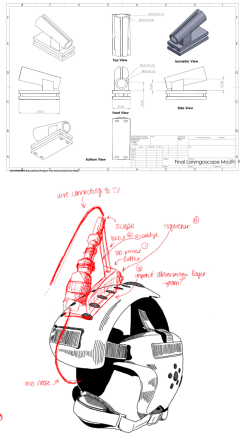
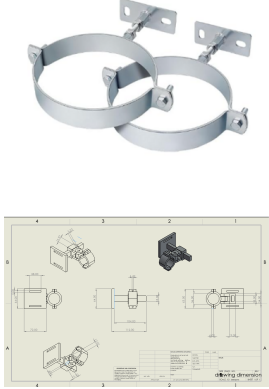
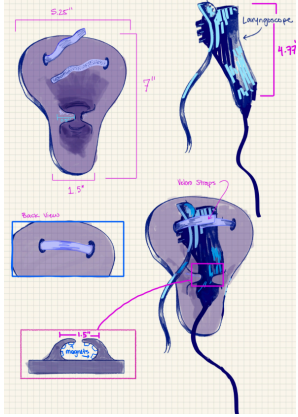


Laryngoscope Mount Design Matrix

Criteria (Weight)	Angled Cone Mount		Split Ring Mount		Magnet+Velcro Mount	
						
	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Stability (40)	4/5	32	4/5	32	2.5/5	20
Durability (15)	5/5	15	4/5	12	4.5/5	13.5
Ease of Fabrication (15)	5/5	15	4/5	12	4.5/5	13.5
Weight (10)	4/5	8	3/5	6	5/5	10
Adjustability (10)	2/5	4	5/5	10	4.5/5	9
Price (10)	5/5	10	4/5	8	3/5	6
Total (100)	84		80		72	

Stability:

Stability refers to the mount's ability to resist relative motion of the laryngoscope to the helmet during full exertion exercise. During the continuous laryngoscopy during exercise test (CLE), the laryngoscope must remain stable under the acceleration of two times gravity [1]. Stability is the most important factor in the design of the laryngoscope mount because if the laryngoscope is able to move independently, the momentum of the patient exercising can cause the laryngoscope to collide with the mount and destabilize the helmet. In addition, independent movement of the laryngoscope will cause the camera probe to move even more inside the patient's larynx, which will cause additional discomfort. Lastly, excess movement of the camera probe will also decrease the video quality and increase the likelihood of necessitating another CLE test or inaccurate diagnoses [2][3]. In

the worst case scenario, if the mount were to break or the laryngoscope detaches from the mount, the laryngoscope would fall, hit the ground, and the camera would be rapidly pulled out of the patient's nasal passageways. This will not only induce a great deal of discomfort for the patient but also cost the medical facility greatly as high definition video laryngoscopes used for CLE can cost up to 18,292 USD per unit [4][5]. Thus, stability is the most important criterion in the design of the laryngoscope mount.

The Angled Cone Mount receives a 4/5 in stability due to the main stabilizing factor being a near 360 contact surface with the laryngoscope, greatly limiting independent movement. In addition, it features two mounting plates, one internal and one external of the helmet. Having two plates rigidly attached to each other and the helmet significantly increases its moment of inertia along the mounting axis, which gives it greater resistance to torsion generated from lateral movements. An adjustable ring clamp will also stabilize the laryngoscope on the cone portion, tightening the cone onto the laryngoscope. The reason this design does not receive full marks is due to a lack of vibration dampening and that the cone does not perfectly contour around the laryngoscope. Thus there will likely be microscopic independent movement of the laryngoscope but this will be contained within the cone, which is rigidly attached to the top mounting plate.

The Split Ring Mount also receives a 4/5 in stability due to its main stabilizing factor is the adjustable ring clamp. The ring clamp stabilizes the laryngoscope by making direct contact with the laryngoscope and tightening it. The active gripping force on the laryngoscope stabilizes it from independent translation and the use of two or more prevents independent rotation. The stainless steel construction also makes the clamp very resistant to jerking forces applied from sprinting as 316L stainless steel has a Young's modulus of 200GPa at 20°C [6]. The reason this does not receive full marks is due to the hinge that allows for adjustability of the laryngoscope's angle relative to the helmet. Hinges allow for some free rotation in the axis that it is mounted on and thus jerking forces from sprinting may cause the laryngoscope to wobble a few degrees at a time.

The magnet and velcro mount receives a 2.5/5 in stability due to the main stabilizing factor being a velcro strap and magnets in a ring mold. Although velcro is very strong, the laryngoscope will slip relative to the velcro during CLE since the laryngoscope is made of plastic and the coefficient of static friction is between 0.15-0.25 for nylon on plastic contact [7][8]. In addition, given that the laryngoscope does not have a very large circumference, the strength of the magnetic forces securing it is limited by the usable area of the inner circumference of the ring mold. Since it is made of plastic, the laryngoscope will need a magnetic metal material to be attached onto the laryngoscope's control body, which will increase the weight and thus increase the forces applied onto the mount and helmet.

