

# Improvements in Preoperative Hair Removal

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## 1. Abstract

Hair is removed from a surgical site prior to surgery to reduce damage to the skin and make a cleaner surgical site. After the patient is shaved, the loose hair is collected with tape, which is inefficient. Our client, Dr. Gregory Hartig, a head and neck surgeon for UW Hospital, has requested a vacuum device that collects the cut hair. Ideally, the device would use the existing suction in the OR, have a relatively low cost, and be compatible with many types of hair.

A design that combined the suction device and surgical clippers currently was proposed. However, based on client request, a separate vacuum device was chosen. Four prototypes were created. A and B as well as C and D are structurally the same with different cross sectional area. A and C have a cross sectional area of  $4.6 \text{ cm}^2$ ; B and D have a cross sectional area of  $2.4 \text{ cm}^2$ .

Each prototype was tested by recording the time of hair removal off of a constant area using synthetic hair. The prototypes were tested using 2 lengths of filters (12 cm and 10 cm). The average time to collect a known amount of hair for each prototype was recorded from 5 trials and statistically analyzed using 2-sample t-tests. Device C was the most time efficient device (vs. tape,  $p = 5.886 \times 10^{-13}$  and vs. device D,  $p = 0.0303$ ). Devices C as well as the tape were tested on the removal of a hair on a volunteer's shaved legs. Device C was more efficient with a time of 84.9 seconds versus 122.6 seconds for the tape. Although this initial data is promising more testing is needed to determine safety and ergonomics.

## 2. Introduction

### 2.1 Biology of Hair

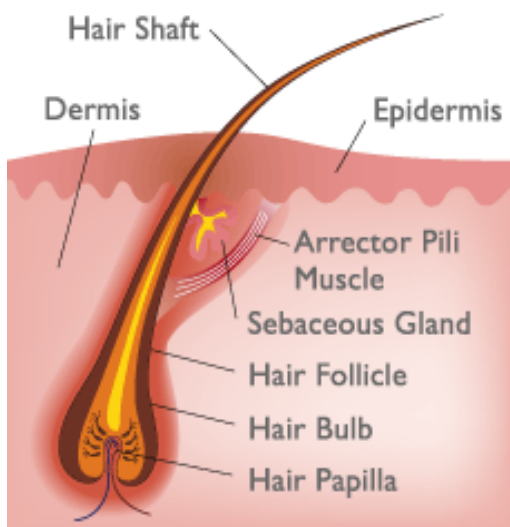


Figure 1: Anatomy of hair<sup>1</sup>.

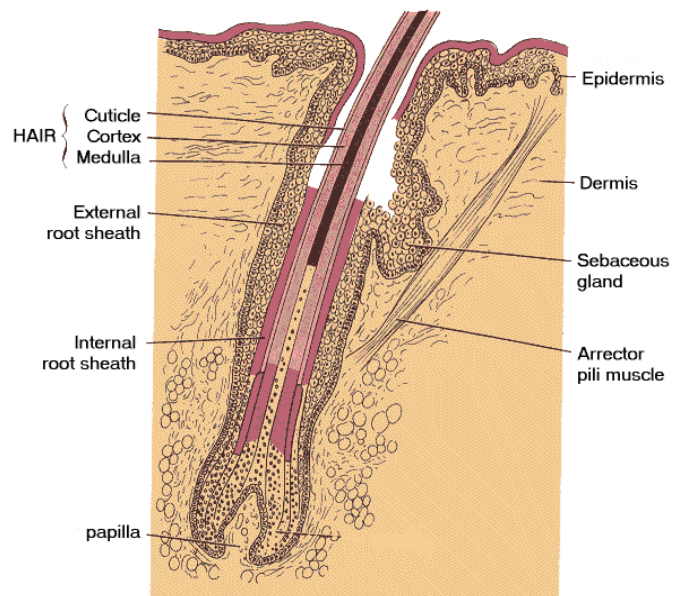


Figure 2: More anatomy of hair<sup>2</sup>.

Hair is comprised of two distinct structures: the follicle and the shaft. As seen in Figure 1, the part of the hair that is found in the dermis of the skin is called the follicle. At the base of the follicle, there exists the papilla, which contains capillaries to supply nourishment to the cells of the bulb that surround the papilla. The bulb cells divide every 23 to 72 hours. As seen in Figure 2, the follicle is

surrounded by two sheaths: an inner sheath and an outer sheath. The inner sheath follows the hair shaft and ends below the opening of the sebaceous gland – a gland that produces sebum which is a natural hair conditioner. The outer sheath also follows the hair shaft and ends at the gland. Below the gland, the arrector pili muscle attaches to the fibrous layer around the outer sheath. Upon contraction of the arrector pili muscle, hair stands up.

The part of the hair that extends above the skin surface is called the shaft. The shaft is composed of intermediate filament proteins called keratins<sup>3</sup>. The cross section of the shaft determines the amount of natural curl. If the cross section is circular, the hair is straight. If the cross section is flattened and elliptical, the hair is curly or kinky<sup>4</sup>. The cross section of the shaft can be broken down into three zones. The outermost layer is the cuticle. It consists of several layers of flat thin cells that overlap one another similar to roof shingles. The main purpose of the cuticle is to protect the medulla and the cortex. The middle layer is the cortex. It is the main source of mechanical strength and water uptake. Also, the cortex contains the majority of the pigment melanin, which gives hair its color. The inner layer is the medulla. It may not always be present in hair. The medulla helps give hair its elasticity. The medulla also contains the pigment melanin<sup>3</sup>.

