Prototype Report

01.25.25

Bairway Trainer

A Mechanical Training Model for Direct Laryngoscopy

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Report Note:

The purpose of this documentation is to better understand and provide a comprehensive analysis of the project scope and status of the device. Much of the background information being provided was collected by Heather Bair and simply re-stated in this document. The CAD model provided was made using CREO in the Seamans Center using the University of Iowa licensed CREO software. This document provides the problem, background research, prior art (current solutions), old and new/evolving prototypes, and much more. It will eventually include research into market analyses, production documentation, and more.

Problem Statement:

Current airway simulators do not accurately model the biomechanical forces of the human jaw, leading to student's learning incorrect form and habits, causing student difficulties including patient harm when transitioning into clinical work.

Introduction:

Current airway models use mannequins that allow for a more visually realistic and multi-step procedure-oriented approach to learning. These mannequins have their place in the classroom and are critical to student learning.

However, these models often cost thousands of dollars and do not accurately model the correct biomechanical forces practitioners experience during clinical work. Current training mannequins are unrealistically difficult to intubate because the jaw does not sublux, and the materials are excessively rigid. Softer, more lifelike materials exist but wear out quickly. This limitation requires learners to apply excessive force, thus, creating an unknown skill gap, considering students' hesitation and nervousness, this causes the transition from mannequin and classroom work to clinical work more difficult. Clinically this presents as students causing frequent tooth-contact events ("tooth-clicks") that would represent dental injury in a patient. While these models provide a high level of challenge, they may not be ideal for initial skill acquisition. Learners often struggle with mechanics, develop poor habits (tilt-back rather than lift-up), and become frustrated before establishing correct motor memory.

Proper technique for airway incubation using a laryngoscope is critical for practitioners to understand and master during there clinical practice. A common analogy for the motion of the laryngoscope is to “Cheers not Drink” seen in figure one below.

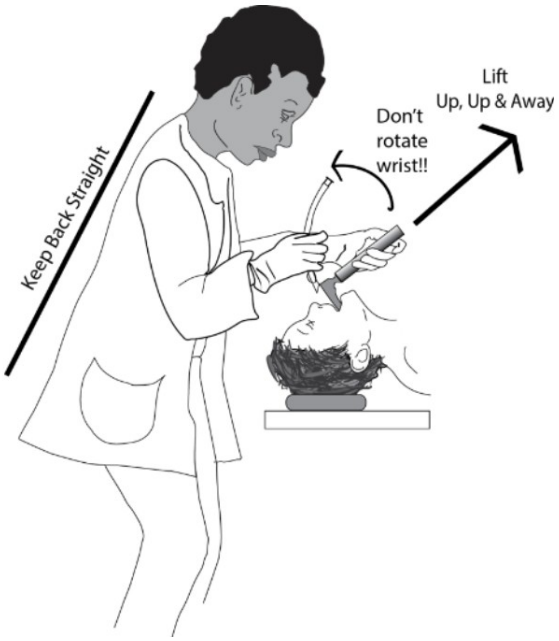


Figure 1: Cheers not Drink image; this image depicts the correct and incorrect form for a practitioner to use when preforming the procedure. (need source for this)

The practitioner needs to be able to obtain a view of the vocal cords to place the endotracheal tube. If you drink or torque your wrist back, you impede your view and risk dental damage, risking everything from a chip to dislodging a tooth. First time intubators in my operating room, they often get the blade in the mouth and then struggle to get a view of the vocal cords. Every failed attempt at intubation increases risk for complications your instrument in the airway can cause edema and trauma, in fact our difficulty airway algorithm limits your attempts to no more than 3 attempts.

Intubation is a low-frequency, high-risk skill for most providers. The first-pass success is critical — failure increases major complications by 40–60%, including death. Most emergency/inpatient providers place only a few tubes a year → limited muscle memory → higher failure rates. Difficult intubations add ≈ $14K per patient and ≈ $6B in annual U.S. healthcare costs. Anesthesia residents approach ~90% first-pass success after ~75 intubations. Most clinicians need ~50 intubations to reach basic proficiency — but many emergency and inpatient providers perform only a few per year.

