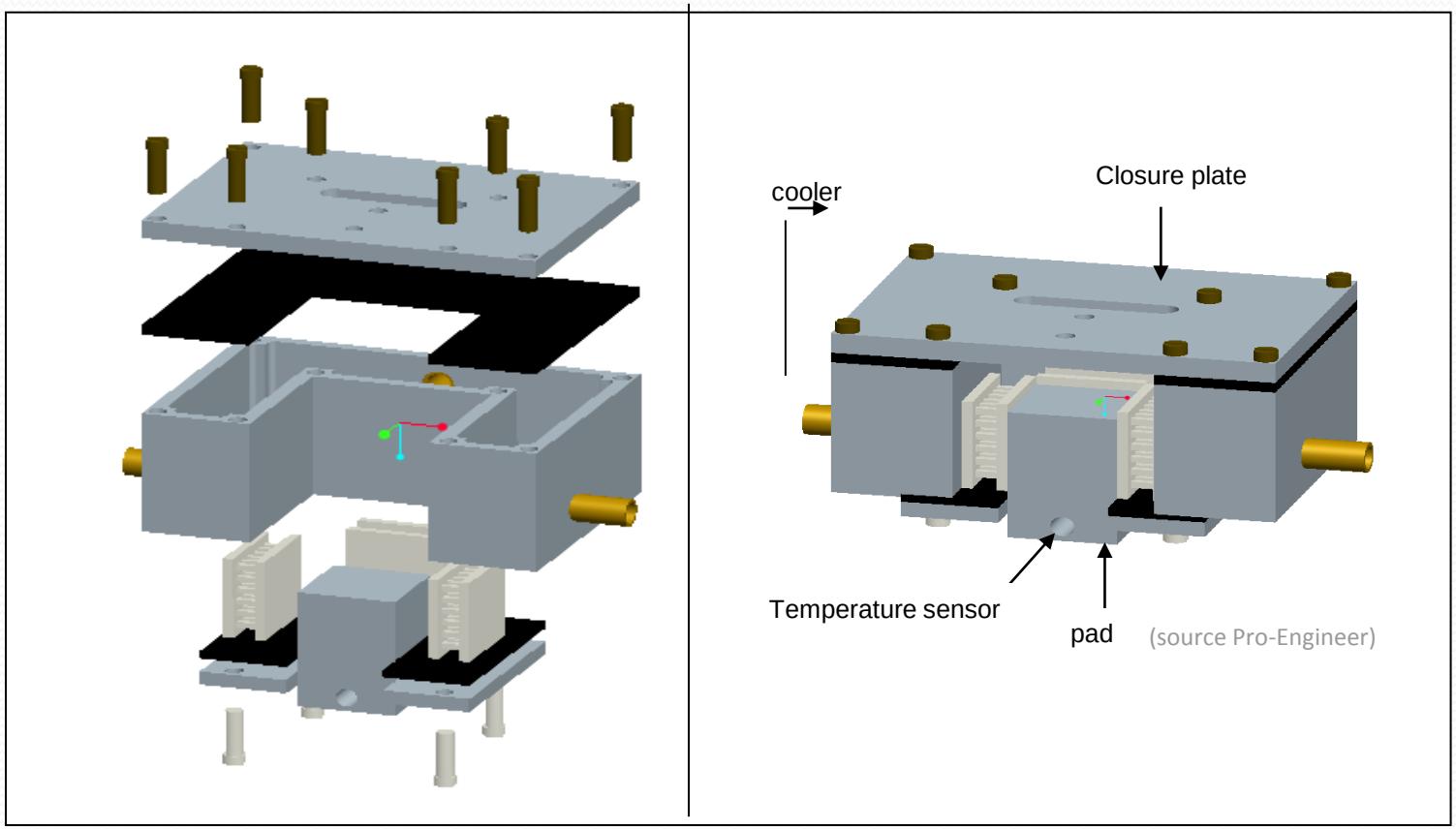


The forearm posture:



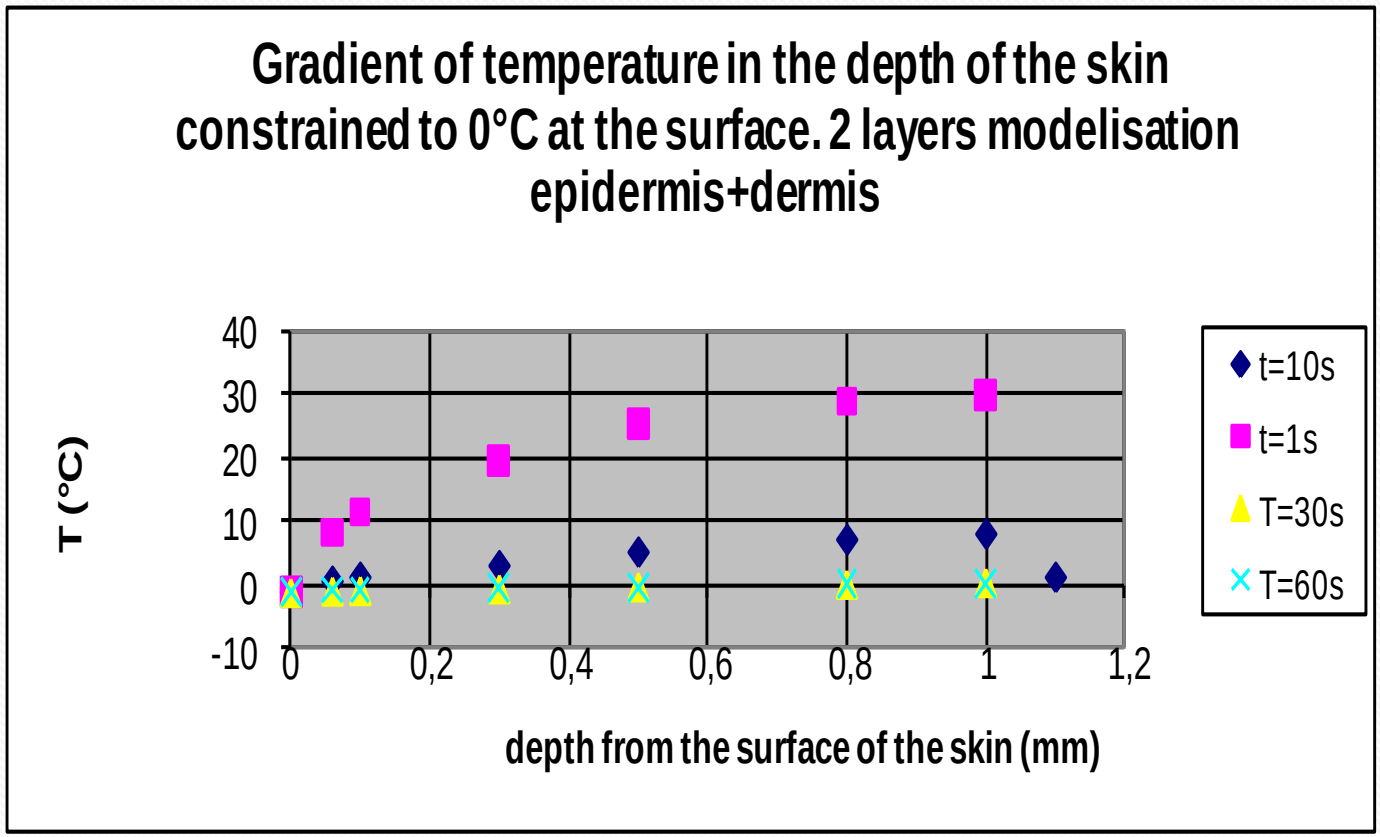
[Jacquet 2006]

Overview of the anchorage system



Modelisation of the thermal response of the anchorage system

- Numerical prediction of the **thermal field**
  - ✓ 2D modelisation of the multilayers material with different thermal properties
  - ✓ Static and dynamic prediction on the surface and in the depth of the skin
- Identification of **thermal parameters** from Infrared tests.
- Validation of the predicted thermal field in the all skin after 30s and 1mn


Gradient of temperature in the depth of the skin constrained to 0°C at the surface. 2 layers modelisation epidermis+dermis
T (°C)
40
30
20
10
0
-10
0
0,2
0,4
0,6
0,8
1
1,2
depth from the surface of the skin (mm)
t=10s
t=1s
T=30s
T=60s