Hair on the scalp grows about 0.3 to 0.4 mm per day. Hair growth can be broken down into three stages: catagen, telogen, and anagen. The anagen phase is the active hair growth stage. Hair growth during this phase will last several years. The catagen phase is the transitional hair growth stage. It last a few weeks where hair growth slows and the hair follicle shrinks. The telogen phase is the resting hair growth stage. Hair growth stops during this phase and will eventually detach from the hair follicle. When a new hair begins the anagen phase, the old hair in the telogen phase will be pushed out if it has not already fallen out<sup>6</sup>.

### 2.3 Need for Surgical Hair Removal

Three main reasons arise for the need for preoperative hair removal. First, preoperative hair removal reduces the time of surgical procedures as well as makes operating easier for the surgeon. It is profoundly problematic for the surgeon to operate on a site that is densely populated with hair such as a woman's scalp. The surgeon is burdened with repositioning the hair out of the surgical site so that they may see what they are doing. This unnecessarily extends operation time and thus increases the risk for the patient<sup>6</sup>. The other reasons are that preoperative hair removal allows later removal of skin and wound dressings to be less painful<sup>7</sup>. Hair has a tendency to cling to contacting surfaces such as articles of clothing, dressings, or bandages. If the contacting surfaces are set into motion, they will pull on the hair, which in turn will pull on the skin connecting the hair. If this area is a wound site, pain and discomfort would be inflicted to the patient.

### 2.4 Current Methods



Figure 3: Example of an electric clipper<sup>8</sup>.



Figure 4: Example of disposable razor<sup>9</sup>.



Figure 5: Example of depilatory cream<sup>10</sup>.

Preoperative hair removal is conducted via three methods: electric clipper, razor, and depilatory cream. Examples of these devices can be seen in Figures 3 through 5. Our client mainly utilizes the razor or the electric clipper. If the razor is indeed employed, the client chooses to perform the hair removal dry without the aid of any creams. After the hair shaft has been detached from the hair follicle, a profoundly problematic issue arises: How to collect the detached hair shaft that lies on the surface of the epidermis? Presently, the client utilizes tape in order to collect the loose hair. However, this method is ineffective as hair is often found on the epidermis of the patient after the tape has been used. The issue of left over hair on the epidermis becomes apparent when hair is found in the surgical field during surgery, which unfortunately this is often is the case. Removing the hair from the surgical site becomes very difficult for the surgeon wearing surgical gloves. Additionally, the surgical time is unnecessarily increased in order to remove the hair lodged in the surgical site, which places the patient under a greater risk for complication due to extended time of surgery<sup>6</sup>.

## 2.5 Problem Statement

Our goal is to create a suction device that is compatible with the -200mmHg (gage) suction already available in the operating room (OR) in order to collect loose hair. The device should be able to remove all cut hair more efficiently than current methods with tape. It should be able to be used for different types of surgeries and varying types of hair. It should be handheld and easy to use and maneuver. The cost should be kept low. The device cannot be abrasive to the skin and not cause harm to the patient.

## 2.6 Design Specifications

Specific design requirements can be found in the Product Design Specifications located in the appendix.

## 3. Initial Designs

### 3.3 Initial Design Options

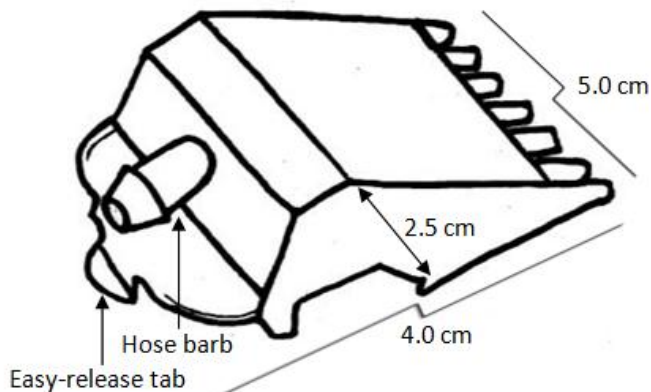


Figure 6: Sketch of trimmer design<sup>12</sup>.

This design is made to clip onto the top of the trimmer, which allows the suction to be on top of the clipper in order to catch the freshly cut hair. This position, however, could be potentially problematic. These attachments are traditionally used to control the length of hair that is removed by acting as a spacer between the blades of the trimmer and the skin. This revised model will not cover the blades and therefore will not prevent the trimmer from removing all of the hair.

#### 3.3.1 Trimmer Design

The first design, as seen in Figure 6, is a modified version of the plastic attachments available for most personal hair trimmers. By simply hooking the front lip on the trimmer and pushing the back tab down into place, the attachment head can easily be applied to the trimmer. Similarly, by raising the tab of the back of the attachment, it is also easily removed. The snap-on and off method already present in the attachment heads allows for easy and repeatable attachment to the trimmer.

For initial prototypes, fitted sheets of rigid plastic will be mounted to the top and bottom of the commercially available attachments. In doing so, the original dimensions and small cross sectional area of the attachment will be preserved. This is ideal since suction is a limiting factor. In addition, a tapered tube to attach the suction tubing will be included in the back plate on the left side of drawing. A simple screen will be placed at the base of this attachment point and inside the plastic device; this will function as the hair trap. Additional testing will include positioning the suction source at different positions on the back plate and varying the size of the screen to maximize efficiency. The production of this device is expected to be very inexpensive both for initial prototypes and in the long term with injection molding or 3D printing. Therefore, once the device loses significant suction after filling with hair, simply a new device can be snapped onto the trimmer, and the old device will be thrown away. Although some time is lost when replacing device, it is believed that this will be more time effective in the long term than attempting to clean or remove the hair from the device, especially when considering the small size.

