Improvements in Preoperative Hair Removal

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Contents

1. Abstract

Hair must be removed from a surgical site prior to surgery for various safety and patient comfort reasons. Currently, after the patient is shaved, the loose hair is collected with tape; however, this method is inefficient and messy. This has led our client, Dr. Gregory Hartig, an ENT and plastic surgeon for the University of Wisconsin Hospital, to request a device that retrieves the cut hair. Ideally, the device would use the existing suction in the OR, have a relatively low cost, and be compatible with many different types of hair.

Three designs were created: 1) trimmer design, 2) brushes design, and 3) fan/blade design. These designs were evaluated based on their cost, safety, efficiency, universality, and ergonomics. After assessing each design on these categories, it was obvious that the first design, the trimmer design, was the best design and therefore, our final design. The prototypes that will be created using this design will be used on synthetic hair and stuffed animals to test efficiency.

2. Introduction

2.1 Biology of Hair

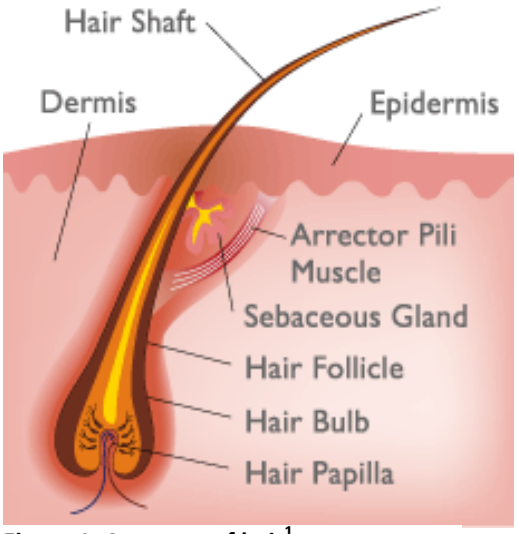

Figure 1: Anatomy of hair[1].

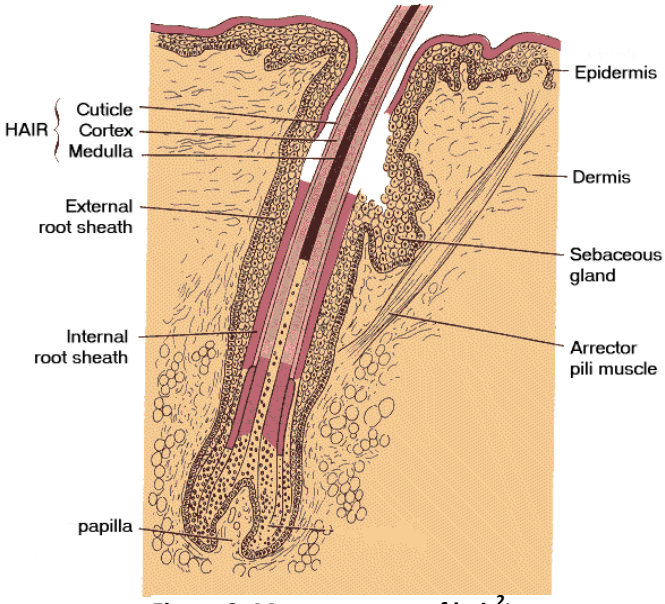

Figure 2: More anatomy of hair[2].

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[3]. 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 [4]. 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[3].

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[6].

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 operative 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 factor for the patient[6]. The other reasons are that preoperative hair removal allows later removal of skin and wound dressings to be less painful[7]. 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[8].

Figure 4: Example of disposable razor[9].

Figure 5: Example of depilatory cream[10].

Currently, 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. For the electric clipper, the skin condition is preserved because hair is cut above the skin surface. Since the electric clipper blade does not come into contact with the skin, the blade is not likely to damage the skin. The electric clipper cuts hair at a length of approximately 0.03 inches or 0.762 millimeters. The hair removal time is less than

5 minutes for knee to groin and up to 45 minutes for neck to ankle[8]. The disposable replacement blades for 3M Surgical Clippers cost from $4 to $7 each. The 3M Surgical Clipper itself with charger cost around $80 to $110[11].

For the razor, the skin is susceptible to injury due to cuts, nicks, and scrapes because the razor blades are in direct contact with the skin. With the razor, hair is cut at or below the skin surface. The hair removal time is similar to clippers[8]. The cost of disposable razor blades is about $0.30 per razor [11]. For the depilatory cream, the skin is not susceptible to nicks and cuts. The depilatory cream, however, removes hair at or below the skin surface. Thus, the depilatory may cause an allergic reaction to some patients. The hair removal time is approximately 20 minutes with application and cleanup. The hair removal time may be longer if touch-ups are required[8]. The cost for a depilatory cream is around $5 to $20 per tube, with each tube varying from 3 to 8 ounces, depending on the brand[11].