Device **validation -** Neoprene sample

[Eva Ruvickova 2009]

Reproducibility

Temperature influence

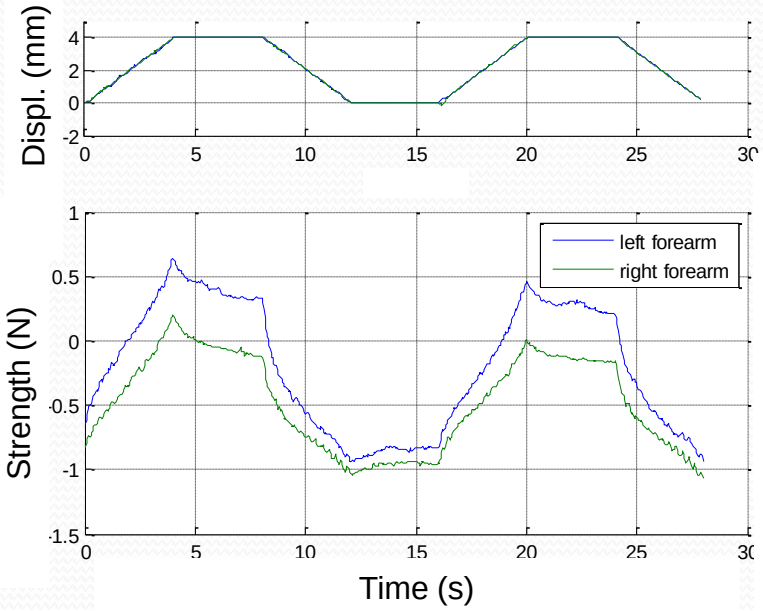
Progressive loadings

Loading speed influence

Holding time influence

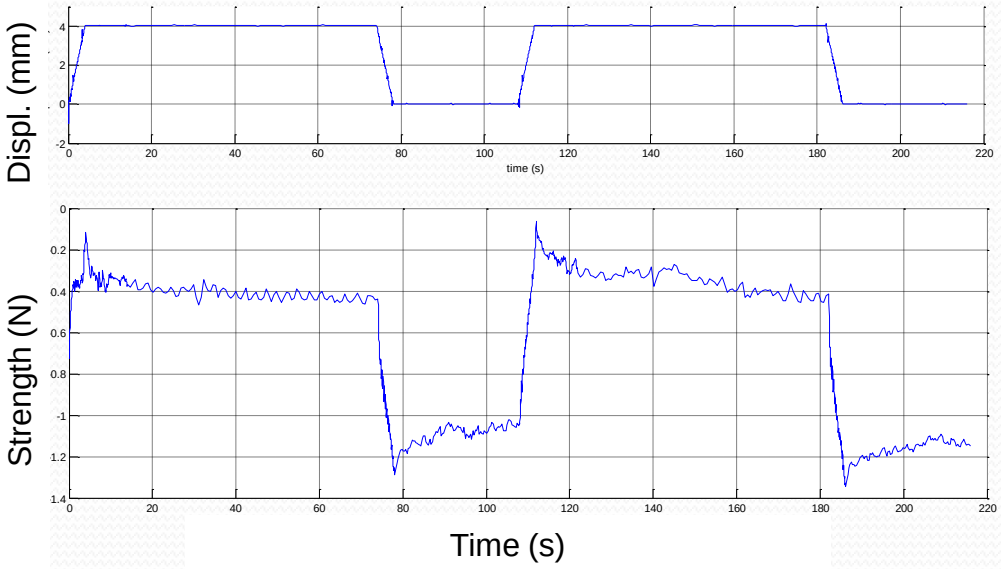
In vivo skin tests

Short time tests



[Eva Ruvickova 2009]

Long time test



Skin response after frozen anchorage and mechanical tests (from 30 s to 3 mn).

Compensation time-off:

between 2mn and 1h

No reaction after 3-4hours


conclusions and outlooks

Conclusion

- In vivo human skin Biomedical mechanical devices
- Modelisation of physical phenomena
- Natural stresses in human skin
- To be continued…

Outlooks

- Harmonic extensometer
- Biaxial test device (TUL czech republic)
- Development of cutaneous substitute (LIBC)
- Optimisation of suture technics (CHU)

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Thank you for your attention !