Comparing Soft Actuators for Enhancing MRI Pituitary Tumor Detection

Demetris Coleman[1], Thassyo Pinto[2], Chunqi Qian[3], Xiaobo Tan[2]
[1]Department of Electrical and Computer Engineering, Auburn University, Auburn, AL
[2]Department of Electrical and Computer Engineering, Michigan State University, East Lansing, MI
[3]Department of Radiology, Michigan State University, East Lansing, MI

Introduction

- The pituitary Gland releases hormones that regulate many organs within your body.
- Malignant tumors on this gland can grow and damage other parts of the brain.
- Benign tumors cause many adverse affects from vision problems to dysfunction of reproductive organs
- MRI scans considered the preferred method of detection
- Scans sometimes lack the detail for detection
- A coil in close proximity (sphenoid sinus) can be used to obtain a local image with higher resolution
- A soft actuator is needed to place the coil in the sphenoid sinus
- **Objective: Select and compare engineering materials to be used to make a biocompatible soft actuator to assist in detecting pituitary tumors.**

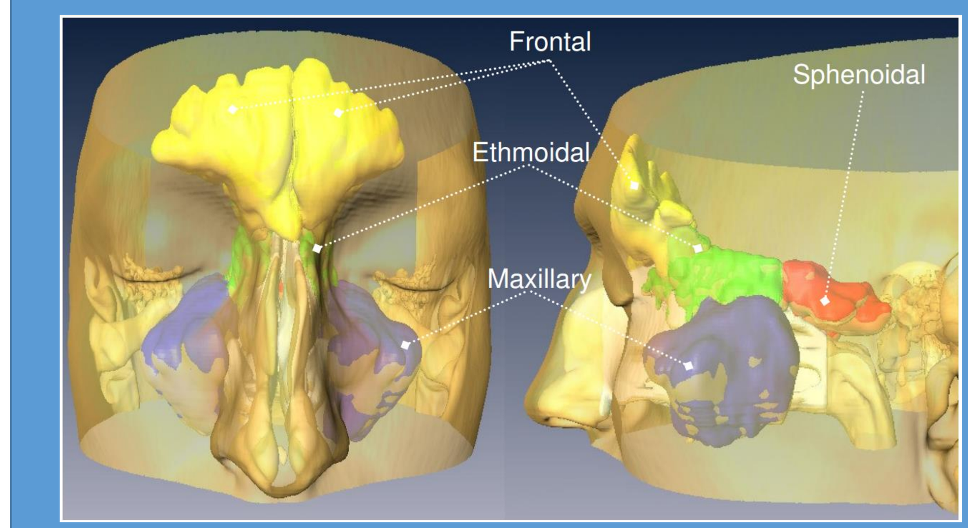

Figure 1: 3D reconstruction of nasal cavity and paranasal sinuses from CT images [1]

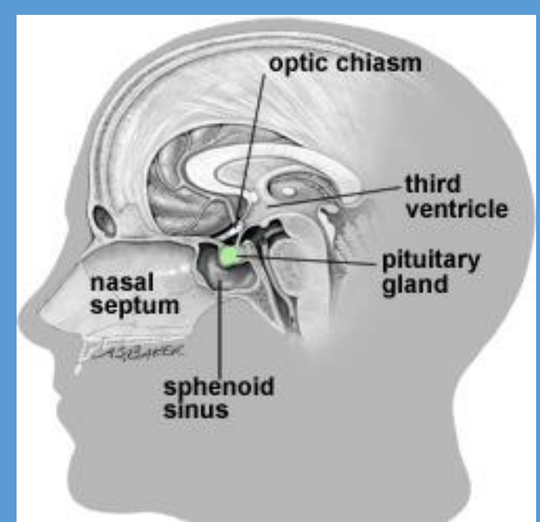

Figure 2: Relative location of Sphenoid Sinus and Pituitary Gland [2]

Methods and Materials

Materials

- 3D Printed SMP
  - Constructed using 3 Materials
  - Actuated by heat
  - Passively stimulated
- Pneumatic Actuator
  - Constructed using Dragon Skin 30
  - Pneumatic network of half-bellows
  - Actuated by pressure

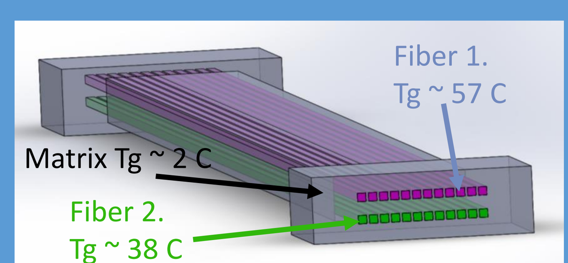

Figure 3: CAD drawing of large 3D Printed SMP

Figure 4: Picture of Pneumatic Actuator

Experimental Design

- Can the material be used in MRI
- Tested material specific properties
- Model of Nasal Cavities and Sinuses

