Automated Bioanalytical Chemistry Sample Tube Uncapping Device

Jake Jaeger, Alec Onesti, Sam Perez-Tamayo, Katie Werth
Client: Dr. Robert Radwin (ISyE, BME) **Advisor**: Dr. Chris Brace (Radiology, BME)
University of Wisconsin - Madison, Department of Biomedical Engineering

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Abstract

Manually capping and uncapping test tubes is a time consuming task that poses a risk of injury in the form of Carpal Tunnel Syndrome. Many labs, including our client's lab, require technicians to manually open and close test tubes in high volumes (up to 700 per day). Our client desires to reduce the risk of technician injury by implementing a novel device that can automatically uncap these tubes in a more ergonomic fashion. Ideally, the device will improve the lab technicians' workflow while significantly reducing the risk of Carpal Tunnel Syndrome and other repetitive-motion-induced injuries.

Carpal Tunnel Syndrome

Carpal Tunnel Syndrome (CTS) is caused by the pinching of the median nerve in the wrist.

- About ⅓ of all occupational injuries are due to repetitive motion and/or exertion[1]
- CTS results in more days away from work than any other workplace injury[2].
- The hand and wrist movements that cause CTS are biomechanically similar to those required to open small tubes

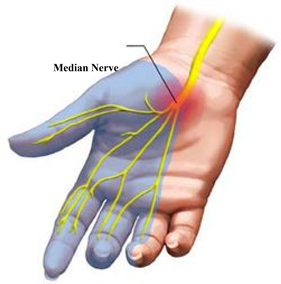


Figure 1: Visualization of CTS, an injury commonly caused by repetitive-motion tasks [1]

Process

Current Procedure:

Technicians scan tubes and manually uncap all of the tubes, then place and order them into a test tube rack.

Goal:

Alleviate hand strain and wasted time that occurs in the current uncapping process.

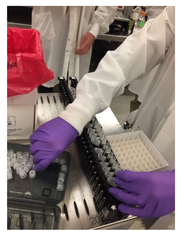


Figure 2: Technician manually uncapping sample tubes in the client's affiliated laboratory [2]

Design Criteria

- Minimize size; should be able to fit in lab space of limited workspace
- Low maintenance
- Designed for heavy use; uncap roughly 10,000 test tubes per month
- Must be equally or more efficient/fast than current manual uncapping process
- Compatible with various test tubes
- Easy to learn and teach how to use
- Prevent any spills or cross-contamination

Final Design

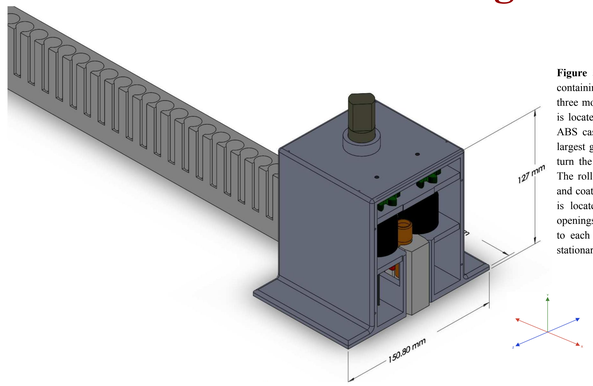


Figure 3: A depiction of the entire Uncapping device containing the 32-sample tube rack, which is holding the three most commonly used sample tube sizes. The motor is located at the top of the device and is mounted to the ABS casing. The D-shaft of the motor is mated to the largest gear, which is mated to the two smaller gears that turn the shafts (See figure 5 for gear ratio explanation). The rollers are fabricated from high-density polyethylene and coated with high-friction silicone caulk. The sprocket is located on the side of the device that contacts the openings within the rack. It functions by applying pressure to each individual sample tube, forcing them to remain stationary while the rollers twist off the caps.

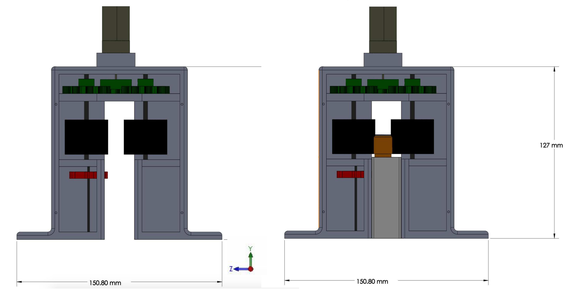
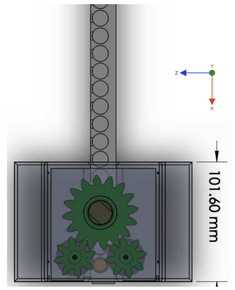


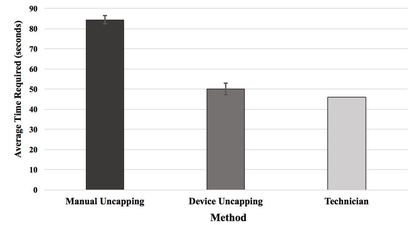
Figure 4: *Left* - a depiction of the device before feeding the sample tube rack through for uncapping
Right - a depiction of the device accommodating the sample tube rack
The technician uses one hand to feed the rack of sample tubes through the device, which continuously uncaps all 32 tubes in one pass.

Figure 5: A bird's eye view of the gear system used to rotate the high-friction rollers; a gear ratio of 2.5:1 was used to increase the speed of the rollers relative to the motor shaft by 2.5x.



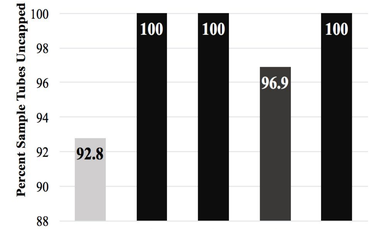
Testing & Results

Uncapping Device Efficiency



A bar graph showing the average time required to fill and uncap 32 sample tubes in the provided rack. Five trials using the Manual and Device Uncapping methods were completed, and the Technician time was submitted by the client's laboratory. A one-way ANOVA comparing the times to uncap an entire sample tube rack showed a significant difference in average time ($p = .000202$). A Tukey Test revealed a significant difference in time ($p < .01$) for Manual vs. Device and Manual vs. Technician, but a nonsignificant difference in time for Device vs. Technician.

Uncapping Device Success Rate



A bar graph showing the success rate of the Uncapping device. Five trials were completed in which the device was used to uncap a rack full of sample tubes. The percentage of successfully uncapped tubes was calculated after each trial. Given these data, the average success rate of the Uncapping device is 97.94%.

Future Work

- Improve **durability**
  - Utilize metal gears to provide more torque and increase lifetime of the device
  - Fabricate casing from a stronger material, such as aluminum
- Improve **accuracy**
  - Develop a sprocket that successfully secures every sample tube every time

Figure 6: Visual representation of metal gears that could be used to improve the durability of the Slide-Through Uncapping device [3]

References & Acknowledgements

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[1] https://medlineplus.gov/images/carpaltunnel.jpg
[2] Image taken by the Uncapping Team at the client's affiliated laboratory
[3] http://www.backgroundsy.com/photos/metal-gears