The Effects of Repeated Depression on Air-Filled Bulbs Used in Tongue Exercises for Swallowing Problems

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Abstract

Our clients, Dr. JoAnne Robbins and Jacqueline Hind, specialize in treating patients with dysphagia. This condition, which is the medical classification for difficulty swallowing, detrimentally affects 40% of people over 60 years old[1]. Our clients combat dysphagia with an exercise protocol that enhances patients' swallowing ability through increasing the amount of pressure their lingual muscles can exert. In this regimen, patients exercise with a lingual pressure-sensing system called the Iowa Oral Performance Instrument (IOPI). The patients have reported a decreased responsiveness within this system over time. As a result, we were challenged to assess the IOPI's functionality and suggest possible improvements to its design. Through rigorous testing, we have discovered that air leakage and material viscoelasticity are responsible for the observed decline in device performance, and we have begun to conceptualize and fabricate a superior design.

Introduction

Dysphagia, or difficulty swallowing, is a prevalent medical symptom that affects over six million people in the United States alone. It can lead to a drastic decrease in quality of life and, in some cases, death[2]. Dysphagia is currently treated with preventative methods such as modification of diet, thickening of liquids, and reduction of bolus size[1]. These approaches merely improve the patient's comfort without enhancing their swallowing ability.

Our clients, Dr. JoAnne Robbins and Jacqueline Hind, are specialists in swallowing and geriatrics. They created an 8-week lingual exercise protocol to improve swallowing ability through strengthening the lingual muscles and increasing tongue pressure. To monitor progress and have their patients perform exercises, our clients use the Iowa Oral Performance Instrument, or IOPI. The IOPI consists of an air-filled bulb that is connected to a digital pressure sensing system.

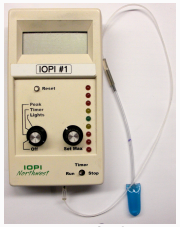

Figure 1: Iowa Oral Performance Instrument (IOPI). The patients of our clients use this device to measure their peak tongue pressures and exercise their lingual muscles.

Patients using the IOPI have been reporting a decrease in bulb performance over time. Our clients asked us to determine whether this was simply a psychological belief of the patients or a decrease in bulb functionality. We were also assigned the task of suggesting a solution to any observed failures in the pressure sensing system.

Design Criteria

- Life in service: at least 8 weeks (1500 compressions)
- Bulb must not leak air or change in elasticity
- Must provide accurate and precise pressure readings
- Bulb cannot damage oral cavity
- Must function properly at conditions of oral cavity (37 °C and pH of 7.2)
- Approximately 20 mm in diameter for safety and ease of use

Exercise Regimen

- **8 Weeks**
  - 1st Week: 60% of maximum pressure
  - Remaining Weeks: 80% of maximum pressure
- **Maximum pressure re-measured biweekly**
  - 2 sets of 3 attempts to achieve maximum
- **Protocol**
  - Compress bulb to attain proper pressure, hold for 3 seconds, and release
  - 10 repetitions in both positions per workout
  - 3 workouts per day
  - 3 days a week

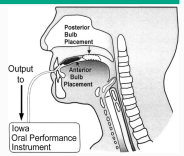

Figure 2: Bulb Exercise Positions[4]. Diagram of where the air-filled bulb was placed during anterior and posterior exercising.

Testing

Compression

Compressing the air-filled bulbs to a distance of 4.75 mm allowed for an evaluation of bulb softening and air leakage. Every week throughout the exercise regimen, 30 pressure values were measured on the IOPI and averaged to assess change over time. Once all of the data was collected, a statistical *t* test was used to compare the initial and final averages. The conclusion was that at the 95% confidence level, the averages were not the same, and therefore the pressures were proven to decrease over time.

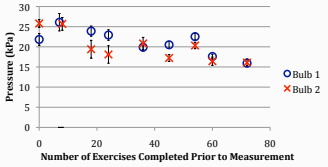

Figure 3: Results from Consistent Compression Applied Over Time.