Clinicians typically need 50–75 intubations to achieve high first-pass success — but most emergency and inpatient providers only perform a few per year. Expert-level first-pass success (~90%) is typically achieved after ~200 intubations. Learning-curve studies suggest that the first-pass success rate plateaus after approximately 100-200 intubations in high-acuity settings (Bernhard et al., 2011).

Prior Art:

As talked about in the introduction, current airway simulators are mannequins that often cost thousands of dollars and do not accurately model the correct biomechanics of the jaw. Four examples of airway trainers are listed below, three without specific patents and one patent.

1. Universal Medical life/form Airway Larry Adult Airway Management Trainer with Stand

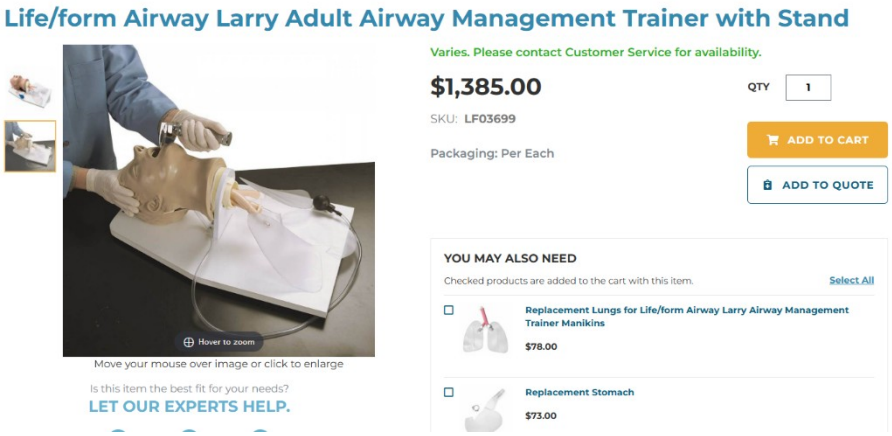


Figure 2: (Universal Medical Inc, n.d.)

2. Medical-X Airway Management Trainer

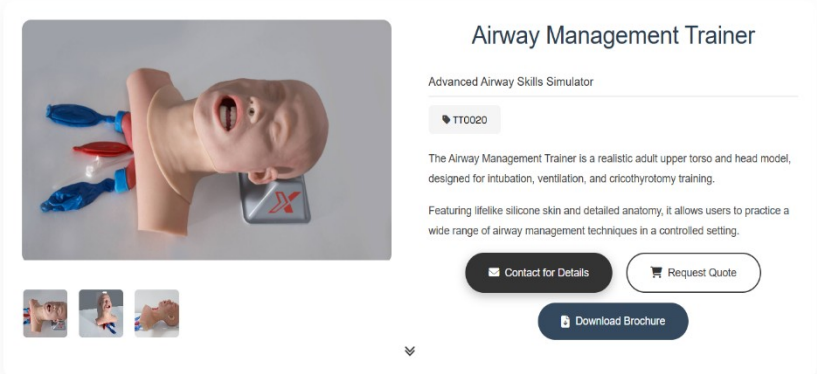


Figure 3: (Airway Management Trainer | Advanced Airway Skills Simulator | Medical-X, n.d.)