### 3.3.2 Blade Design

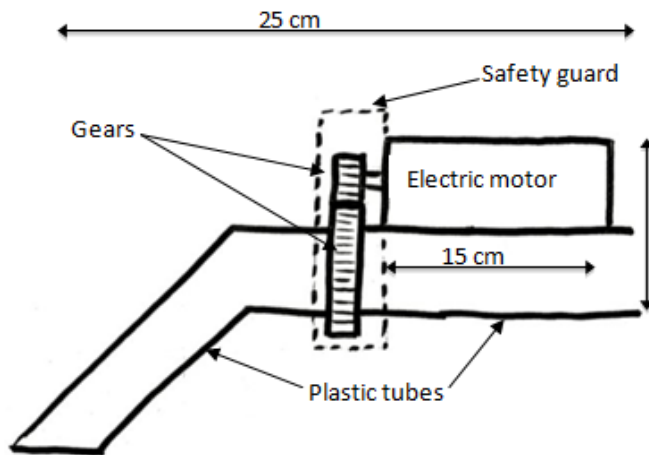


Figure 7: Sketch of blade design<sup>13</sup>.

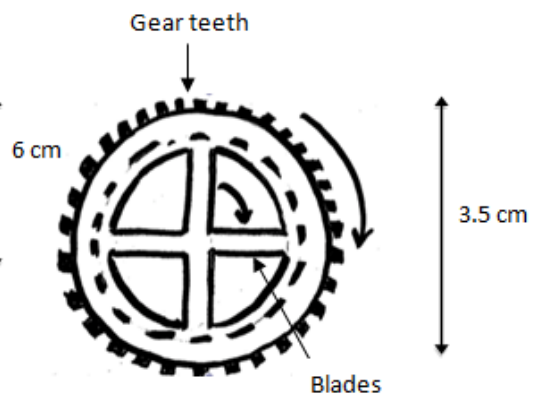


Figure 8: Sketch of blade<sup>13</sup>.

The blade design, as seen in Figure 7, is comprised of four major components: the two hollow connecting pieces, the blade that doubles as a gear, and an electric motor that is the driving force of the blade. The major appeal of this design is that the hair would not need to be collected by a hair trap. The blade would cut the hair as it's being drawn in by the suction and would then be able to travel down the OR tubing and be caught in the pre-existing OR trap.

The blade in this design, as seen in Figure 8, would be a metal ring with the blades radiating from the center. The outer portion of the blade would also have a larger diameter than the connecting tubing so that the outside circumference would be exposed when in-between the two connecting hoses as shown in the dotted box in Figure 7. The exposed portion of the ring would consist of gear teeth. The electric motor would spin a shaft that has a small gear at the end, which would be in contact with the exposed portion of the blade and therefore make the blade spin.

A safety guard would be needed to protect the user from the spinning gears. Because the electric motor would not be in contact with the contents that are picked up via the suction, it would be reusable. In enhance reusability, part of the design would be need to be assembled before use. This involves placing the blade in-between the two plastic tubes, and then attaching the electric motor, which ideally would be just clipped on.

The first hollow connecting piece with the opening to the outside would be able to be designed to reduce cross sectional area to minimize suction loss. The second connecting piece would be designed to insure an ergonomic grip and would connect to the OR suction hosing. Both of these pieces would be

made out of plastic with the goal of one day manufacturing them with a simple mold. This is the basic design, however, more intricacies would need to be designed to properly connect the two plastic elements while sealing the device to the outside and still allowing the blade to spin freely. The use of ball bearings or a lubricant of some kind could come into play if this design is to be used.

### 3.3.3 Brushes Design

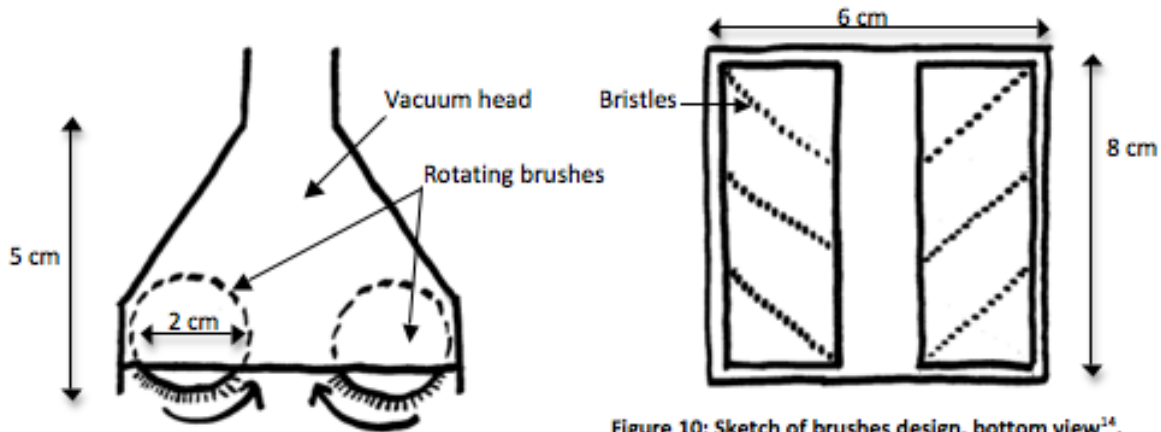


Figure 9: Sketch of brushes design, side view<sup>14</sup>.

Figure 10: Sketch of brushes design, bottom view<sup>14</sup>.

