3D MODEL OF THE MOUTH AND TONGUE

Marie Greuel[1] (Team Leader), Tyler Lieberthal[1] (Communicator), Kelly Hanneken[1] (BWIG), Denise Wong[1] (BSAC)
Client: Dr. JoAnne Robbins[2,3] and Jackie Hind[2] · Advisor: Mitch Tyler[1]
[1]Department of Biomedical Engineering, University of Wisconsin-Madison, [2]VA Hospital, Madison, Wisconsin, [3]Professor, Department of Medicine, UW School of Medicine and Public Health

1. Abstract

Swallowing is essential for life. However, a large geriatric population suffers from dysphagia, which is having difficulty in swallowing. A 3D mouth model is needed for research and educational purposes to fully understand normal and abnormal swallowing. Building upon the tongue prototype developed by previous BME Design teams, the team built a stable base to act as the pharyngeal wall and support the tongue; and a mouth cavity compatible with the Madison Oral Strengthening Therapeutic (MOST) device. The hard palate and the base were manufactured via 3D printing and a laser cutter respectively. The team tested the prototype with the MOST and found that the data collected were precise but generally lower than the human data provided by the literature.

2. Background/Motivation

Client: Dr. JoAnne Robbins, Professor of Medicine at UW School of Medicine and Public Health, and Associate Director of the GRECC.

Background:
•Swallowing is a very complex physiological process
•Swallowing primarily consists of 3 stages: oral, pharyngeal, and esophageal[2]

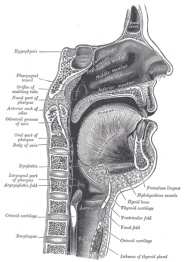

Figure 1: Anatomy involved in swallowing[1]

Motivation:
- Our client has requested a device that can model the human swallow
- Dysphagia, or difficulty swallowing, affects many and can lead to life-threatening illness such as dehydration, malnutrition, and pneumonia. Also, quality of life is significantly decreased
- Dysphagia can be caused by neurodegenerative diseases, brain injury, and stroke

3. Design Specifications

- Allow for full tongue movement
- Be compatible with the MOST device in order to detect pressures generated by the tongue
- Permit realistic pressures during testing
- Mirror the physiology and anatomy of the human oral structures
- Allow for future modifications

4. Design – Enclosed Mouth Cavity

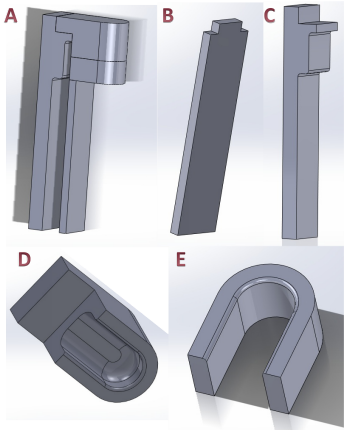

Figure 2: SolidWorks images of the enclosed mouth cavity design. (A) Fully assembled model with (B) front wall support, (C) pharyngeal wall, (D) hard palate (ventral view), and (E) mandible.

Features:
- Removable hard palate that is secured in place by hooks on pharyngeal wall and mandible
- Hard palate with a cavity for the tongue to press against
- Mandible to support the tongue
- Front support to elevate tongue to appropriate height
- Pharyngeal wall extended toward the tongue in order to allow for the tongue to press up against it
- Tubes between pharyngeal wall and front support to mimic the esophagus and trachea

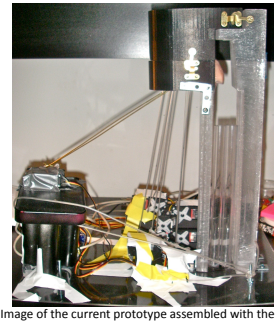

Figure 3: Image of the current prototype assembled with the hard palate, mandible, front support, and pharyngeal wall around the tongue.

5. Testing

- Lingual pressure measured with MOST device
- Measurements of max isometric pressure for each sensor taken

Protocol:
1. Start and Zero the MOST Device
2. Mold the mouthpiece of the MOST to the hard palate
3. Secure the hard palate to the prototype
4. Run MInT_program concerted movement or individual servo movement for ~5 seconds
5. Return the MInT_program to default, stop the MOST device, and remove MOST from hard palate

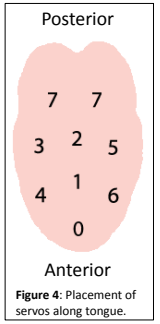

Figure 4: Placement of servos along tongue.