3. Laerdal Airway Management Trainer
4. Patent WO2017123852A1 – Parametrically adjustable airway training

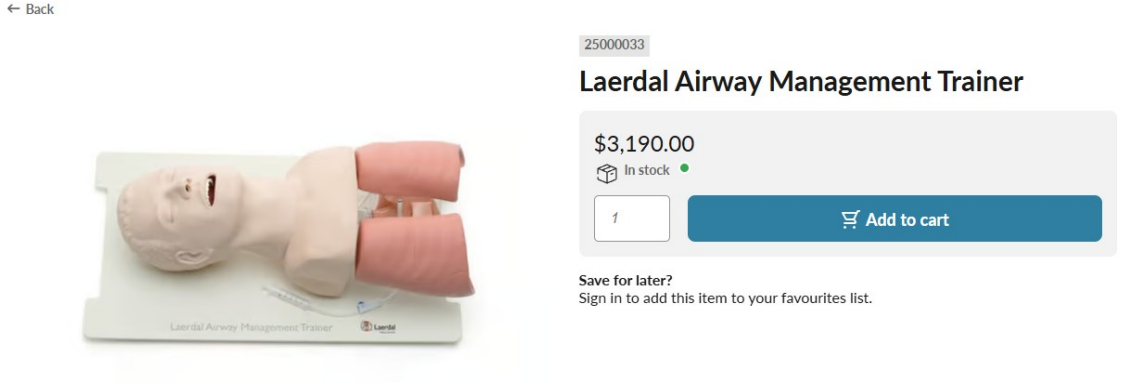


Figure 4: (Laerdal Medical, n.d.)

mannequin with instrumented parameter assessment.

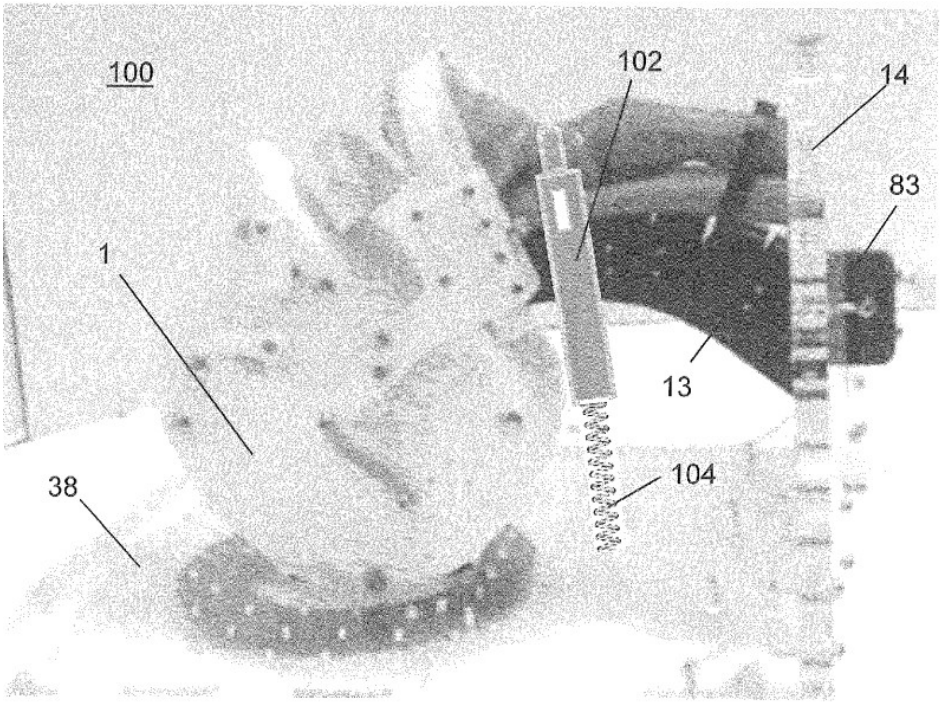


Figure 5: (Hastings & Delson, n.d.)

Bairway Trainer Design:

Design Description:

The Bairway Trainer is a novel airway management simulator that focuses specifically on the biomechanics of laryngoscopy—the lift, angle, and torque used to visualize the airway and insert a breathing tube. Unlike current airway trainers that prioritize full anatomical fidelity, the Bairway Trainer isolates the mechanical movement and force dynamics essential to safe and effective laryngoscopy. Its unique value lies in its ability to provide realistic, repeatable feedback on lift mechanics, allowing learners to develop the “finesse of technique” and muscle memory necessary for airway management without relying on expensive or fragile manikins.

The invention combines a simplified upper-airway form with a mechanically responsive jaw and tongue assembly that simulates realistic tissue resistance and movement when the laryngoscope blade is inserted and lifted. The result is a durable, portable, and affordable training tool that can be used in simulation labs, classrooms, or clinical settings such as the operating room.

