Development of an in- vitro model mimicking mechanical properties of brain cortex tissue

N. Neupane[1], K. Krajeswki[2], C. Damiani[3]
[1] Biomedical Engineering, Lübeck University of Applied Sciences (THL), Lübeck, Germany
[2] Altonaer Children's Hospital, Hamburg, Germany,
[3] Department of medical sensors and devices (MSGT) lab, Lübeck University of Applied Sciences, Lübeck, Germany

Introduction

- **Goal of this work:** Development and characterization of a stable phantom material that mimic the mechanical properties of the brain cortex tissue
- Materials such as hydrogels, polyvinyl alcohol, gelatin/ agarose are widely used for soft tissue mimicking phantoms. Unfortunately, these materials are not stable in the long-term and needs to be stored in a special storage conditions.
- In this work, Room Temperature Vulcanizing (RTV) silicone with different amounts of silicone oil was used as a phantom material.
- Preliminary tests were done by surgeons under simulated surgical condition to assess the samples properties and measure maximum force and deformation.

Methodologies

- Silicone samples with up to 50% vol. of silicone oil were prepared as explained in fig.1

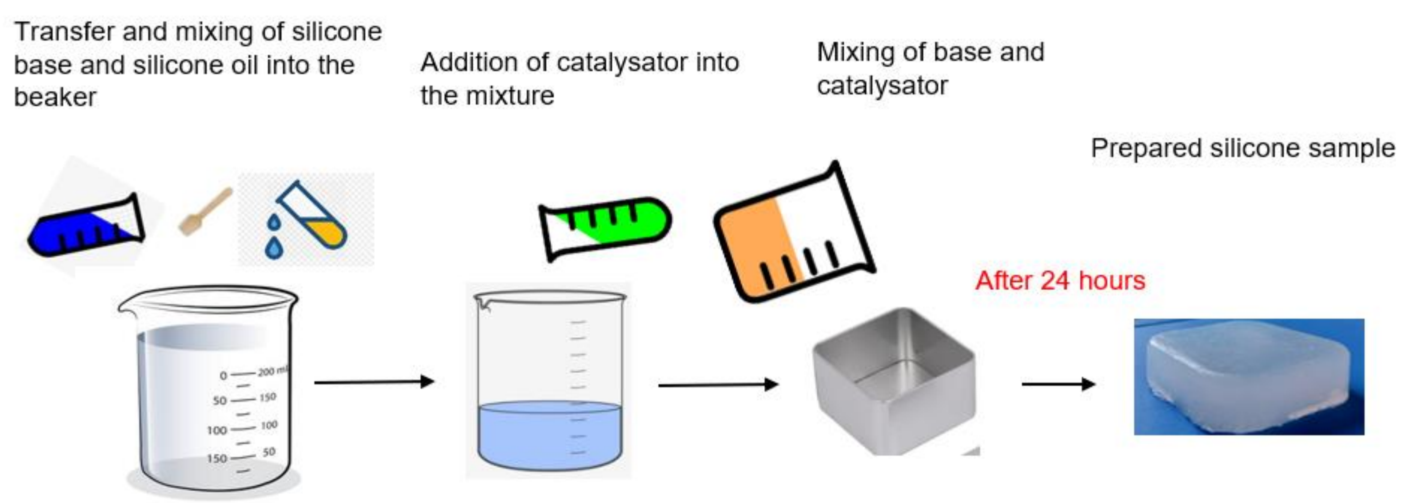

Fig. 1 – Preparation of silicone sample

- Unconfined compression relaxation testing with a flat, cylindrical indenter was done on the samples to determine the relaxation modulus at 120 s (see Fig. 2).
- Using an experimental setup developed at the lab (see contribution from R. Catena et al. at this conference), force and deformation applied to the specimens by brain surgeons with the help of a dissector and bipolar forceps were estimated empirically.
- The Surgeons were also asked to give a semi-quantitative feedback regarding the characteristics of the samples during the tests.

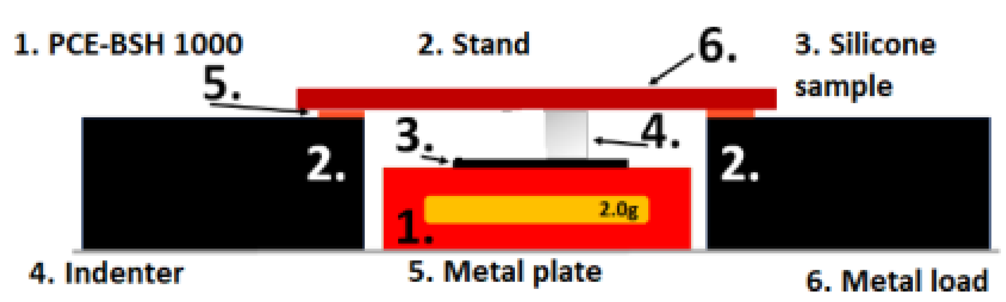

Fig. 2 – Experimental setup for unconfined compression- relaxation testing.