2.5 Problem Statement

Our goal is to create a suction device using the -200mmHg (gage) suction already available in the operating room (OR). The device should be able to remove all the hair that is cut preoperatively in a timely manner. 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 and the device must follow OR sanitation guidelines. 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. Designs

3.3 Design Options

3.3.1 Trimmer Design

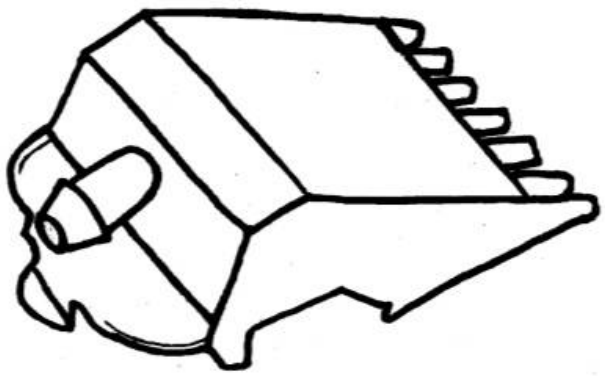

Figure 6: Sketch of trimmer design[12].

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.

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.

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

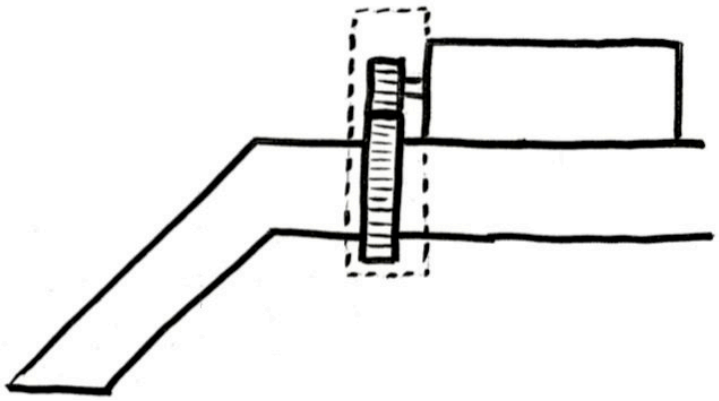

Figure 7: Sketch of blade design[13].

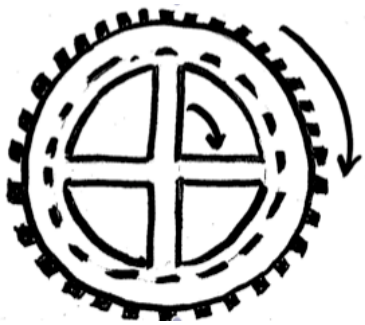

Figure 8: Sketch of blade[13].

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 be larger than the connecting tubing so that the very outside would be exposed when in-between the two connecting hoses. 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 potion 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. The whole design would be need to be assembled before use by placing the blade in-between the two plastic pieces, 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 in any way most efficient to harness the limited OR suction. 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. A rest of some sort would also be needed inside the plastic pieces for the blade to reside so to prevent it from moving laterally or horizontally as it spins.

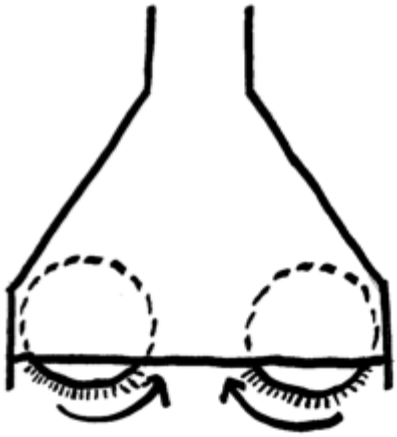

Figure 9: Sketch of brushes design, side view[14].

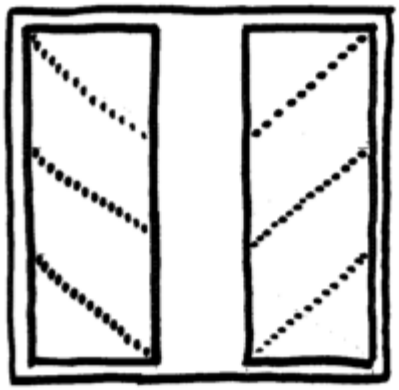

Figure 10: Sketch of brushes design, bottom view[14].