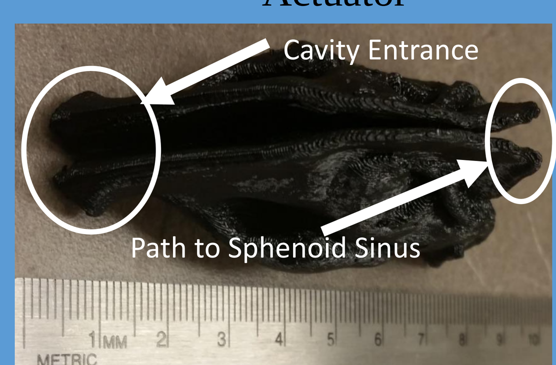

Figure 5: Picture of Nasal Model

Results

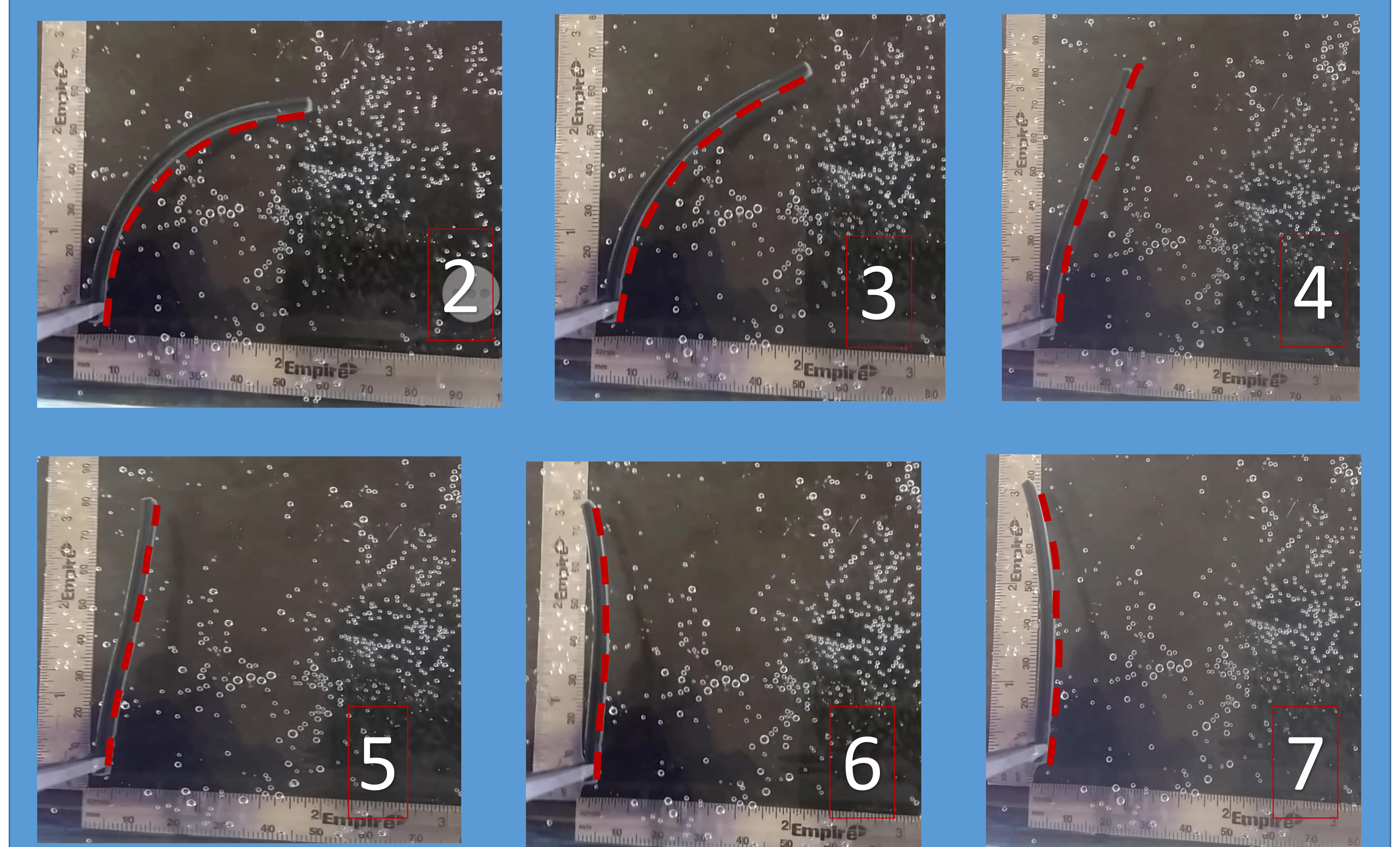

Figure 6: 3D printed SMP put into a water bath at 70 C about 45 seconds after being programmed. Dashed lines highlight curvature and numbers are seconds from entering bath.