Results

Tab. 1 – Obtained relaxation modulus of the samples from compression-relaxation testing. It is seen that the relaxation modulus of the sample decreases with oil content.

Sample	Volume of silicone(ml)		Volume of oil (ml)	Concentration of oil (% vol)	Relaxation modulus (kPa)
	Base	Catalysator			
Sample 1	31	31	0	0	3.29
Sample 2	23.25	23.25	15.5	25	2.59
Sample 3	21.7	21.7	18.6	30	1.83
Sample 4	18.6	18.6	24.8	40	1.27
Sample 5	15.5	15.5	31	50	0.98

Tab. 2. – Semi- quantitative feedback of the samples from surgeon 1.

Sample	Stiffness compared to brain tissue	Stiffness compared to previous sample	Resemblance with the brain	Region of brain
0% vol. of oil	Higher		No	None
35% vol. of oil	Higher	Lower	Yes	Stiff glioma
40% vol. of oil	Similar	Lower	Yes	Cortex
25% vol. of oil	Higher	Higher	No	None
50% vol. of oil	Lower	Lower	Yes	Cerebellum

Tab. 3. – Semi- quantitative feedback of the samples from surgeon 2.

Sample	Stiffness compared to brain tissue	Stiffness compared to previous sample	Resemblance with the brain	Region of brain
0% vol. of oil	Higher		No	None
35% vol. of oil	Higher	Lower	Yes	Cortex
40% vol. of oil	Similar	Lower	Yes	Cerebellum
25% vol. of oil	Higher	Higher	No	None
50% vol. of oil	Lower	Lower	Yes	Cerebellum

- According to the surgeons, sample 4 closely resembled the behavior of brain cortex tissue.
- Sample 3 also felt similar to the brain cortex during the test, but it required higher effort during the dissection compared to brain cortex tissue.

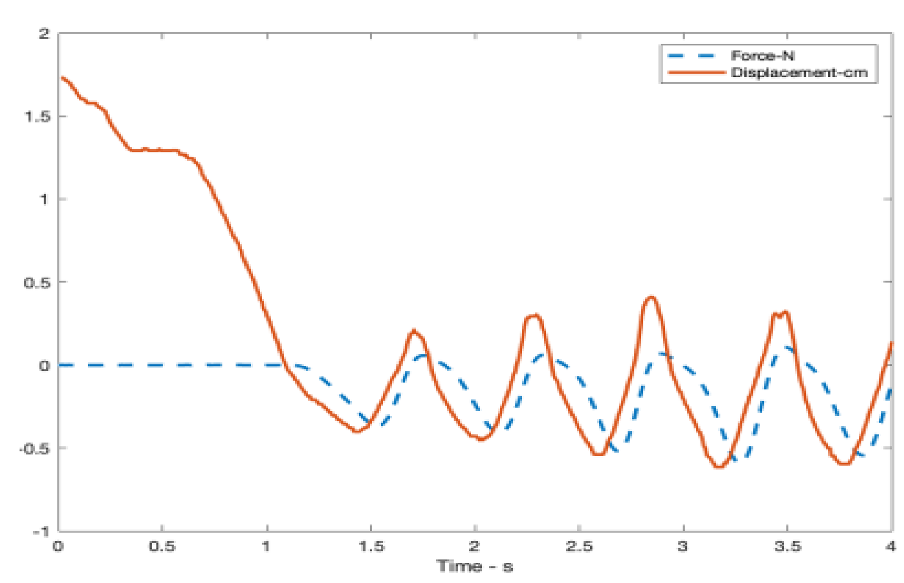

Fig. 3 – Force- deformation curve for 40% vol. of silicone sample under simulated surgical condition. Negative peaks represents compression. The deformation peak appeared before the force peak due to compliance of the sensor and inertia of the samples during the test.

Conclusion

- Silicone samples with similar mechanical properties to the brain cortex tissue were manufactured.
- The surgeons applied higher forces to samples with higher stiffness than to the sample similar to the brain cortex.
- A Larger number of empirical tests with optimized parameters are being planned to obtain more representative results.

References

[1] S. Budday, Fifty shades of brain: a review on the mechanical testing and modeling of brain tissue. Archives of Computational Methods in Engineering, vol. 27, no. 4, pp.1187-1230 , 2020.
[2] R. Catena, K. Krajeswki, C. Damiani, Experimental setup for the investigation of forces and displacement during brain surgery using medical phantoms . Luebeck student conference, 2023.

Corresponding author
Christian Damiani, M.Sc.
Lübeck University of Applied Sciences (THL)
Medical Sensors and Devices Laboratory
Mönkhofer Weg 239, 23562 Lübeck, Germany
Christian.damiani@th-luebeck.de

Acknowledgement
We thank Dr. Michael Worsch, Altonaer Children's Hospital, Hamburg, for participating in the experiment.