The third design, as seen in Figures 9 and 10, is made of two rotating bristle brushes in a vacuum head, very similar to traditional handheld vacuums. A pivoting head allows for better maneuverability. It is made to sweep up the hair into the base of the suction source. Since it does not have a component to cut the hair, this design will be used in addition to a razor or electric trimmer. Ideally, the device will be modular and could be used for a wide array of hair types. This universality will be achieved through different sized vacuum heads as well as replaceable brushes of varying size. Testing would show which type of bristles and brush size would allow for the most efficient use. Due to the moving parts, this design is expected to be more expensive than the trimmer design.

Although essential to mechanical motion of the hair, the rotating brushes pose a small hazard to both the patient whose hair is being removed and the operator performing the hair removal procedure. Holes will be placed in the head (location to be determined by testing) of the device to prevent creating a vacuum seal on the skin, which would damage blood vessels and possibly cause bruising; however, if blocked a vacuum could still form. In addition, the rotating brushes create an additional source of potential injury. A fine balance is needed for the strength of the bristles – stiff enough to lift hair but soft enough to prevent scratching of the skin. The device will be safe for a wide arrange of skin types but especially loose or thin skin is at risk for damage from the bristles. Pinching of the skin is possible. Although only the bristles will touch the skin, skin or uncut hair could become lodged around the bar that the bristles are attached to, which would pull out the hair or damage the skin.

### 3.4 Initial Design Matrix

The three different designs were evaluated using a design matrix (Table 1) that evaluated the cost (which incorporated up-front cost as well as the ability to one day be mass produced) the safety, the perceived efficiency, the universality (broad applicability), and the ergonomics of each design. Cost, safety and efficiency were the most heavily weighted categories because these were deemed the most important factors involved in satisfying our client’s desires in the project.

Categories	Weight	Trimmer Design	Brushes Design	Blade Design
Cost	30%	4	3	2
Safety	25%	4	2	3
Efficiency	20%	4	4	5
Universality	15%	5	3	3
Ergonomics	10%	4	2	4
<b>Total</b>	<b>100%</b>	<b>4.15</b>	<b>3.2</b>	<b>2.85</b>

**Table 1: Design matrix was used to compare designs based on select categories.**

The trimmer design ranked the highest in nearly every category. This is due to the design's nature of modifying a trimmer that is already used in the OR. The entire structure of the design will be able to be plastic molded, which makes the goal of mass production feasible. Also, since the finished device will mostly consist of a pre-existing device, the safety and ergonomics of the device are already ensured. The attachment may slightly increase the bulkiness and cover up the blades of the trimmer but the device's ergonomics and safety will remain sound. The attachment will also be manufactured at different sizes to accommodate different hair volumes. Limited suction will be the only limitation in picking up the cut hair, but because the hair will be collected as it is cut loose from the body, this design should be very efficient.

The brushes design has many components to it, including electrical work that would need to be done. These factors require a more complex manufacturing process and therefore more expensive. Another concern about this device is that the rotating brushes and the sidewalls may catch and pinch the skin. It will also be very difficult to design brushes that are able to flick up hair while not irritating the skin, especially because of the wide range of patient skin sensitivity. However, the idea of loosening the cut hair would make it easier for the suction to collect it. Ideally, the design would be able to incorporate different brush sizes, but the head of the design would be so large that there is a fear that doing so would require too large of an area at the opening and disrupt our already limited suction. The bulkiness of the head and specific handling required to make proper contact with the skin also makes the ergonomics of this design a concern.

The blade design also has many components to it, which include electrical and gear components, but a larger concern is that the pieces of this design would need to be very specifically custom made. This complexity of manufacturing directly increases the cost associated with this device. The nature of having a device that requires assembly before every use and that encompasses a very fast spinning blade also possess a safety threat, due to the severity of a malfunction. There could be serious damage to the user and/or patient if any went wrong while in use, but again this is only in the unlikely event of a malfunction. The ease in maneuverability, maximized utilization of the suction power at hand, and elimination of the need to collect and house the hair makes this design extremely efficient in collecting the hair. However, because the design does not collect the hair, the one blade design must be able to handle and efficiently cut all different hair densities and lengths. The overall shape of the raw design allows for the final design to incorporate an ergonomic grip.

Neither the brushes design nor the blade design was able to compete with the cost, safety, or universality of the trimmer design and is the clear choice in our steps moving forward.

#### **4. Design Change**

Hair trimmers used in the OR are not compatible with plastic attachments that form the basis of the trimmer design as described above. In addition, the 3M clipper provided by our client also has a



pivoting head as an essential design feature. In order to conserve this function, a new design was created.

