

DEVELOPING A 3D MODEL OF THE TONGUE AND MOUTH TO ASSESS PRESSURE GENERATION WHEN SWALLOWING

TEAM: Don Weier, Matthew Zanotelli, Naomi Humpal, Lucas Haug
CLIENT: Professor JoAnne Robbins, Ph.D. – UW School of Medicine and Public Health
ADVISOR: Thomas Yen, Department of Biomedical Engineering – University of Wisconsin - Madison

Abstract

Swallowing is a unique and complex system of muscle movements that the body performs hundreds of times each day. The process is perceived as a fairly automatic motion that is usually only considered in the case of malfunction, such as choking or aspiration [1]. These disorders and dysphagia in general are areas in need of further research. A synthetic hydrostat that can replicate the motions of a true tongue would be invaluable in advancing current knowledge of dysphagia. This mechanical tongue will be used to measure pressure distribution and pressure points in the mouth, and ultimately would be used to study the effects of specific muscle failure during the swallowing process. Using a complex system of cables and distributed forces, the model tongue is constructed to accurately model the movement of the tongue throughout a swallowing motion. Silicone is used to represent the overall structure of the tongue and nylon cables are embedded in the tongue to actuate the structure.

Problem Definition

Motivation

- Dysphagia (the inability or difficulty for to swallow properly) is a disorder affecting a large number and wide variety of people [2]
- When left untreated can lead to more damaging and sometimes lethal complications
 - Pneumonia
 - Malnutrition
 - dehydration
- No current devices dedicated to studying dysphagia
- a phantom mouth model needs to be constructed
- This semesters focus: mechanical tongue

Current Devices

- No device has been specifically created to study swallowing mechanics
- Other animatronic devices have been developed
 - Robotic Dental Test Dummies
 - Showa Hanco 2 [3]
- Animatronic Model of a Human Tongue and Vocal Tract [4]
- Hollywood special effects

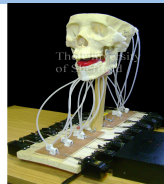


Figure 1. The Anton Model of a Human tongue and Vocal Tract. [4]

Problem Statement

- No current devices are available for studying Dysphagia
- A phantom mouth model needs to be constructed
- Needs to be able to:
 - Accurately mimic mechanical properties of the tongue and palate
 - Replicate proper pressure distribution and mechanics
- Used to compare pressure generation at various points in the oral cavity during swallowing

Design Criteria

- Produce pressure of 40 – 80 Kpa
- Actuators fail at 180 Newtons (40 lb.)
- Actuators directed along the lines of action in a true tongue
- Actuator coordination
- Temperature resistant
- Waterproof
- Can return to resting shape easily
- Ability to easily clean and sterilize
- All moving pieces must be protected
- Non-allergenic material

Swallowing Process



Figure 2. MRI photographs of significant stages of the the swallowing process in series.

Final Design

Muscles Replicated

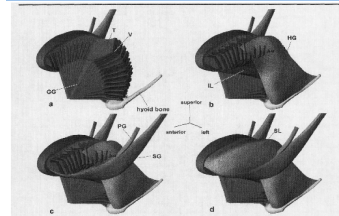


Figure 3. Three-dimensional schemata of the tongue musculature indicating geometrical arrangement of muscle fibers [5].

Lines of Action

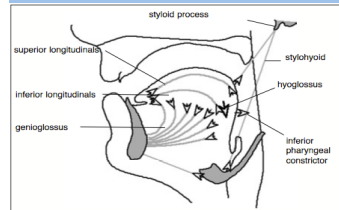


Figure 4 Schematic diagram of the actions of some of the muscles of the tongue [6].

Molding Process

Molding was accomplished in a series of 4 modeling stages. Each stage further developing the previous mold. The following clay model depicts the process

Stage 1

- Alginat mold for entire model tongue created
- Initial silicone mold created

Stage 2

- 3 meshes
- 5 attachment points
- Muscles to be replicated:
 - Anterior Genioglossus
 - Inferior longitudinal muscle
 - Styloglossus



Stage 3

- 1 mesh
- 1 attachment point
- Muscles to be replicated:
 - Central Genioglossus



Stage 4:

- 1 mesh
- 3 attachment points
- Muscles to be replicated:
 - Posterior Genioglossus
 - 2 Hyoglossus muscles



Results

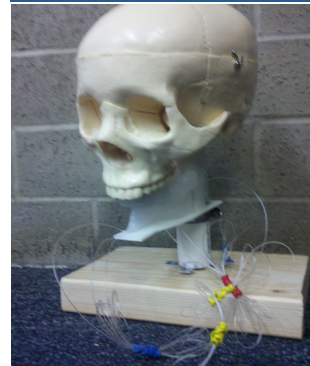


Figure 5. The prototype model tongue mounted to properly rest within a replicate human skull. The series of cables departing from the model tongue replicate the lines of action and can be manipulated to reproduce muscle motions during the swallowing process.

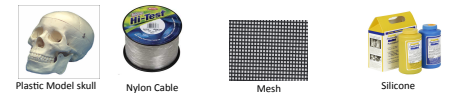


Figure 6. The prototype model moth adhered to a mount.

- 9 cables connect to system of meshes embedded in silicone body
 - Mesh distributes forces
- Muscle movements replicated:
 - Genioglossus – protrudes, depresses center
 - Hyoglossus – depresses
 - Styloglossus – elevates and retracts
 - Inferior longitudinal – flattening and rounding

Parts List and Cost

•2 Quarts Silicone.....	\$60.00
•3 lb. Alginate Molding Material.....	\$21.00
•Plastic Screening Mesh.....	\$6.00
•Nylon Cable.....	\$4.00
•Base and Support.....	\$6.00
•Sculpey.....	\$11.00
•Shipping.....	\$15.00
•Plastic Model Skull.....	\$25.00
•Plastic Tubing.....	\$1.00
TOTAL:	\$149.00



Future Work

- Improve molding process
- Refine prototype efficiency
 - Mesh placement to include lengthwise genioglossus
 - Silicone density
 - Cable lines of action
- Add automatic system
 - Series of servo motors
 - Programming to coordinate actuators
- Construct surrounding tissue to complete mouth and throat model
 - Mechanical jaw
 - Mechanical throat muscles
- Testing
 - Pressure mapping
 - Motion replication

References

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