Bioreactor for Laryngeal Tissue Engineering

Product Design Specifications, v2

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Client: Dr. Nathan Welham

Problem Statement: The larynx has three major functions physiologically. It separates the windpipe from the esophagus, is important in swallowing, and has a major function in sound production. When a problem occurs in the larynx, all three functions can be disrupted. Our purpose is to design a laryngeal bioreactor that can decellularize a larynx to make a scaffold and recellularize it with patient-specific cells. A previous team designed a device that adequately decellularized the tissue, but recellularization had not been thoroughly tested. The client would like an iteration of the design that keeps the larynx horizontal during the experiment and allows easy access to the catheters supplying fluids through the vasculature. This semester, the team should focus on building a design that allows cells to be exposed to both air and media during cellular growth while allowing researchers to view the experiment taking place. Additionally, the team should seek to incorporate and build upon the automation system that the previous team began constructing.

Function: The device will serve to perfuse and support laryngeal tissue to aid in the decellularization of existing cells and recellularization with patient-specific cells.

Client requirements:

- The bioreactor must be able to decellularize and recellularize a human, pig, or dog larynx
- The bioreactor must be able to function in a lab environment, in a refrigerator, and in an incubator
- The bioreactor must be able to function continuously for up to three weeks in time
- The bioreactor must be sterile and capable of interfacing with the previous group's pumps

Design requirements:

1. Physical and Operational Characteristics

a. *Performance requirements*: The bioreactor needs to be able to create an acellular scaffold by decellularizing a larynx. After decellularization, the bioreactor needs to be capable of housing the larynx and repopulating the scaffold with new cells. Tubes and inlets connecting to various parts of the larynx must not be torn out or slip out during use. Additionally, the bioreactor should be able to be programmed to be filled and drained automatically. Finally, the bioreactor should not be airtight.

b. *Safety*: The device will be used in conjunction with chemicals; therefore chemical exposure must be prevented. The device needs to be sterile to prevent future contamination/inflammatory responses, or functional loss after implantation and therefore needs to be autoclavable.

c. *Accuracy and Reliability*: The device must be able to provide and/or facilitate consistent decellularization and recellularization over multiple larynges. The bioreactor needs to function for up to three weeks in time without functional loss. The bioreactor should be able to be programmed to rotate the larynx at a rate between 1 rotation per 10 minutes and 1 rotation per hour. Any partial rotations should be accurate within 10° of the desired orientation. As the scaffold becomes decellularized, it becomes more flaccid, and the bioreactor must be able to still hold the larynx in place even with these changes.

d. *Life in Service*: Our client intends to use the device for several months over the course of the current research study. The device must function accurately and reliably over that time in segments of continual use for several days (for decellularization) to three weeks (for recellularization). The bioreactor must be reusable.

e. *Shelf Life*: The device should maintain its functionality for as long as possible so the client can use it in multiple similar studies

f. *Operating Environment*: The device must be able to function in a refrigerator environment, a standard lab bench environment, and an incubator environment for up to 3 weeks at a time.

g. *Ergonomics*: The device must not place unnecessary strain on the user. It needs to be reasonably movable and provide easy access to the tissue specimen.

h. *Size*: Overall size of the device must be limited to prevent crowding on the bench top, but large enough to house a human or large animal model larynx. Additionally, the bioreactor should be small in order to conserve media while being large enough to easily allow the installation of a larynx.

i. *Materials*: All materials used in the device must be biocompatible with fresh tissue and support cell viability. None of the materials should degrade in the media used during decellularization or recellularization. All materials must be autoclavable.

j. *Aesthetics*, *Appearance, and Finish*: Although the client expressed no preferences as to aesthetic quality, the design should appear finished and professional.

2. Production Characteristics

a. *Quantity*: One prototype serving as the second iteration of the design, with the assumption of future modifications.

b. *Target Product Cost*: $1-3,000

3. Miscellaneous

a. *Standards and Specifications*: None aware of at this time

b. *Customer*: Dr. Nathan Welham and his fellow researchers

c. *Patient-related concerns*: None

d. *Competition*: None for the whole larynx. However, bioreactors have been made for whole trachea as well as vocal folds.