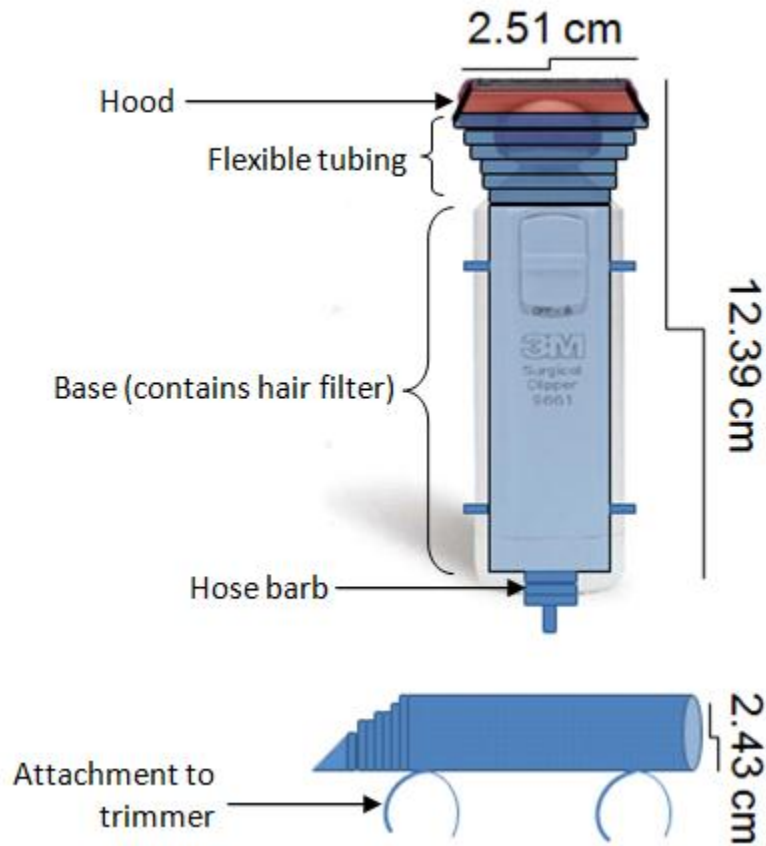


Figure 11: Sketch of revised trimmer design, (top) top view, (bottom) side view<sup>14</sup>.

This design, as seen in Figure 11, was created to snap directly on to the trimmer. It would allow hair to be collected as it was being cut. Flexible tubing would connect the hood (near the trimmer blades) to the base and hair trap (above the handle of the trimmer). The flexible tubing would not restrict the range of motion of the clipper head as the pivoting head is a key feature that contributes to the device ergonomics. Our client, however, desires a vacuum device that is separate from the trimmer.

## 5. Additional Design Change

Per our client's request, the design was again changed. The vacuum device is separated from the trimmer.

## 5.1 Prototypes A and B



Figure 12: Close up of top view of prototypes A and B.



Figure 13: Close up of the bottom view of prototypes A and B.

Prototypes A and B, Figures 12 and 13, were constructed using the same basic design; however, the dimensions differ. The heads of A and B were constructed from two pieces; the top of the each device was made using vinyl tubing while the bottom of each device was constructed from hard plastic. The making of Prototype A began by cutting a 5 cm by 4 cm rectangle from the hard plastic. The plastic was then cut so that it was 5 cm on one end and tapered down to 3 cm for the other end on both sides. The length of the plastic remained the initial 4 cm. The plastic piece was then folded along the tapered end so there were two 1 cm tabs along the tapered edges. Then, a 4 cm long segment of 1.9 cm diameter vinyl tubing was cut. The tubing was again cut lengthwise so it could lay flat. The tubing was stretched over the plastic bottom and glued to the tabs. The head was completely taped and vent holes (1 mm diameter) were placed on the top of the head to prevent a vacuum seal to the skin from forming. Foam was placed over the open edges of the head to prevent skin abrasions. The finished head was then taped to a 15 cm plastic tube with a diameter of 2.4 cm and which could easily bend. The plastic flexible tube contained a 10 cm or 12 cm nylon hair catch. The plastic flexible tube also included an adapter glued to the end so that the surgical tubing could easily attach.

Prototype B was constructed in a very similar way but began by cutting a smaller 4 cm by 3 cm plastic rectangle. The vinyl tubing cut for this head was also smaller length (3 cm). The tubing also was cut widthwise by 1 cm. Prototype B tapers from 2 cm down to 2/3 cm and also includes the 1 cm tabs that attach to the tubing. Prototype B also received the same treatment of poking vent holes (1 mm diameter) in the top of the head and covering the opening with foam to prevent the vacuum seal and skin abrasions.

## 5.2 Prototypes C and D



Figure 14: Close up of top view of prototypes C and D.



Figure 15: Close up of top view of prototypes C and D.

The suction heads C and D, figures 14 and 15, have the same overall shape but have different cross-sectional areas at the openings. The two different areas match the two cross-sectional areas of the suction heads A and B. Designs C and D were made with the idea of trying to maximize the width of the head to allow for a wider area of pick-up with each pass but minimizing the open cross-sectional area to ensure sufficient amount of suction. The cross-sectional area is also at a diagonal to the horizontal plane, so that when the device is in use it must be held at an angle, making it more ergonomic.

The materials used to manufacture of C and D were sheets of plastic from old design notebooks, hot glue, tape, plastic bendable tubing with a diameter of 2.4 cm and the nylon filter. The sheet of plastic was cut out into two shapes (Figure 16), which were then folded and glued together using the hot glue. The plastic tubing was then attached by inserting it into the back of the head and then used tape to both connect the two pieces and create an airtight seal at the junction. Because the plastic tubing needed to be inserted into the back, only a small section of tubing was inserted. This allowed easy insertion of the filter 3 cm from the head and allow us to take apart the devices with ease to clean out the filters between testing. In total, 15 cm of the plastic bendable tubing was attached behind each head, with an attached junction for the suction tubing. The nylon hair catch was placed into the tubing just as it was in devices A and B.

Suction head C was much wider than the plastic tube, and at first the hair was getting stuck in to head rather than flowing into the plastic tube and then into the filter. This problem was fixed by having two plastic strips attach to the insides of the head and then taper into the connected plastic tubing. Suction head D did not have this problem, as hair was able to flow from the head into the plastic tubing without any issue. The edges around the cross sectional opening were lined with foam to prevent any abrasion to the skin. Two holes (1 mm diameter) were also placed in the heads to prevent a suction seal from taking place between the device and skin. Both were then wrapped in white tape to make our prototypes more visually pleasing.