Durability:

Durability refers to the mount's ability to maintain its structural integrity and function through repeated use. During continuous laryngoscopy exercise, the mount will experience repeated loading, vibration, and force caused by the motion of the patient's head and the weight of the laryngoscope. Therefore, the mount device will need to resist deformation, loosening, failure, or cracking from the repeated use. Beyond physical change, the material that will be used to fabricate the mount will also have to resist common clinical disinfectants such as bleach wipes and Super Sani-Cloth Germicidal Disposable wipes (purple wipes/quaternary ammonium compound).. Maintaining durability is important because loosening or degradation of the mount can increase unnecessary movement of the laryngoscope during exercise and reduce image quality when inside the patient's

larynx. For this reason, design with components that can withstand repeated mechanical loading will score higher in this category.

The angle cone mount receives a 5/5 in durability because it is relatively simple and rigid with few moving components. The angled holder would secure the laryngoscope in place, while the mount would be attached to the helmet using a two layer feature, with the upper plate positioned outside of the helmet and the lower plate be in the helmet. The proposed double layer would allow for shock absorbing material installation between the gap between the helmet and the mount to help reduce vibration/impact generated from the patient during exercise. This system is expected to reduce stress transferred to the mount and help maintain structural integrity during repeated use. And in order to resist common hospital disinfectant such as bleach wipe and Super Sani-Cloth germicidal disposable wipe (purple wipe), the mount will be fabricated from PETG. PETG is selected as it demonstrates resistance to sodium hypochlorite and isopropyl alcohol base disinfectants, which are common disinfectants used in clinical settings [9][10][11]. Thus, the design is expected to maintain its shape/function during the exercise session.

The split ring mount receives a 4/5 in durability because the double ring clamp system would provide a 2 point of support around the laryngoscope which can help distribute load and securely support the laryngoscope during exercise. The rigid ring structure would allow deformation resistance, while the adjustable pivot join near the center would allow for angle adjustment without needing to bend the mount itself. However due to components that need to be screwed down and rotational pivot connection, it will be susceptible to wear and tear in frequent use. The material that will be used to fabricate the split ring mount design will also be made out of PETG for the same reason stated by both, however, the double ring itself will be stainless steel and a concern for stainless steel is that bleach is will aggressively corrode away the stainless steel but are compatible with purple wipe [12][13]. For this reason the design is expected to be highly durable but is scored lower than the angle cone mount as the moveable part will wear over time.

The magnetic velcro mount receives a 4.5/5 in durability because it has relatively few moving components. And in order to be resistant to frequent disinfection, the design will use PTFE (Teflon) Coated Magnets and polyester hook and loop strap velcro. PTFE magnet would be used because PTFE coating offers excellent chemical resistance and protects the underlying neodymium magnet from moisture and corrosive materials [14]. The strap that will be used to help secure the laryngoscope in place will be a polyester hook and loop strap. The polyester strap would tolerate diluted bleach solutions and quaternary ammonium base disinfectants, polyester fabric may be disinfected with bleach solution up to 3% concentration [15]. However, repeated exposure can cause polyester to become weak, brittle, and decorate. [16]. The rest of the mount will be printed with medical grade TPU strictly Covestro medical-grade TPU grade Texin RxT76D, which provides flexibility and deform underloading rather than behaving as a fully rigid material. The flexibility would allow the applied force and vibration to distribute a wide range of area of the mount, effectively reducing the stress concentration at a single point and lower the likelihood of cracking or mechanical failure during repeated exercise. Covestro medical-grade TPU grade Texin RxT76D also offers great chemical resistance to many cleaning agents used in hospitals including bleach wipes and quaternary ammonium compounds (purple wipes) [17].

Ease of Fabrication:

Ease of fabrication refers to the creation process and how time-consuming and intensive that process will be. This includes factors such as printing time for 3D printed objects, assembly time for those either 3D printed or otherwise, and the manual labor required. As the time increases in 3D printing, assembly time increases, and manual labor gets more intense, the ease of fabrication will decrease. If all factors are kept relatively simple and time effective, it will result in a higher score.

When scoring the angled cone mount, it was taken into account that this will be 3D printed in one piece. It is estimated to be around 24 hours total. Because this will be made in one piece, this is the extent of assembly, including manual labor. This quick and simple process qualified the angled cone mount to be the highest-scoring mount of all of them, earning a 5/5 that translates to 15 as a weighted score.

When scoring the split ring mount it was taken into account that a split ring can be bought and the base attachment 3D printed. This will also require the insertion of screws. The 3D printing process can be estimated to be around 24 hours, the same as that of the angled cone mount. The assembly does require manual labor of putting together the split ring along with the 3D printed base being held together by screws. The printing time is the same as the angled cone mount and the purchasing of the split ring does not add to that time, the only difference is assembly. Because of the additional steps of adding screws and potential challenges added by the insertion and storing of these screws, the split ring mount was given a 4/5 that translates to a 12 as a weighted score.