Functional Requirements: (will be expanded and refined later)

1. Correctly model the biomechanics of the jaw
2. Cleanable
3. Proper jaw and teeth representation
4. Manufacturable
5. User replaceable parts when applicable
6. Ability to use accurate tools when using the model
7. Affordable
8. Easy to use

Prototype Revision History:

Prototype One

Purpose:

The primary purpose of the first prototype is to start the visualization of the device beyond paper and pencil. Allow others to comment on and

better understand the idea. It focuses on modeling the upper jaw and starting the model the lower jaw, teeth are highlighted in this model as well as the starting heigh differences between the upper and lower jaw structures.

Design:

Using foam blocks, clay, sticks, and rubber bands. Molding the jaw with clay. The upper jaw with the addition of teeth. The teeth are made with a different color to draw attention to them. The upper jaw is placed on a larger foam block to represent the rest of the head. The lower jaw is a simple clay block with a deep indentation that allows the blade to be placed stablely. Rubber bands are used to provide tension between the upper and lower jaw.

Images:

Figure 6: Prototype One Images

Purpose of New Prototype:

Moving forward the model should be more anatomically accurate and introduce the ability to create realistic jaw motion. A 3D CAD model was made before physical prototyping. However, the model will allow for almost infinite modularity of rubber band placement, allowing the user to refine the model over time and test the model. This action will then allow for the device to be re-simplified to only the critical attachment points for the rubber bands.

This prototype is not intended to be the final product but simply a mechanical modeling prototype.

Prototype Revision:

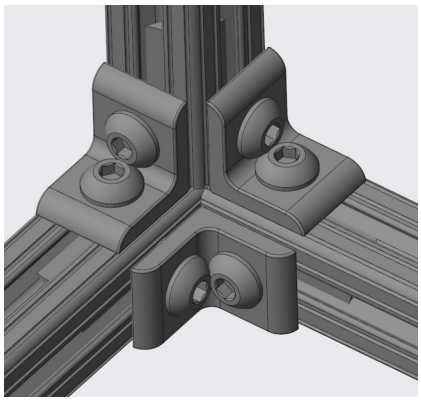
The prototype uses 1” T-Slotted Framing parts including rails, sensor attachments, rubber feet, and L bracket plates to create a frame around the jaw. Rubber bands connect from the lower jaw to the rail system allowing the user to adjust the placement and number of rubber bands to create a realistic biomechanical movement. The almost infinite mobility of band placement to the frame should allow us to pinpoint over time and testing the best places for rubber bands to be. Once this is done, a re-design can be made placing rubber band attachment points only at the required areas. Extensive testing with practitioners should be done prior to major re-design and simplification.

Custom designed lower jaw tissue extension can be 3D printed. However, it is recommended that a more accurate lower jaw is to be used as the teeth placement is critical and simply guessed for now. An upper jaw with teeth should be used as well, and can be printed 3D as well.

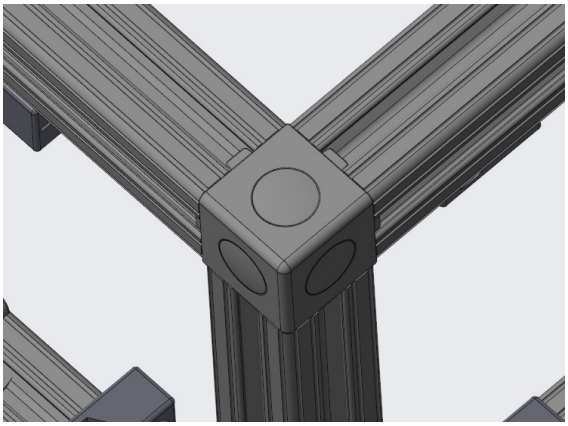
The tissue extension is designed to give the user a place to put the laryngoscope such that the scope handle is realistically close to the teeth. Further testing and feedback as to where exactly that point should be is needed. The tong is left out for simplification of the model as putting it in would increase production cost, device complexity, and would not help in the goal of this device. The goal being to replicate the biomechanical motion of laryngoscopy.