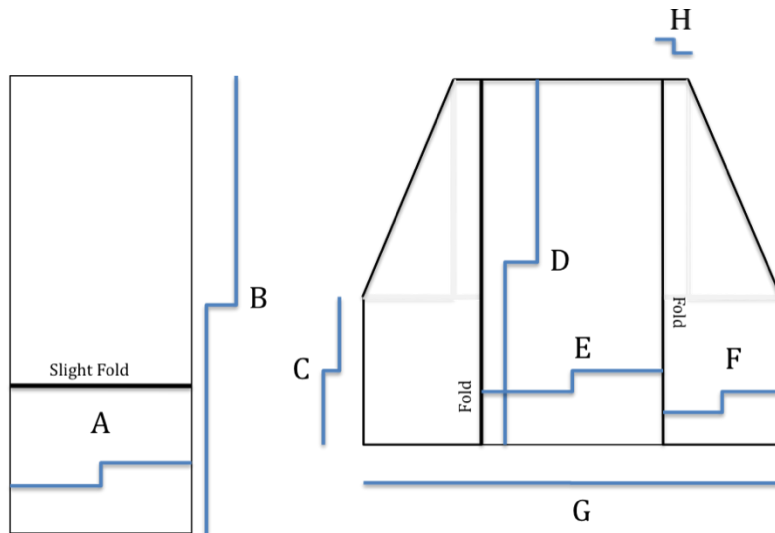


Figure 16: Blueprints of devices C and D<sup>16</sup>.

	Device C	Device D
A	3.5 cm	3.0 cm
B	7.0 cm	5.8 cm
C	2.0 cm	2.0 cm
D	5.2 cm	5.0 cm
E	3.5 cm	3.0 cm
F	2.0 cm	1.5 cm
G	7.5 cm	6.0 cm
H	0.7 cm	0.5 cm

Table 2: Specifies the dimensions of Device C and D

## 6. Testing

### 6.1 Initial Testing



Figure 17: Photo of initial testing in progress.

Designs were first tested using synthetic hair. It was assumed that the synthetic hair was similar to actual hair. The faux fur fabric was cut into 10 cm by 10 cm squares, and the hair was then removed from the fabric with a scissors. The fur had a length of 1.6 cm. A total of  $0.84 \pm 0.04$  grams of hair was removed from each square. The hair was then spread out over a 26 cm by 34 cm board. The amount of time to pick up all of the hair was recorded. Figure 17 illustrates a testing trial in progress. Ten trials were run for the tape, and five trials were run for each filter size for designs A, B, C and D. All vacuum tests were performed with a suction of 200 mmHg. From trial to trial, care was

taken to allow for steady and consistent movement over the board surface until all hair was collected. Statistical analysis (two sample t-test) was used to compare the results. The following factors and their effects on device efficiency: head shape, cross sectional area, and filter size.

### 6.2 Human Subject Test

The anterior portion of a volunteer's legs were shaved using OR trimmer from ankle to knee. Tape was used to pick up hair from the left leg, and the most efficient vacuum device from the initial testing was used to pick up hair from the right leg as seen in Figure 18. Suction was set at 200 mmHg. Of note, white paper was positioned below the subject's legs for contrast so that the hair could easily be seen. The time to collect all of the hair was recorded for both the tape and the most efficient vacuum design.



Figure 18: Photo of human subject test in progress.

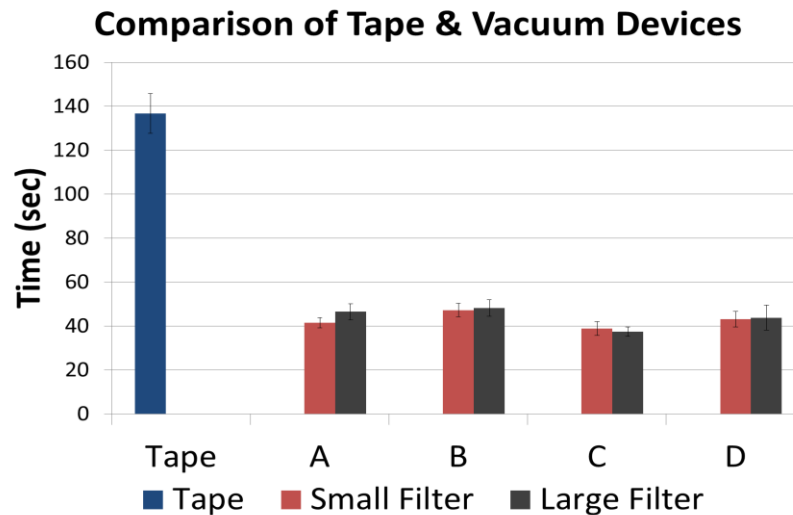
### 6.3 Testing Error

Sources of experimental error include small variations in amount of hair removed from fabric squares or subject's legs as well as rate of motion in initial testing trials. Less hair removed and faster movements would artificially decrease time, and more hair removed and slower movements would artificially increase time. Other sources of error include possible leaks in seals, which would decrease suction. Additionally, because human judgment was required to determine as when there was no hair left on the testing board or the human leg as this determined when the test ended, errors associated with it may have been introduced. Our prototypes were also handmade so while we tried to stay true to varying only the cross-sectional areas of each shape, other confounding variables may have been introduced in the manufacturing process of the different sized heads.

