Abstract: The Tooth Savers

Problem Description:

Intubation is the process of inserting an endotracheal tube into a person's airway for the ventilation of oxygen into the lungs. For patients under anesthesia, experiencing respiratory failure, or trauma injury, airway intubation is a potentially life-saving procedure. A laryngoscope is inserted through the pharynx. The blade of the laryngoscope is then used to lift the tongue and epiglottis, a bundle of tissue which covers the larynx, ultimately exposing the trachea. An endotracheal tube is then inserted through the trachea and inflated to make sure the tube remains in place. The endotracheal tube is then attached to a mechanical ventilator. During this process, the laryngoscope blade often comes into contact with the central maxillary teeth. As a result, excessive exerted force on the blade can lead to dental trauma and prolonged issues such as speech impediments [1].

Figure 1. Patient with dental trauma

With the nearly 50 million intubations occurring worldwide, 25 million of which occur in the United States [2], there is a need to design a device which prevents dental trauma. The solution is a real-time pressure feedback sensor that alerts medical trainees when they have reached the critical force which causes dental trauma. This problem can be prevented with better training practices by way of the proposed device.

Reduction to Practice:

A fully operational prototype was obtained with thorough analysis. The team chose a SparkFun Pro Micro microcontroller which includes analog to digital converter, in-system programming, flash memory and USB port. The approximate force value was approximated using a mathematical model. This model incorporated force equations, normal and shear stress, and the mechanical properties of teeth to estimate the forces causing dental fractures. The calculated force value was then incorporated into the microcontroller's code as the threshold value for dental fracture causing the embedded alarm to sound. The team chose a robust sensor that would ensure this load capacity. Per the client, the sensor had to be lightweight and fit on the blade of a Macintosh 2 blade with limited additions to the top and outer portions of the blade. A disk load cell capable of measuring up to 200kg was chosen. The sensor was placed where the blade creates the most force on the upper incisors. This position was determined by literature review as well as consulting the client. Code was written in C++ to translate voltage changes to force values.

Solution Concept:

The selected design meets the user needs and requirements. The most important criteria ensured the device does not obstruct the intubation procedure and could easily provide real-time feedback of reached critical force values. A laryngoscope-based concept was chosen and fundamentally consists of a laryngoscope, a sensor, and a microcontroller as seen in Figure 2. The design includes a modified laryngoscope handle cap that will house the microcontroller, auditory alarm, load amplifier, microcontroller, and light fixture. These components will be tight fit and secured into the laryngoscope handle. The laryngoscope handle cap will contain a cutout for convenient access to the USB port of the microcontroller for the acquiring data of intubation training sessions and to power the device. The portion of the laryngoscope blade that contacts the upper incisors will be cut out. Here, a force-sensing load cell is mounted onto a bracket and mounted on the cut-out portion of the blade. A loading-plate apparatus will add less than 2 mm in thickness, minimizing visual obstruction, and providing a wide contact surface to measure forces. A small hole has also been cut out on the top portion of the laryngoscope handle. This feature is meant to conceal the wires that will run from the handle cap to the sensor placed on the laryngoscope blade. Software components allow the user to extract and clear data. Once the user connects the device to a computer via USB port, a simple python script will enable data extraction or clearing. The team has provided the client with standard operating protocols for these procedures. Ultimately, the selected design has a sleek profile which increases the ease of use while ensuring critical forces applied on teeth are obtained and alerted to the user.

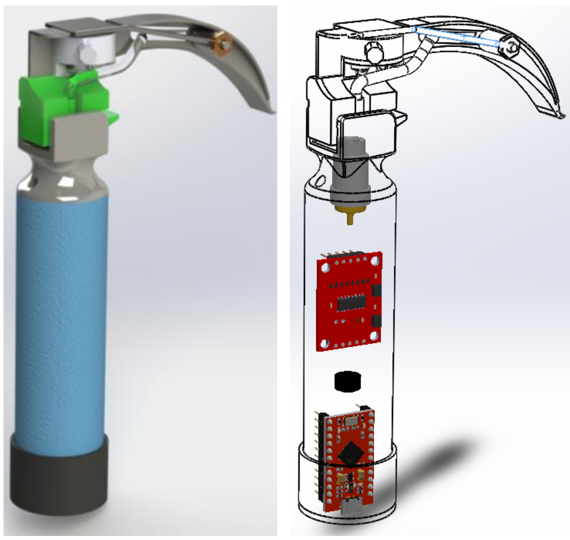

Figure 2. Final Prototype

Pathway to Implementation:

Various verifications tests will be conducted to ensure the user's requirements are met. These include ensuring an accurate real-time audio alert system, and not obstructing the intubation process. After the prototype is constructed validation tests will be conducted to ensure the client's needs are met. Ultimately, these features will ensure that intubation training is as informative as possible and that the best training techniques are learned to prevent dental trauma.

The device will be used by Jason Woods, MD at Children's Hospital Colorado. He will be able to conduct a study to pinpoint when dental trauma commonly occurs. The device will also be used by pediatric residents Dr. Woods is training to improve their intubation techniques as they enter clinical roles. Additional work can be done to improve the device including having an embedded power source and improving the user interface to more easily graph and organize data from multiple intubation sessions

Citations:

[1] Comparison of the glidescope, CMAC, storz DCI with the Macintosh laryngoscope during simulated difficult laryngoscopy: A manikin study - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Difficult-Laryngoscopy-Manikin_fig2_22785576

[2] (n.d.). Advanced Video Guided Laryngoscopy. Retrieved from http://www.velosal.com/?page_id=15.