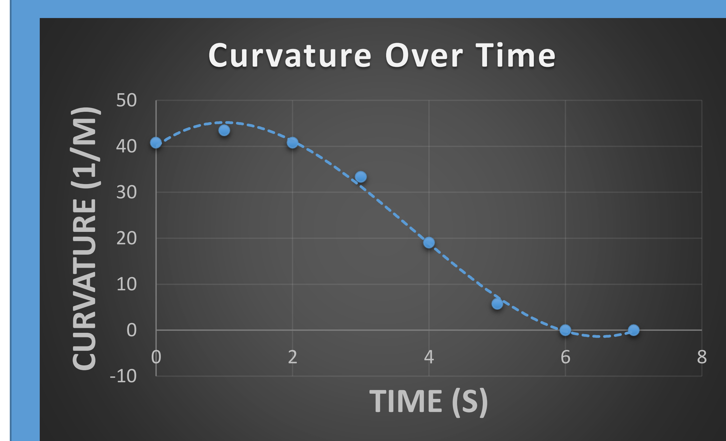

Figure 7: Curvature of 3D printed SMP as a function of time

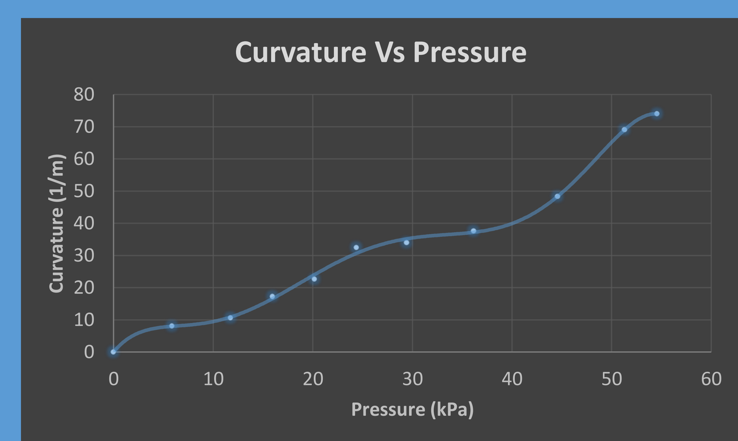

Figure 8: Curvature of Pneumatic Actuator as a function of pressure

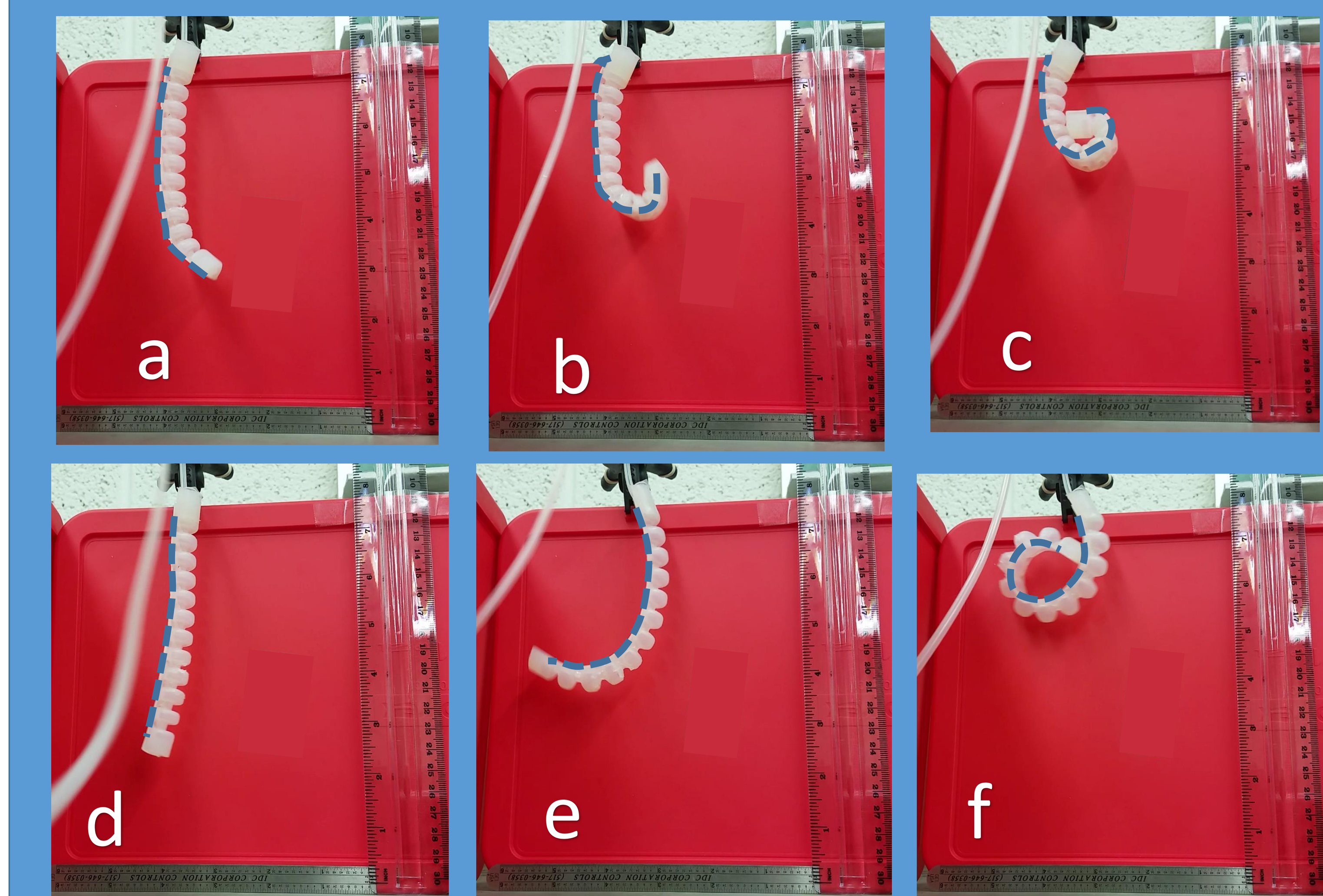

Figure 9: PNA actuated with positive (a-c) and negative (d-f) pressure.

Table 1: Properties and preliminary measurements

Material	Peak Curvature	Tg (C)	Load carried without large deformation	Hardness	Toxic	Pressure at failure	Max heat Requirement (C)
3D SMP	43	F1~57 F2~38 M~2	0.2 g	Shore D 82 Shore A 95 Shore A 28	No	NA	70
PNA	~70	NA	~.0 7 g	Shore A 30	No	~152 kPa	NA

Discussion and Conclusion

Pneumatic Actuator

Advantages

- Easy to control.
- Uses air pressure for actuation
- Multidirectional actuation.

Disadvantages

- Fabrication can be tedious and time consuming.

3D Printed SMP

Advantages

- Easiest to Reproduce and easily modifiable.
- Actuation is predictable

Disadvantages

- Actuation is passive (function of time and temperature).
- Must be reprogrammed after every actuation
- Weak actuation force.
- Stiff outside of actuation plane.

Pneumatic Actuators will be more suitable for the task due to the ease of control actuation. Both need to be tested at intended size under different loads and in an accurate replica of the nasal cavity.

Future Work

- Obtain Hardness and Elasticity Measurements for Tissue and Cartilage
- Create or obtain materials that mimic the cartilage and tissue to improve model of the nasal cavity and sinuses