## 6.4 Methods to Reduce Testing Errors

While the methodology used to test the devices was sufficient to accomplish the task at hand, it could still be improved. The errors associated with fabricating the cross sectional area by hand can be limited and even eliminated if the prototypes were fabricated using 3D printing. This would then increase the chances of prototypes A and C as well as B and D to have the exact cross sectional areas. Additionally, to eliminate the errors involved in human judgment in determining as when to terminate a trial, a more quantitative method would need to be instilled. One manner to do this is to use coat the hair with a fluorescent die and utilize a fluorometer to quantify the intensity of light. When the intensity of light reduced to a pre-defined threshold, the experimenters would know to end the trail.

## 7. Data Analysis



**Figure 19: A graph that illustrates the comparison of tape and vacuum devices.**

All of the prototypes performed well, they were all successful in retrieving all of the hair off the wooden board faster than the current standard, tape. However, B failed to pick up all hair on its first trial but this was attributed to improper filter installation and that trial was not counted. Device C was the most time efficient as seen in the Figure 19. U

Using the 5 first trials with the 12 cm filter, the average time for each device were calculated. The average time for device C was 37.37 seconds with a standard deviation of 3.174 seconds. This data can be compared to the next fastest device, D, that had an average completion time of 43.79 and a standard deviation of 5.606. Using a 2-sample t-test, device C was compared to device D. The p-value calculated from this comparison determines if C is indeed faster than D with certainty. The calculated p-value was 0.0304 ( $p < 0.05$ ) confirming that device C is more efficient than device D. Next, device C was compared to the third fastest device, device A. Device A had an average time of 46.49 seconds and standard deviation of 2.28/ Using the same 2-sample t-test, the calculated p-value was 0.00129, again confirming that device C is also faster than device A. Finally, device B was compared using the 2-sample t-test. Device B had an average time of 47.22 seconds with a standard deviation of 3.003. The p-value for this comparison was a very small,  $5.184 \times 10^{-4}$ . Lastly, the final design was compared to the standard, tape. Tape had an average completion time of 136.75 seconds with a standard deviation of 9.006. This statistical analysis allows confirmation with excellent certainty that device C is the most efficient device.

The data from the 5 trials with the 10 cm filter was also compared to the data of the 5 trials using the 12 cm filter. All data from prototypes (A through D) with a 12 cm filter were compared to their

10 cm filter counterparts. Again, using the same 2-sample t-test, p-values were larger than 0.05. Therefore, for the amount of hair collected, filter size did not affect the efficiency of the prototypes. All p-values calculated were larger than 0.05 suggesting that filter size did not influence the results for our tests.

In our human subject test our device C was also more efficient as compared to the tape. The tape completed the hair retrieval in 122.6 seconds whereas device C retrieved all hair in 84.9 seconds; device C was 30.75% faster than the current standard, tape. Also, during the human subject test, the device was effective in preventing a suction seal to the skin as well as scratching.

## 8. Cost Analysis

The following items were obtained or purchased for our project.

Material	Item Cost	Quantity	Total Cost
Suction Tubing (6 feet)	\$0.00*	2	\$0.00
3M Trimmer Base	\$0.00*	1	\$0.00
3M Trimmer Disposable Head	\$0.00*	1	\$0.00
Hot Glue Gun	\$0.00*	2	\$0.00
Glue Sticks	\$0.00*	1	\$0.00
Duct Tape	\$0.00*	2	\$0.00
Super Glue	\$0.00*	1	\$0.00
Epoxy Glue	\$0.00*	1	\$0.00
Board	\$0.00**	1	\$0.00
Window Screen	\$0.00**	1	\$0.00
Design Notebook (Cover Plastic)	\$0.00***	2	\$0.00
Vacuum Gauge	\$0.00***	1	\$0.00
Faux Fur	\$6.71	1	\$6.71
Pantyhose	\$1.49	2	\$2.98
Clear Tape	\$3.49	2	\$6.98
Foam Tape	\$2.55	1	\$2.55
¾" x 6' Discharge Hose	\$8.59	2	\$17.18
¼" x ¼" Nylon Hose Barb	\$1.09	5	\$5.45
½" x ¼" Nylon Hose Barb	\$2.29	1	\$2.29
½" x ¼" Brass Hose Barb	\$2.79	2	\$5.58
Tee Brass Pipe Fitting	\$5.58	1	\$5.59
White Electric Tape	\$1.99	1	\$1.99
9/16" Vinyl Tubing	\$1.18	1	\$1.18
5/8" Vinyl Tubing	\$1.18	1	\$1.18
¾" Vinyl Tubing	\$1.79	1	\$1.79
Cable Ties	\$2.49	1	\$2.49
<b>Sub-Total</b>			<b>\$62.76</b>

\*Item was obtained/purchased by client. Actual price is unknown.

\*\*Item was borrowed from Marie's house and will be returned. Therefore, there is no cost.

\*\*\* Item recycled/borrowed from BME Department.

**Table 3: Itemized cost break down.**

Item	Competitive Price	Quantity	Total Cost
Suction Tubing (6 feet) <sup>17</sup>	\$1.65	2	\$3.30
3M Trimmer Base <sup>18</sup>	\$60.90	1	\$60.90
3M Trimmer Disposable Head <sup>18</sup>	\$4.83	1	\$4.83
Hot Glue Gun <sup>17</sup>	\$8.58	2	\$17.16
Glue Sticks <sup>17</sup>	\$4.48	1	\$4.48
Duct Tape <sup>17</sup>	\$3.97	2	\$7.94
Super Glue <sup>17</sup>	\$5.21	1	\$5.21
Epoxy Glue <sup>17</sup>	\$4.53	1	\$4.53
		<b>Sub-Total</b>	\$108.35
		<b>TOTAL</b>	\$171.11

Table 4: Competitive price for items provided by client<sup>17,18</sup>.