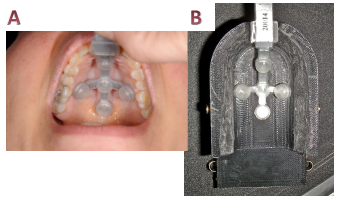

Figure 6. Placement of MOST mouthpiece in (A) human subject[3] and (B) MInT device. The five sensors of the MOST device record the forces applied.

	Sensor targeted	Program run	Servo(s) moved
Trials 1-3	--	Generic swallow	All
Trials 4-9	Anterior midsagittal	Individual servo	0
Trials 10-15	Left lateral	Individual servo	6
Trials 16-21	Middle midsagittal	Individual servo	1
Trials 22-27	Right lateral	Individual servo	3
Trials 28-32	Posterior midsagittal	Individual servo	2

Table 1. Sensor test and servo position. Trials 1-3 gathered data from all sensors during a sequenced swallow. Trials 4-32 gathered data for peak isometric pressure against one sensor.

6. Results & Discussion

	SD	Percentile
Anterior Midsaggital		
Group 1 (21-40 Years)	-1.794	3.6
Group 2 (41- 60 Years)	-1.083	14
Group 3 (61+ Years)	-1.079	14
Left Lateral		
Group 1 (21-40 Years)	-1.514	6.55
Group 2 (41-60 Years)	-1.183	13.14
Group 3 (61+ Years)	-0.04187	33.8
Middle Midsaggital		
Group 1 (21-40 Years)	-0.7266	23.27
Group 2 (41-60 Years)	-0.4408	33
Group 3 (61+ Years)	-0.2466	40.13
Right Lateral		
Group 1 (21-40 Years)	-0.6469	35.78
Group 2 (41-60 Years)	-0.4604	32.28
Group 3 (61+ Years)	-0.114	45.62
Posterior Midsaggital		
Group 1 (21-40 Years)	-1.0624	14.46
Group 2 (41-60 Years)	-1.0508	14.69
Group 3 (61 + Years)	-0.6388	26.11

Table 2: Standard deviation (SD) device falls from human averages and percentiles

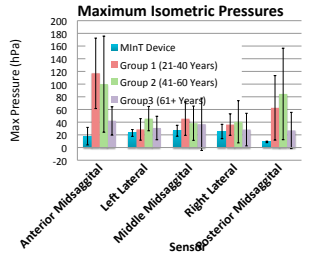

Figure 7: Mean (±SD) maximum isometric pressures. Human data for three age groups compared to MInT test results.

- All sensors performed below the human average (percentile<50) found by Banaszynski[3]
- Model best represents population of 61 years and up (Mean Percentile: 31.93), followed by 41-60 year olds (Mean Percentile: 21.422), and lastly 21-40 year olds (Mean Percentile: 16.72)
- Right lateral consistently performed most accurately

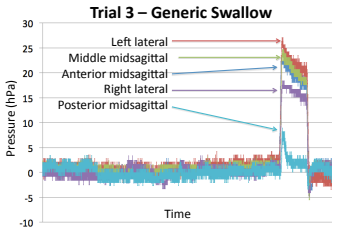

Figure 8. Pressures generated during swallow for trial 3. Real-time subject data for pressures along various locations of the tongue during swallowing not available.

7. Future Works

Tongue:
- Materials: servo movement &
- Servos: not powerful enough to simulate real tongue movement
- Organization: better placement of servos and stabilization

Oral cavity:
•Transparency of hard palate preferred
•Inner coating and lubrication are needed to mimic the friction generated
•Shape of the mandible

8. Acknowledgements

Special thanks to:
Professor JoAnne Robbins and Jackie Hind (clients), Mitch Tyler (advisor), Naomi Humpal, Junerose Juan, and Professor Puccinelli.

9. References

[1] Gray's Anatomy 1918 edition
[2] McCaffrey, Patrick. (1994). The Neuroscience on the the Web Series: CMSD 642 Neuropathologies of swallowing and speech. CSU, Chico. Physiology of the Swallow.
[3] Banaszynski, (2012). Normative Lingual Pressure Study Using the Madison Oral Strengthening Therapeutic (MOST) Device. Unpublished raw data.