BME 484 Capstone Design Project
Department of Electrical, Computer and Biomedical Engineering
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Silicon Head/Upper Airway Model

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ABSTRACT—Our Senior Capstone Deisgn Project is a continuation of the development of a silicone rubber human head that was started by a group of students in Dr. Sun's summer internship, summer 2012; Gemma Downey, senior, University of Rhode Island; Connor Walsh, junior, University of Rhode Island; and Yasaman Jafari, sophomore, University of Connecticut. The silicone human head, or "Head Model" includes the sternal notch and functioning airway with nasal and oral passageways, sinuses, and the trachea. The model will be used to study the acoustic recordings of human breath sounds. The end goal after creation of the Head Model is to hook the lower part of the trachea opening to a breathing machine to mimic human breathing during sleep.

Proposed Materials

- Smooth-On's Mold Max Silicone – this silicone has become the industry standard for making molds that capture very fine detail down to a finger print. With several to choose from, the Mold Max line covers most mold making scenarios and offers our group tremendous versatility, which is important because the density of the silicone should be close to that of the density of human tissue so that sound wave velocity through our model closely match the sound velocity through human tissue.
- AGAR AGAR gelatin – will be used to create the "void" that is the trachea. Agar Agar gelatin is a vegetarian gelatin substitute produced from seaweed. It has a consistency similar to jelly, a thick liquid, when wet. Once the gelatin sets, the substance is closely related to Jell-o, however offers better stability. Agar Agar will hold up better against the dense silicone and will still melt out of the mold revealing the trachea void when boiled.
- Plaster of Paris—is a model building material that begins as a dry powder similar to mortar or cement. Like those materials, it is mixed with water to form a paste which liberates heat and then hardens. It is softer than mortar and cement and can be manipulated with the right tools.
- Oven-bake clay—clay is one of the oldest building materials on Earth It is a primary part of our project as we will cut out a trachea and sinus piece from the slab of clay for the filling and hardening of the Agar Agar gelatin.

NEEDS AND RESOURCES

The Design Process

To successfully complete our project, the following steps must be taken:

- The Outer Mold—In a plastic tub filled with the plaster of Paris water mixture, we will create the outer or "negative" mold of the face. We have already been supplied a life-sized mannequin head as the basic model of our model. This mannequin spans from the breast-bone of the human body up. This mannequin will be dipped face-first in the plaster mixture. One the plaster dries, we will seal the hardened plaster with a sealant for the pouring of silicone later. This outer mold will be a reusable basis for our project and future projects.
- The Void—Using the oven-bake clay that has been provided to us, we will carve out two halves of the trachea outer mold. One cardboard stencil of the trachea will be used to trace the trachea and sinuses. Once we are done tracing the trachea, we carved the oven-bake clay into to form a trachea and sinuses of the nasal and esophageal passageways. This clay was then hardened over night.

- The Inner Mold- We began forming AGAR AGAR gelatin in a bowl. We did this by heating up hot water, and stirring in the agar agar with the boiling water. We then poured this liquid into the clay model. After words, we let it cool within our clay model until it went from a liquid solidus state to an actual solid state.
- Silicon Head- We will then take the AGAR AGAR gelatin out of its mold, and place it within the outer mold. We plan to heat the silicon at a high temperature, and pour the silicon into outer, plaster mold. After the silicon head is set, we plan use this silicon head, with the nasal and esophageal passageways, to record the human breathing sounds.

Origin of Problem

- The silicon head model was introduced to us because of a problem concerning the disease sleep apnea. Sleep apnea is a sleeping disorder caused by abnormal breathing sounds or abnormally low breathing during sleep. Regardless of type, an individual with sleep apnea is rarely aware of having difficulty breathing, even upon awakening. Symptoms may be present for years (or even decades) without identification, during which time the sufferer may become conditioned to the daytime sleepiness and fatigue associated with significant levels of sleep disturbance.
- The reason why we are creating a silicon head model with esophageal and nasal passageways, is because we wanted to study the acoustic recordings of human breath sounds. The end goal after creation of the Head Model is to hook the lower part of the trachea opening to a breathing machine to mimic human breathing during sleep.