The trimmer base, a large perceived expenditure, will be returned to our client at the end of the semester.

## 9. Timeline Evaluation

To remain on task in completing the final design, a schedule was composed and followed as strictly as possible, as shown in Figure 20. The largest deviation in the timeline occurs in manufacturing and testing of the final design. Multiple design changes since mid-semester have prolonged the manufacturing and testing process. This also caused a delayed start in drafting the poster and final presentation. The absence of advisor or client meetings is due to scheduling conflicts.

### Project Schedule:

Task	September				October					November				Dec.	
	4	11	18	25	2	9	16	23	30	6	13	20	27	4	11
Project R&D															
Background Research	X	X	X												
Design Brainstorm			X	X	X										
Final Design Selection					X	X	X	X						X	
Manufacturing								X	X	X	X	X	X		
Testing											X	X	X		
Deliverables															
Progress Reports	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PDS		X					X	X							X
Midsemester Presentation						X	X	X							
Midsemester Paper						X	X	X							
Final Poster														X	
Final Paper														X	X
Meetings															
Team	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Advisor	X	X	X	X	X	X	X	X		X	X		X	X	X
Client	X														X
Website															
Updates	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

\*X indicated a worked on or completed task. Shaded boxes indicate projected timeline.

Figure 20: A table of our project timeline

## 10. Future Work

Our next step for this project would be to get our design into Solid Works, or another similar computer program. This would allow us to 3D print our suction heads. This would also necessitate designing a better junction between the head and the bendable plastic tubing as well as better way to attach the filter. With these two things accomplished, the need for tape or hot glue would be eliminated. Computer drafting would also allow easily manipulation of the designs as needed for testing to streamline the ergonomics of our device.

Other materials for the hose, head and filter will also need to be considered to achieve both the best device as well as the most inexpensive one. The device will also need to be tested for safety. One way of doing this would be to run it over sensitive carbon-copied paper to see if any marks show up on the carbon copy, which would indicate scratching. The amount of scratching could be quantified using high resolution photography and contrast analysis in programs like IMAGEJ. Eventually, after we have a finalized prototype and approval from the IRB, we would test in on human subjects in the OR setting to get feedback both from those that use it and those it's used upon.

## 11. Conclusion

There is a need for a device to pick up shaved hair prior to surgery. Our client requests a device that is compatible with the existing suction in the operating room or exam room. Four designs were tested both using synthetic hair and on a human subject to determine the most efficient design. Effects of cross sectional area, shape and filter size were examined. Design C proved to be the most efficient when compared to tape and the other designs. Rapid prototyping and additional material testing are needed before the device can be used on additional human subjects.

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## 13. Appendix

### 13.1 Product Design Specifications

#### Improvements in Preoperative Hair Removal

##### Product Design Specifications

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December 14, 2011

**Function:** Current methods in preoperative hair removal, brushing hair aside or picking it up with tape, are ineffective and messy. The client, Dr. Greg Hartig, has requested a universal device that attaches to suction already present in the OR that is capable of collecting hair after a patient is shaved. This device should be able to collect hair from any part of the body and do so in an efficient manner. It is essential that the hair retrieved does not plug or impede suction.

##### Client Requirements:

Our client wants a retraction device is:

- Compatible with -200 mmHg suction present in OR
- Capable of removing hair more efficiently than current method (tape)
- Handheld & easy to use
- Applicable for different types of surgery and varying hair types
- Inexpensive
- Not be abrasive to skin or causes other harm to the patient
- Simple Storage

##### Design Requirements:

###### 1. Physical and Operational characteristics

- Performance requirements:* Needs to be compatible with the already existing suction, which has a pressure of 200 mmHg. The device will only be used once.
- Safety:* Device must be made of hypoallergenic materials (ex. No latex). Device also cannot puncture or burn the skin or break superficial blood vessels.
- Accuracy and Reliability:* Device must be capable of collecting hair more efficiently than current methods (i.e. tape). Hair must not impede suction of the device.
- Life of Service:* The device will be disposable but must be able to fill filter with hair and prevent release of hair if failure were to occur.
- Shelf Life:* The device must be kept sterile and must be easily storable in large quantities.

- f. Operating Environment:* Device will be exposed to various amounts of hair, wet and dry hair, shaving creams, antiseptics, blood and bodily fluids. Device will be used at room temperature and pressure.
- g. Ergonomics:* Device should be easily handheld and easy to use by one user. Hose attachment and strength of suction should not prohibit functionality.
- h. Size:* Device is approximately 5 cm wide and 27.5 cm long. The bendable plastic tubing has a diameter of 2.4 cm.
- i. Weight:* The device weighs 36 grams, which does not impede or prevent any user.
- j. Materials:* Device should use hypoallergenic material and be able to withstand operating environment as described in part *f*. Current materials include vinyl and other types of plastic as well as electrical and duct tape.
- k. Aesthetics, Appearance, and Finish:* Finish should be conducive for gripping and have no ill effects on patient.

## **2. Production Characteristics**

- a. Quantity:* At least one functional prototype is needed. Design should be conscious of possible mass production.
- b. Target Product Cost:* Design should be competitive to the current method.

## **3. Miscellaneous**

- a. Standards and Specifications:* Design must not harmful to patients and meet operating room requirements.
- b. Customer:* Client is environmentally conscious and would prefer a reusable or semi-reusable device. Functionality is a priority to the client and therefore will consider many different designs.
- c. Patient-related concerns:* Device cannot be harmful to patients and must remove hair as to prevent infection.
- d. Competition:* Competition includes the tape currently being used in operating rooms.