- Explore alternative placement of the coil
- Thoroughly test force/load capabilities of materials
- Design expandable coil that will increase the area from local image
- Design and develop medical tool to assist with detection of pituitary tumor

Selected References

[1]M. Kunkel, A. Moral, M. Rilk and F. Wahl, "Towards a FEM Model of the Nasal Cavity and Paranasal Sinuses for Robot Assisted Endoscopic Sinus Surgery", *Institute for Robotics and Process Control*, 2016.
[2] M. Spine, "Pituitary tumors, adenoma, craniopharyngioma, rathke cyst", *Mayfieldclinic.com*, 2016.
[3] "What are pituitary tumors? | American Cancer Society", *Cancer.org*, 2016. [Online]. Available: http://www.cancer.org/cancer/pituitarytumors/detailedguide/pituitary-tumors-what-is-pituitary-tumor.
[4] S. Wakimoto, K. Ogura, K. Suzumori and Y. Nishioka, "Miniature Soft Hand with Curling Rubber Pneumatic Actuators", *Robotics and Automation*, pp. 556 - 561, 2009
[5] J. Wu, C. Yuan, Z. Ding, M. Isakov, Y. Mao, T. Wang, M. Dunn and H. Qi, "Multi-shape active composites by 3D printing of digital shape memory polymers", *Sci. Rep.*, vol. 6, p. 24224, 2016
[6] J. Leng, X. Lan, Y. Liu and S. Du, "Shape-memory polymers and their composites: Stimulus methods and applications", *Progress in Materials Science*, vol. 56, no. 7, pp. 1077-1135, 2011.

Acknowledgements

I would like to give a special acknowledgement to the SROP facilitators and faculty.