Force

Applying a force of 8.9 N to the air-filled bulbs enabled bulb responsiveness to be determined. As with the compression testing, the IOPI was used to measure the pressure every week throughout the exercises. After repeating 30 times, the results were averaged to assess change over time. A statistical *t* test was used on the data to compare the initial and final averages. At the 95% confidence level, the averages were found to not be the same, and thus the pressures were proven to decrease over time.

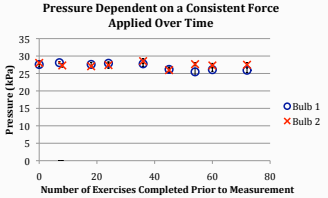

Figure 4: Results from Consistent Force Applied Over Time.

Underwater Clamp

To ascertain the effects of air leakage and bulb viscoelasticity, clamp tests were performed. Bulbs connected to the IOPI with the currently-used, Vaseline-sealed, and Teflon tubing were continuously clamped to 2.25 mm for a period of time. Pressure readings were taken every hour with the IOPI. Although all conditions showed a decrease over time, the sealed tubing yielded higher final pressures because some of the air leakage was prevented. Viscoelasticity therefore accounts for the decrease in this case.

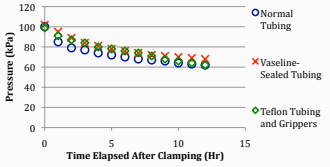

Figure 6: Results from Continuous Compression Applied for a Period of Time.

Exercise Simulation

The amount of air leakage and effect of bulb viscoelasticity that result from the exercise regimen were found by imitating the protocol. Bulbs connected to the IOPI with the currently-used and Teflon tubing were manually squeezed to 50 kPa for 3 seconds, then released. Pressure values were obtained with the IOPI at intervals corresponding to one week by clamping the bulbs to 3.50 mm. The initial decrease of 7 kPa was attributed to air leakage whereas the fluctuations after this point were accredited to viscoelasticity.

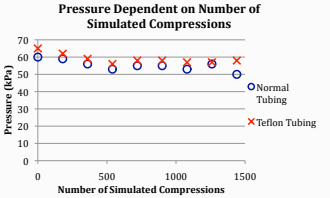

Figure 7: Results from Simulating an Entire Exercise Regimen.

Final Design

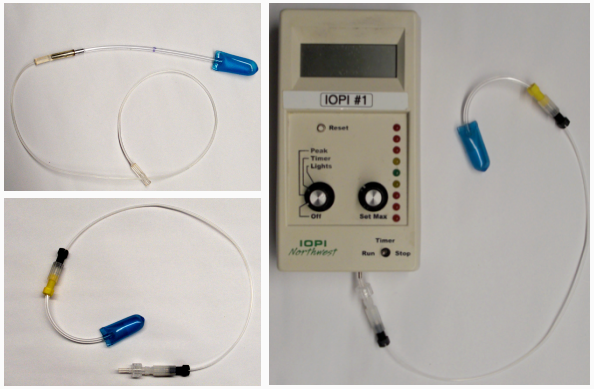

Figure 5: Comparison of Currently-Used Tubing and Teflon Tubing.
A. Current: PVC bulb connected to vinyl tubing.
B. Final Design: PVC bulb outfitted with Teflon tubing and airtight connections.
C. IOPI with final design tubing.

- Advantages of Teflon over vinyl
  - Naturally flexible without plasticizer
  - Low gas permeability
  - FDA approved
- Improvements bulb-tubing connection
  - Teflon screw connectors and gripper fittings
  - Airtight lock instead of tube sliding mechanism
  - Does not expand or loosen

Future Work

Figure 8: Pressure Distribution Sensor[3]. A pliance mat sensor such as this one can detect a complete pressure distribution and display it in a digital output.

- Find primary source of air leakage
- Determine chemical composition of bulbs
- Retrofit IOPI with threaded Teflon connector
- Replace PVC bulb with elastic alternative
- Investigate pressure distribution sensors
- Device comparison

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