Validation of a new device dedicated to the mechanical characterisation of cartilage micropellets

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INTRODUCTION

- **Articular cartilage** ensures smooth motions and facilitates force transmissions.
- **Cartilage micropellet** is known as cartilage growth model [1].
- In literature, **very few studies** focus on the evolution of **mechanical properties over time** during growth [2].
- **A new device** were designed to assess mechanical properties of micropellets without removing there from their culture environment.

Objective : (i) To test if the new fluidic device damages soft microspheres subjected to large deformation and (ii) to estimate the precision of this new device to quantify mechanical properties.

MATERIALS & METHODS

- **Home made device :**

Fluidic system with 3D-printed tank (Figure 1). Fluid pressure applied at the top causes the sphere to sink into the cone and to deform. Pressure and displacement were recorded in order to estimate mechanical properties of the beads.

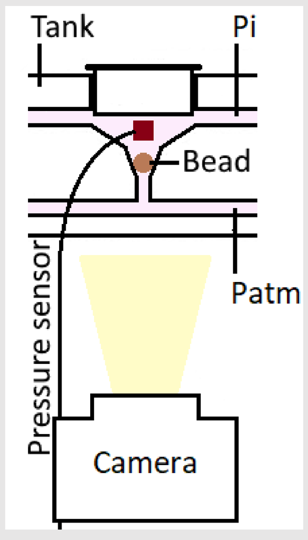
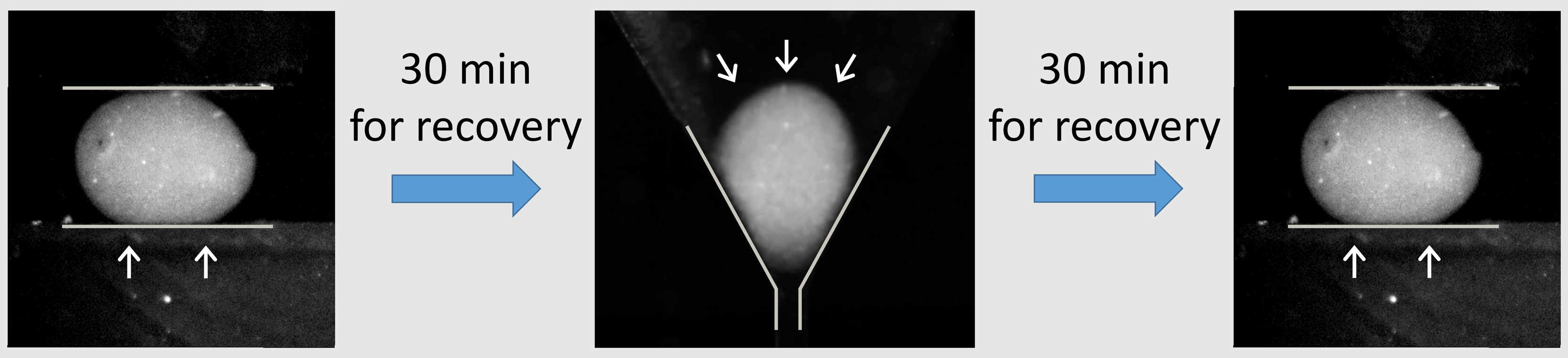


Figure 1 – Fluidic system of compression for microspheres.

- **Conventional compression device :** Beads were compressed between 2 planar surfaces in order to get ground values of the mechanical properties of the beads.
- **Beads :** 13 alginate beads (1,36 ± 0,13 mm in diameter) were made by polymerisation of a solution of 3% w/w sodium alginate in 0.15 M NaCl, in 0,1M CaCl2 during 24h.
- **Chronology of mechanical tests** (Figure 2) : In order to check if the beads were damaged by the large deformation with the new fluidic device, conventional compression tests were driven before and after the new fluidic test.

Figure 2 – Alginate beads in the conventional (left and right) and fluidic (centre) system during compression test.



Multi-relaxation test 1 :
8 ramps of 0,025 mm at about 0,1 mm/s
Maintained displacement during more than 30 sec

Multi-creep test :
6 ramps of 13 ± 1,4 kPa at about 160 kPa/s
10 picture during 2 min at the set pressure

Multi-relaxation test 2

- **Finite element identification procedures** (Figure 3) :

Specific finite element models, with Neo-Hookean law, were used to identify the mechanical properties of the beads. Briefly, numerical data were fitted on experimental data by tuning the mechanical properties of the bead.