Constraints

- *Health and Safety:*

Silicone is a synthetic rubber which contains bonded silicon and oxygen. Commonly, cookware is made from food grade silicone. Silicone mold generally requires little or no mold-release or surface preparation, as most materials do not adhere to silicone. Silicone rubber does not react with food or beverages, nor does it produce any hazardous fumes.

Silicones increase the functionality and absorption of some medications. Silicones soften and smooth topical medications so they can be applied without leaving a greasy residue, and form a seal that protects wounds during the healing process.

Silicone tubing in some medical devices such as drug delivery systems or heart pacemakers helps reduce the risk of infection. Silicone-enhanced lubricants ease the insertion of needles and devices.

Silicones can most closely approximate the consistency of skin and offer exceptional cushion and comfort in prosthetics.

- *Manufacturability:*

As far as manufacturability goes, our product has reusable features for the creation of additional Head Models. Our outer mold, made of Plaster of Paris in the plastic tub, can be used multiple times for the pouring of the silicone rubber.

The gelatin trachea cannot be reused time and time again, however, the clay "trachea mold" can be reused for another gelatin pouring. The gelatin itself is somewhat reusable, it can be reheated, melted, re-poured, and remolded. For example, after the formation of the gelatin trachea, we came across a crack in the gelatin mold. The hardened leftover gelatin was melted and poured over the crack to restore the gelatin trachea to its original state.

- *Environmental:*

The Silicones Environmental Health and Safety Council of North America (SEHSC) does not believe that silicone warrants the development of a chemical action plan. Medical applications and infant care products with silicones satisfy the highest quality standards demanded by health care professionals, patients and families. Resistant to bacteria, silicones are easy to sterilize. They do not react with other materials and do not irritate the body. Used externally or intravenously, they do not generate unwelcome byproducts or trigger allergic reactions.

Engineering Standards

Silicones are among the most extensively studied materials used in consumer and industrial applications today. More than 1,000 studies have been conducted by silicone manufacturers to assess the safety of silicones relative to workers, consumers, the environment and manufacturing processes. The results of this continued research and testing demonstrate the safety of silicones in their diverse and important applications.

Results

- The results of this design project the following:

The outer mold-The outer mold was created using plaster of paris in a plastic tub. We had already been supplied a life-sized mannequin head as the basic model of our model. This mannequin spans from the breast-bone of the human body up. This mannequin was dipped face-first in the plaster mixture. The results of this were successful. We were left with an outer model that was complete.

- *The void*- Using the oven-bake clay that has been provided to us, we carved out two halves of the trachea outer mold. One cardboard stencil of the trachea will be used to trace the trachea and sinuses. Once we are done tracing the trachea, we carved the oven-bake clay into to form a trachea and sinuses of the nasal and esophageal passageways. This clay was then hardened over night. The results of this carving process were successful. We carved out this mold in one sitting. There was some error in the fact that the mold for the void was not completely flat and could not be pushed together. However, we were able to fix this error by insuring that the clay void was level. We used a knife and ruler to cut the clay and make sure that the two pieces were the same height. We then used a piece of glass in between the clay to insure that they were flat.

- The Inner Mold- We began forming AGAR AGAR gelatin in a bowl. We did this by heating up hot water, and stirring in the agar agar with the boiling water. We then poured this liquid into the clay model. After words, we let it cool within our clay model until it went from a liquid solidus state to an actual solid state. The AGAR AGAR results were successful. We were able to add the gelatin mix in the clay. However, the first time we added the AGAR we did not make enough, so we needed to make more of the gelatin mix. We then made enough the second time around so that there was enough gelatin mix once it cooled.

Resources

Dr. Ying Sun, University of Rhode Island

- http://www.sehsc.com/science.asp
- http://www.sehsc.com/health-care.asp
- http://www.smooth-on.com/