3.3.3 Brushes Design

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 sheer number of 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. 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 Design Matrix

The three different designs were evaluated fairly and efficiently 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
Total	**100%**	**4.15**	**3.2**	**2.85**

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 make the manufacturing process very intricate 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 at 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, which seemed to dominate the design matrix, and is the clear choice in our steps moving forward.

4. Future Work

For the remainder of the semester, prototypes will be made for our first design, the trimmer design, using common materials. We plan to make small changes with each prototype to test efficiency and ergonomics. These changes will include altering the screen in the attachment that will catch the hair, and moving where the suction attachment is located. Testing will be performed on loose synthetic hair as well as stuffed animals or fake fur. The loose synthetic hair will be used to evaluate the power and efficiency of our suction device. The amount of hair in square area retrieved in an allotted time will be measured. The testing involving the stuffed animals will mimic how human hair is attached to the skin. This testing will be used to evaluate the design as a whole, both the trimmer and the suction device. We will compare the efficiency and cost of the design to that of the old method of tape. It is essential that our product is more efficient than this old method while keeping the price low. After this preliminary testing is completed and the most efficient prototype is discovered, the prototype will be recreated using 3D printing as time permits. Further testing will be done with these prototypes again using the loose synthetic hair and stuffed animals to evaluate the effectiveness of our final design.

To remain on task in completing the final design, a schedule was composed as shown in Figure 11. Even though our client gave no specified budget and that he would support anything that is reasonable, the team's goal is to remain under $500 in the design and fabrication of the final design. However, it is the team's goal to have the market price of the design to be less than $50.

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								
Manufacturing															
Testing															
Deliverables															
Progress Reports	X	X	X	X	X	X	X								
PDS		X					X								
Mid-semester Presentation						X	X								
Mid-semester Paper						X	X								
Final Poster															
Final Paper															
Meetings															
Team	X	X	X	X	X	X	X								
Advisor	X	X	X	X	X	X	X								
Client	X														
Website															
Updates	X	X	X	X	X	X	X								

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

Figure 11: Project Schedule

5. 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. After evaluating three

design options, prototypes will be fabricated of the final design, the trimmer design. Loose synthetic hair and fur will be used to test the efficiency of the device after small modifications to the location of the vacuum attachment and size of screen for hair trap. The most efficient version of the prototype will then be 3D printed if time permits.

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[13] Cody Williams. (2011). Blade Design Sketch.

[14] Cody Williams. (2011). Brushes Design Sketch.

7. Appendix

7.3 Product Design Specifications

Improvements in Preoperative Hair Removal

Product Design Specifications

Kim Maciolek (Team Leader), Marie Greuel (Communicator),
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October 26, 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 suction device that:

- Efficiently picks up all types of hair
- Is compatible with existing suction source
- Is inexpensive
- Can easily be stored

Design Requirements:

1. **Physical and Operational characteristics**

   a. Performance requirements: Needs to be compatible with the already existing suction which has a gage pressure of -200 mmHg. The device will only be used once.

   b. Safety: Device must be made of hypoallergenic materials (ex. no latex). Device also cannot puncture or burn the skin or break superficial blood vessels.

   c. Accuracy and Reliability: Device must be capable of collecting hair more efficiently then current methods, which include shaving hair with a razor and using tape to collect dry hair. Hair must not immediately impede suction of the device.

   d. Life of Service: The device will need to be able to withstand at least 45 minutes (from personal experience) or duration of shaving for one patient. If more than one device is needed to complete the procedure, then it must be easily replaced or emptied.

   e. Shelf Life: The device must be easily storable in large quantities.

   f. Operating Environment: Device might 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 should not exceed 5 inches in length and 4 inches in width excluding the hair trap. The device should also have a minimal size for storage. Size should not impede function or significantly reduce suction.

   i. Weight: Maximum weight of device should be no more than one pound.

   j. Materials: Device should use hypoallergenic material and be able to withstand operating environment as described in part *f.*

   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 cost less than 50 dollars, ideally less, if mass produced. Design should be less expensive than current method.

3. **Miscellaneous**

   a. Standards and Specifications: Design must not harmful to patients and be easy to use.

   b. Customer: Client is environmentally conscious and would prefer a reusable or semi-reusable

device. Functionality, however, is main priority to the client.

c. Patient-related concerns: Device cannot be harmful to patients and therefore must remove hair safely with little skin damage.

d. Competition: Competition includes the tape currently being used in operating rooms as well as depilatory creams.