When scoring the magnet+velcro mount it was taken into account that it would require only velcro and relatively strong magnets, both of which can be purchased. It is simple to lace the velcro through the holes in the chosen helmet. In regards to the magnets, securing them within the helmet is the only process that would require some labor. While assembly can be slightly complicated, the manual labor won't be too difficult and time won't be as large a factor as in 3D printing the other objects. Taking all of this into consideration the magnet+velcro was given a 4.5/5 that translates to a 13.5 as a weighted score.

Weight:

Weight refers to the amount of extra force placed on the patient's head by the mounting system itself. A heavier mount increases the force transferred through the helmet, meaning the mount must minimize this added weight in order to maintain the patient's comfort and safety. Without weight management, the product may cause strain on the patient's neck and back during use. Testing must account for this factor by evaluating how mount weight affects overall comfort across different testing durations.

The angled cone mount's weight was kept small to minimize the strain on the patient's neck and back. The design is made out of PETG (a lightweight 3D print plastic), which weighs about 10.5 grams per cubic inch. This means the design weighs roughly 72 grams [18]. The screws used to keep the attachment on the helmet weigh around 48 grams total (~24 grams per screw) and 34 grams for the two nuts to tighten the screws [19]. This design weighs a total of 154 grams

The split ring's design provides a heavier weight on the patient's head. The attachment itself is light, being made out of PETG plastic (~88.45 grams), however this design includes steel rings for the laryngoscope to attach to [18]. The steel rings weigh ~771grams total. This design in total weighs 859.5 grams, this is a lot of weight displacement that sits on the front of the patient's head. This means that the patient may experience significant strain on their neck and back, giving this design a 3/5.

Assessing the weight of the magnet+velcro mount provides the ideal low weight range that will provide the least amount of strain on the patient as possible. The TPU 3D print plastic top will weigh around 28 grams, the rubber back plate is made out of 3D printed resin and will weigh ~40.65 grams [18]. Including the velcro straps (28 grams) and magnets (~13 grams), the total weight of this mount is ~109.65 grams total (3.8 ounces)[20]. This small sum is why this design received a score of 5/5.

Adjustability:

Adjustability refers to the ability of the mount to utilize different models of laryngoscopes (inclusiveness) and adjust the position of the laryngoscope itself (position adjustment). Laryngoscope models come in different sizes and shapes, meaning a secure mounting system will have to conform in order for overall product function. Without proper inclusiveness, the product severely limits its range of operations to a singular product. Position adjustment allows for repositioning of the laryngoscope itself while mounted to the helmet. This aspect allows for consistent levels of outcomes for patients with varying head sizes and further accounts for laryngoscope model differences.

Assessing the adjustability of the angled cone mount provides poor inclusiveness and poor position adjustment. The diameter of the cone itself cannot be adjusted and is therefore limited to the selected laryngoscope it is designed for. The angled cone mount cannot be repositioned across multiple axes. The mount is angled by one end, suspended upwards by a rod on its tail. This means the mount cannot move outside its fixed position giving this mount design a score of 2/5.

Assessing the adjustability of the split ring mount provides the best results, with excellent inclusiveness and excellent position adjustment. A split ring is an inclusive type of clamp that uses a tightening system to compress the object it is intended to hold, meaning the shape of the laryngoscope can be accounted for by clamping further or less. The mount's ability to pivot about its attachment point provides high flexibility by adjusting the positioning angle, which provides a rotational degree of freedom about this point giving this mount design a score 5/5.

Assessing the adjustability of the magnet+velcro mount provides moderate inclusiveness and moderate position adjustment. Velco is a highly inclusive stabilization material due to its ability to adjust its length to various diameters of laryngoscope. Magnets, however, aren't as inclusive. The addition of magnets requires the laryngoscope to be composed of magnetic material at the designated area the magnet mount attaches, severely limiting the laryngoscope that can be used with the product. The only position adjustment possible while the

laryngoscope is mounted is sliding further up or down the magnets/velcro, additionally doubling as a stability concern. Giving this mount design a score of 3/5.

Summary of Adjustability findings for each mounting system

Mount	Angled Cone	Split Ring	Magnet+Velcro
Inclusiveness	Poor	Excellent	Moderate
Position adjustment	Poor	Excellent	Moderate

Price:

Price refers to the total price of materials used to create the mount and attach it to the helmet. Iteration costs are considered but not included in the price estimates below.

The angled cone mount serves as the most economical option; adding an adjustable angle mechanism slightly increases its cost due to extra hardware and iteration needed, but its low part complexity still keeps it at \$15-20.

The split ring mount sits at a moderate price point of \$25-40 by pairing 3D printed parts with off the shelf metal split rings/clamps.

Finally, velcro and magnet mount is the least cost-effective choice around \$50 driven up by specialized N52 neodymium magnets, 3M Dual Lock fasteners, structural epoxy, and alignment pins.

All three designs fit within the \$500 budget, but the angled cone mount is the most economical choice and gives the most spending room for iteration.

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