

Developing a 3D model of the Tongue and Mouth to Assess Pressure Generation When Swallowing

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Function:

The device must be a physical 3D model of the tongue, mouth, and throat that closely mimics the mechanism of human swallowing. This semester's design will focus on creating a functioning, mechanical tongue that have the ability to realistically mimic swallowing motions of an adult, human tongue. The synthetic tongue will need replicate proper pressure distribution and mechanics. It will be used to test different pressure testing devices and also to determine the ease of swallowing different foods and liquids under different neuromuscular conditions.

Client requirements:

- A sturdy design to allow for daily use
- Waterproof material for liquid studies
- Easy to clean (Sterilization not necessary)
- Ability to be swallow hot and cold samples
- Stain-protected material

Physical and Operational Characteristics

Performance Requirements:

The product will be demanded to perform the functions of the tongue, specifically the swallowing mechanism. In order to fully model and replicate swallowing and the fluid dynamics of the human mouth, the product will be required to: transport the bolus from the anterior to posterior oral cavity for passage to the pharynx, simulate epiglottis down-folding, perform top to

bottom contractions of pharyngeal constrictor muscles, and ultimately relaxation of the cricopharygeus muscle. In order to achieve this, a functioning, animatronic tongue will be needed. The mechanical tongue will be required to make all necessary movements in a life-like manner, as well as create proper pressure distribution. Additionally, the product will need to perform these tasks on a daily basis and interact successfully with both hot and cold food, as well as liquids.

Safety:

The product should be made to be very user friendly. This requires all proper safety factors including safety guards for any hydraulic systems and smooth surfaces on exposed parts to prevent injury. All air compressed powered hydraulic and electrical systems need to properly labeled with necessary warnings. Again, to ensure safety and functionality, all animatronics cables need to be imbedded in material, properly covered, and properly secured to the base structure. Servomotors, circuit boards, and other animatronics mechanisms need to be securely mounted to a base structure and covered. Additionally, non-allergen materials should be utilized.

Accuracy and Reliability:

This product will need to have a great deal of precision (repeatability) in the movements and replicated swallowing fluid dynamics it will provide. Furthermore, the product will need to accurately simulate the swallowing mechanism of the tongue. To model the most typical case, the design should mimic an adult's tongue as closely as possible. In order to ensure accuracy and reliability the tongue will be mounted to a rough structure of the lower mandible/jaw and rest inside a scale model mouth. The proper mouth specification (both size and function) should be designed as close to a typical adult's as possible.

Life in Service:

The product will need to be used daily for multiple demonstrations by various users. This continuous use should be able to persist for several years without any deterioration of materials and with sustained mechanical efficiency.

Shelf Life:

While in storage, the product should be able to withstand temperature changes from a range of 15° C – 40° C. The product will use servomotors and electricity to power its functions. Consequently, the shelf life of batteries and other powering sources do need to be taken into consideration. The materials the product will be comprised of will need to have shelf life of 5 – 10 years, so the product can be cost effective and have proper usage.

Operating Environment:

The device will be exposed to a great deal of water and anything edible during its time of use. It will need to operate with both hot and cold food (15°C - 40°C). The product also be required to endure frequent contact with fluid (i.e. water, other consumable fluids, saliva), vibrations (i.e. air compressor), and specific parts of the model will need to endure pressure conditions created by the physiology of swallowing. During storage, the model will need to be able to be exposed to dust, dirt, humidity, and extended non-use. Because of the nature of this device – modeling – the product will be exposed to extended handling and use.

Ergonomics:

This device will need to be very user friendly and easy to use. The forces exerted by the pulling and pushing of the animatronics system used will be similar to the force exerted by the typical human tongue during swallowing. Primarily, the product should be light enough to be easy and straightforward to transport by a single individual.

Size:

The size of the product should be similar to the dimensions of the typical human mouth and jaw, while being easy to transport. This will require a degree of portability and limitation of additional components besides the model mouth itself.

Weight:

The maximum weight of the product is 50 lbs. to ensure ease of transportation and there is no minimum weight for the design. A lighter product would be ideal; however, weight is a low priority consideration in this design.

Materials:

Materials that will resemble the human figure should be used for the product. There are no specific materials that should not be used. All synthetic material and animatronics cables and motors need to be of a durable nature.

Aesthetics, Appearance, and Finish:

The product should resemble an actual human tongue as much as possible. There should be proper color and texture to the design that will resemble the tongue in order to suitably depict adult, human swallowing movements and feel. The client has requested to avoid red materials and utilize materials that do not absorb dye.

Production characteristics

Quantity:

The client has requested a single model for use in the lab. If the project is successful, more could be produced for labs elsewhere.

Target Product Cost:

The cost of the materials used to construct the prototype should not exceed \$300, in order to fit the budget provided.

Miscellaneous

Standards and Specifications:

The device is not drug related so therefore doesn't have to be approved by the FDA, but could possibly have to undergo some other inspection in order to be used by businesses. Mainly, the students building the model will set the standards for this project.

Customer:

The product's most important use will be to serve as a testing subject for the other pressure sensors developed, The Madison Oral Strengthening Therapeutic (MOST) device and The Iowa Oral Performance Instrument (IOPI). The main use of the device that will be focused on is recreating the pressure and swallowing motion created by the tongue. The highest priority for the customer is ensuring accuracy in this regard.

Patient-related Concerns:

Because its purpose is outside of clinical contact with human subjects, the device does not necessarily need to be sterilized between uses, but will need to be easily cleaned to avoid mold and rotting food particles building up.

Competition:

Currently there are few devices resembling the proposed design, and none meant to study swallowing. There is, however, one line of devices that will be considered while designing the prototype. The dental community has innovated several versions of mechanical, interactive robots for clinical practice. The animated robots are, in various combinations, capable of "feeling," wincing, vomiting, and moving its tongue all in response to the practicing dentist's ministrations. The device uses some of the same ideas put forth by this team in creating a replica of a human mouth, notably, air powered "muscles." The most significantly similar technology is the functional tongue. It may not be capable of the fine motions necessary to mimic swallowing however.