Options for frame construction:

a. Use all L brackets for affixing frame rails together: requires 3x (47065T236) L brackets at $7.29 ea -> $21.78



b. Use square three way end brackets at $10.71 ea (half as expensive, recommended)



Prototype CAD Images

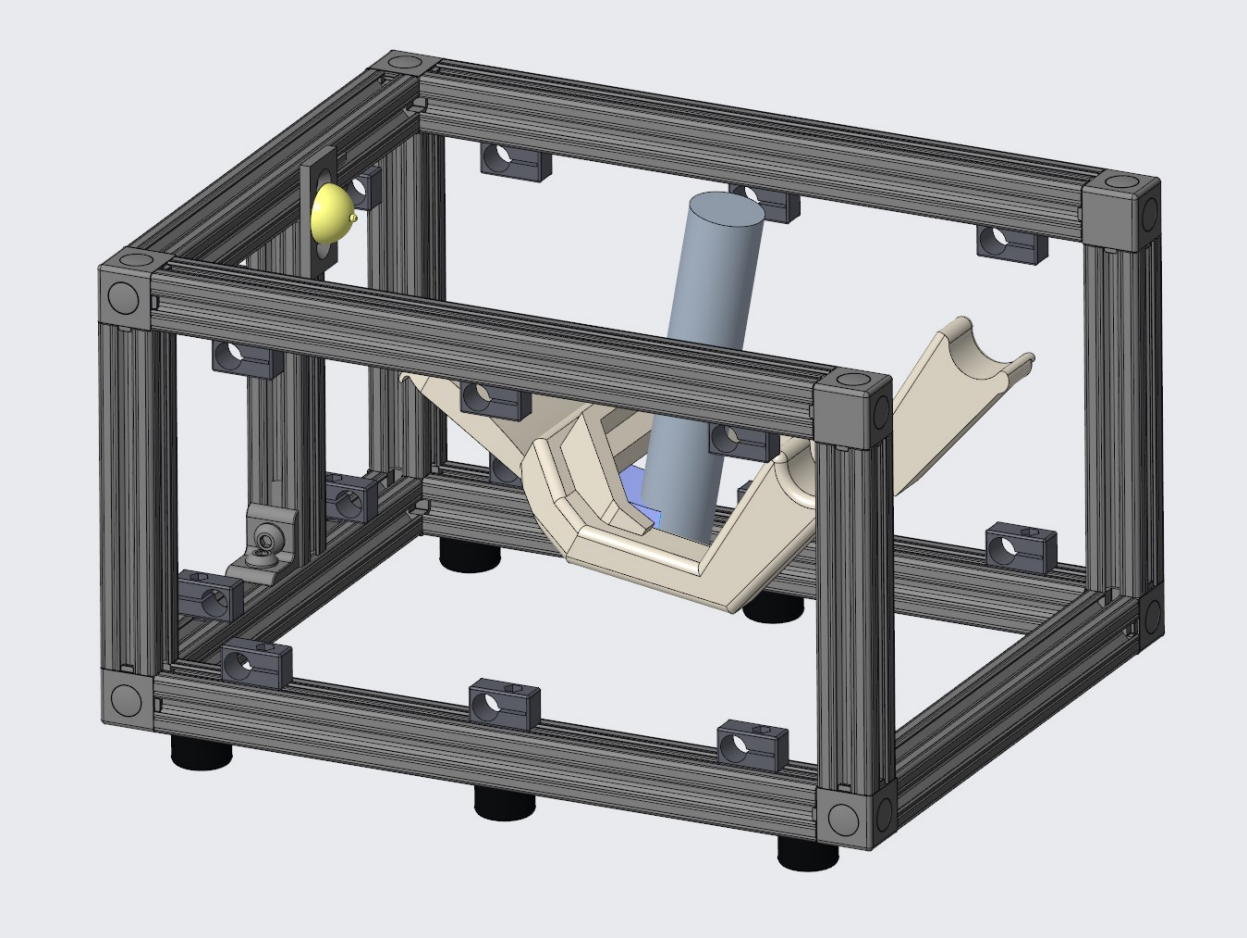


Figure 7: CAD model Pectoral View

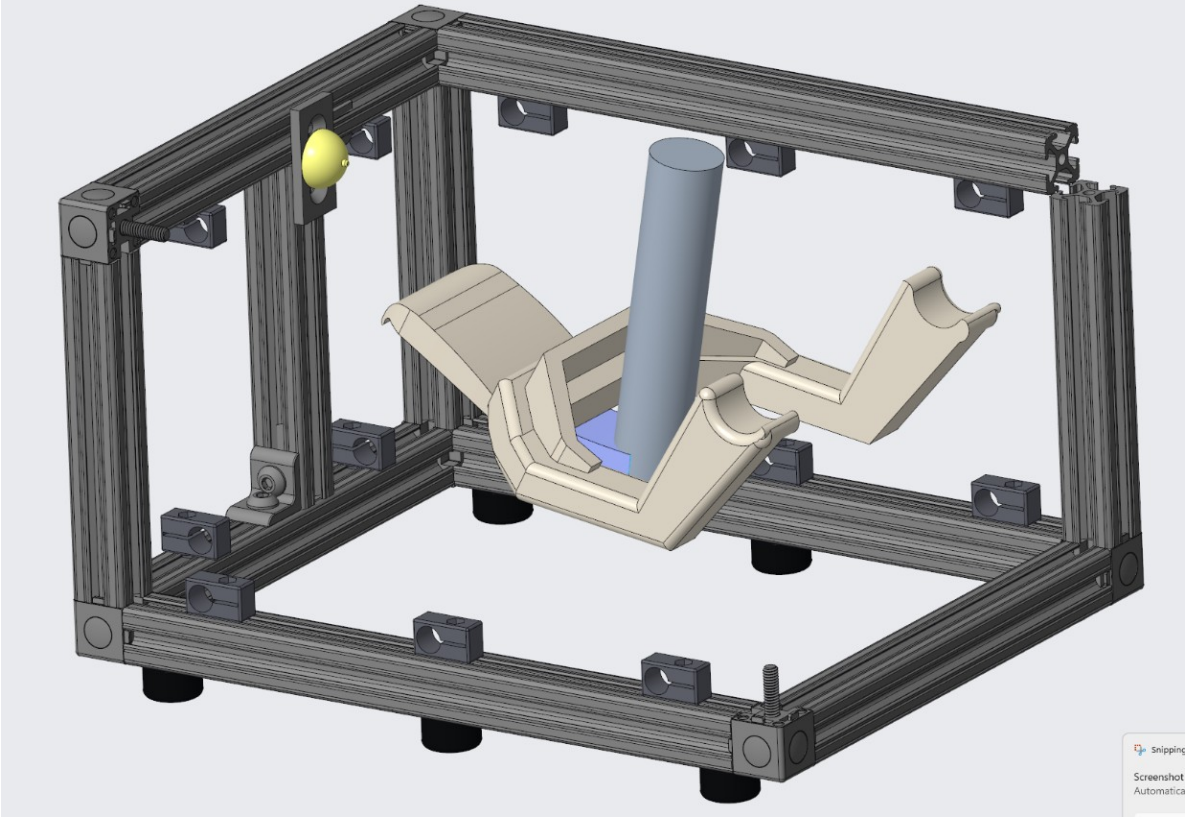


Figure 8: CAD Model Exposed Pectoral View

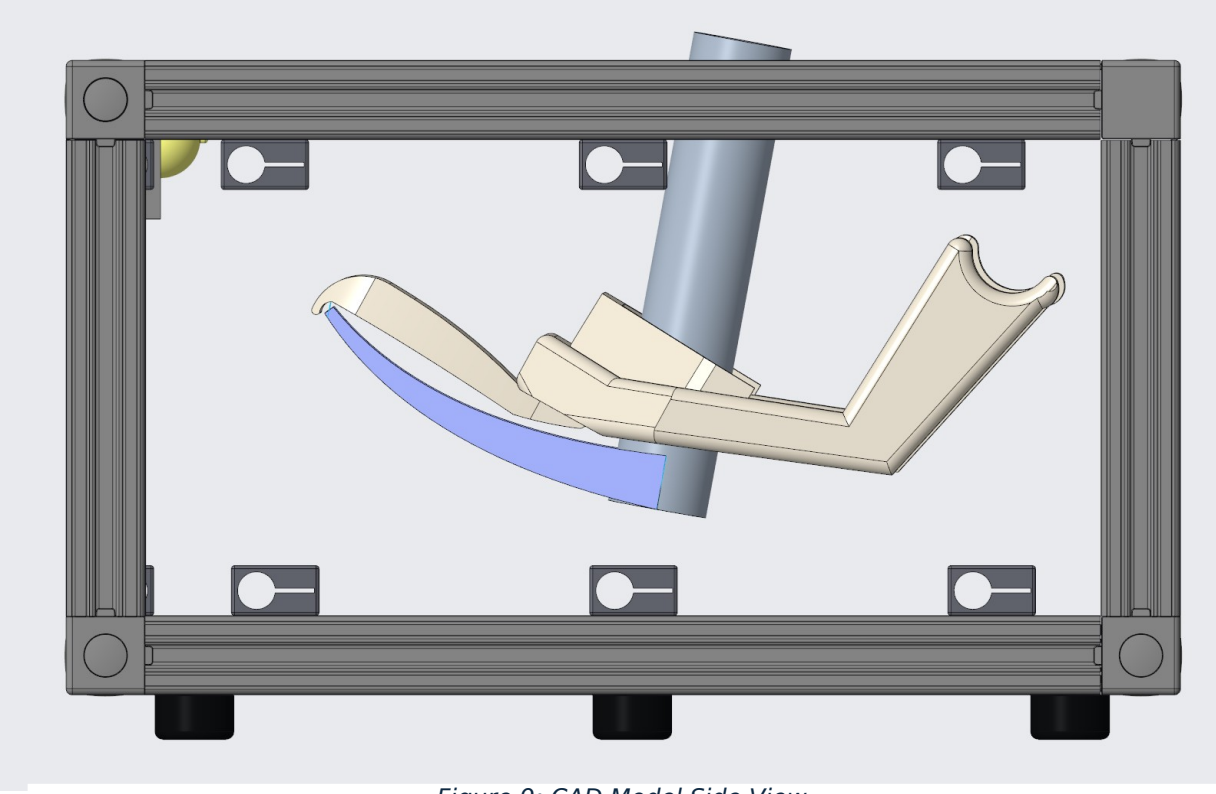


Figure 9: CAD Model Side View

Next Steps:

At the moment the next biggest step is to model the jaw and tissue parts more accurately either via 3D printing or molding and casting. Secondly the purchase of rail systems for the prototype. Once the prototype is built then it will need to be tested. Testing procedures will need to be developed.