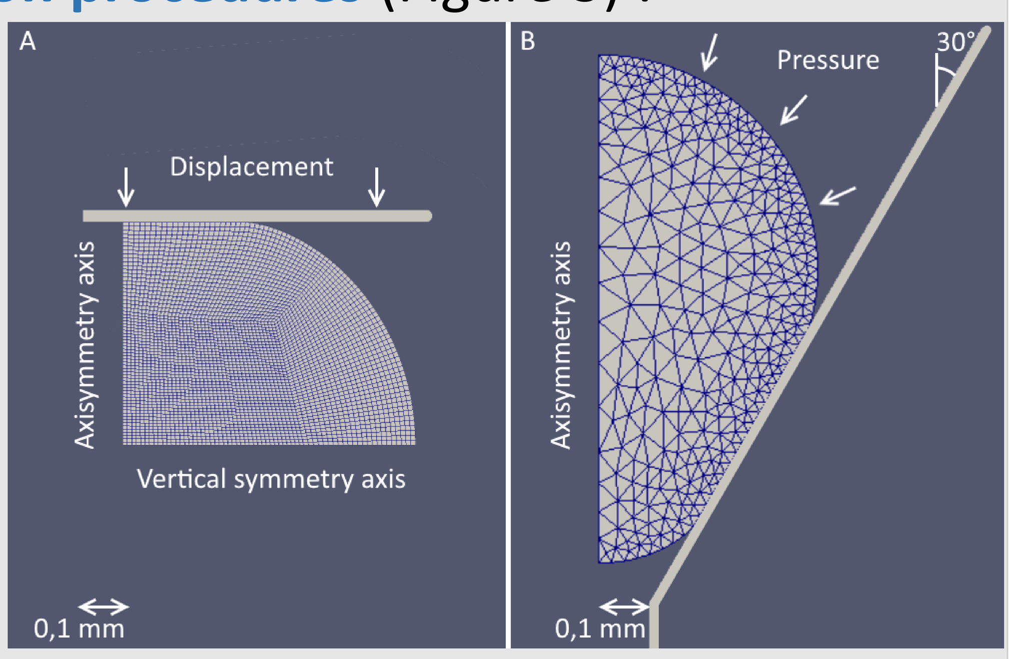


Figure 3 – Finite elements models and their boundary conditions for planar (A) and conical (B) compression – LMGC90.

- **Statistical analysis :** paired bilateral T-tests were used to compare the 3 mechanical tests.

RESULTS

- Fitted curves:

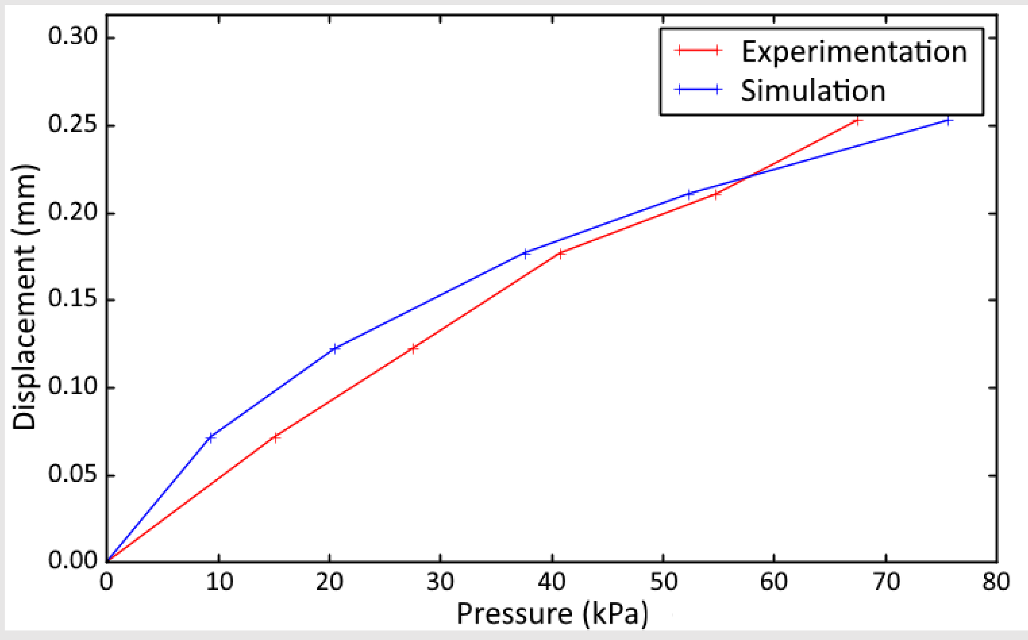


Figure 4 – Experimental and simulated displacements of the bottom of an alginate bead as a function of the pressure applied at the top of the bead.

- Determined Young's moduli:

	Conventional compression 1	Fluidic compression	Conventional compression 2
Mean	104,7 *$	107,0	97,8 *
Sd	29,1	36,0	19,1

Table 1 – Mean and standard deviation of Young's moduli (kPa) obtained for both testing devices; * p>0,25 compared to fluidic compression test; $ p=0,31 compared to the second conventional compression test.

DISCUSSION

- **No damage of alginate beads** (p=0,31 between both conventional tests) : results of both conventional and fluidic compression test can be compared and the system is non destructive for the spheres.
- **Similar Young's moduli** with both type of tests : new device allowed to characterise the mechanical properties of small spherical samples in a quantitative manner.
- **Limitation :** No perfect fit between experimental and numerical data because of a quite simple hyperelastic law.

CONCLUSION

- A **new fluidic system** is proposed to pressurise small soft spheres into a conical shape.
- This new setup, together with an identification procedure, is able **to quantify mechanical properties.**
- Fabricated with fully biocompatible materials, this new device should be able to **mechanically stimulate and to follow up mechanical properties of cartilage micropellets**.

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REFERENCES

[1] - Barry F, Boynton R E, Liu B, Murphy J M. 2001. Exp. Cell Res. 268. 2:189 200.
[2] - O'Conor, Christopher J, Case N, Guilak F. 2013. Stem Cell Res Ther. 4:61.