Appendix A: References

Airway Management Trainer | Advanced Airway Skills Simulator | Medical-X. (n.d.).

Bernhard, M., Mohr, S., Weigand, M. A., Martin, E., & Walther, A. (2011). Developing the skill of endotracheal intubation: implication for emergency medicine. *Acta Anaesthesiologica Scandinavica, 56*(2), 164–171.

Hastings, R., & Delson, N. (n.d.). *WO2017123852A1 - Parametrically adjustable airway training mannequin with instrumented parameter assessment.*

Laerdal Medical. (n.d.). *Laerdal Airway Management Trainer.*

Universal Medical Inc. (n.d.). *Life/form Airway Larry Adult Airway Management Trainer with Stand.*

Appendix B: Bill of Materials

Prototype Two

Note: all part numbers are from McMaster unless otherwise linked, part numbers are McMaster part numbers, parts to be 3D printed are noted, and all T-slotted parts are 1in height T-slotted Frames (then noted by length) all threaded. (they only make 1 ft so may need to find another supplier)

Quantity	Name	Part No.	Price ea.
4	12in T-Slotted Frame	4601N24	14.23
5	6in T-Slotted Frame	4601N24	14.23
4	9in T-Slotted Frame	4601N24	14.23
6	3-way Outside Corner End Bracket	47065T244	10.71
2	Outside Corner Bracket	47065T242	7.42
2	Corner Bracket	47065T236	7.92
1	2in Plate	47065T255	9.23
1	Bell	Unknown	3.00
16	Fixed Sensor Holder (Rubber Band Holder)	5537T352	4.23
1	Laryngoscope	Already Have	0.00
1	Lower Jaw Model	3D print	0.00
1	Tongue/Tissue Blade Holder	3D print	0.00
Unknown	Rubber Band	Already Have	0.00
		Total	356.84

Appendix C: Prototype Images

Prototype One

Model Images:

Prototype Two

CAD Images:

See above