Dental Hygiene

Final Proposal

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Executive Summary

The team project was to design a dental triturator for the NAU Dental Hygiene Department. A dental triturator is a device that shakes dental capsules filled with amalgam and a glass ionomer sealant. The capsules produce a homogeneous mixture, when properly mixed, that acts as a hard coating/filling that is applied to holes in teeth. The problem with the current triturator is that it runs on a 120 VAC outlet and this plug is not always available to the NAU Dental Hygiene Department when they travel to other countries.

Customer requirements were the basis of the initial research that was conducted to determine possible solutions to the problem.The main requirements for the design was lightweight, easily transportable, and the device mixes the capsules properly. After design research was concluded, ten design choices were considered. A decision matrix was constructed and based off of customer requirements and design requirements, a final design was chosen.

The final device chosen was an electric toothbrush with a 3D printed attachment on the shaft to hold the dental capsule. This design fit the customer and engineering requirements better than all other design choices. The basis for choosing electric toothbrush is that the mechanical system is already constructed, low cost, light weight, easy to find or replace, and it is easily operated.

The testing procedures were to test the viscosity of the toothbrush compared to the original dental triturator. Testing variables included percentage fill of the 3D printed attachment, time of operation, and type of electric toothbrush used. After many different tests, the results concluded that a OralB 5000 Series electric toothbrush with a 10 percentage fill attachment at 12 seconds run time output similar results to the original triturator. A timer relay module was used and set at 12 seconds to ensure proper mixing time. The timer relay module required a separate power source and four 1.5V AA batteries are used to power the device.

The final device proves to mix the dental capsules properly and meet customer and engineering requirements. This device is shelled in a case to protect its components from drops and normal wear and tear. Battery life for the device is projected to last up to 500 capsules or approximately 100 minutes on one charge. In conclusion, the design was successful in all categories for the requirements of the clients and the team.

Acknowledgements

The team would like to extend our gratitude to all of those who contributed to the success of the project. The initial team advisor,Dr. Jennifer Wade pushed the team to think outside of the box and use skills learned in other courses. The course instructor, Dr. Sarah Oman supplied all the tools and knowledge in the classroom that gave the team the appropriate course of action in a successful design. Dr. Timothy Becker allowed us to use the rheometer to test the viscosities of the capsules. Without these tests the team would not of been able to confirm proper function of the device. Thank you to the NAU Dental Hygiene Department, specifically Tracye Moore and Amy Smith, for giving us constructive feedback and for donating a toothbrush and capsules for testing. Last we would like to thank the NAU CEFNS Department for giving us an opportunity to work with great people and to take a course that will help the team succeed in the future.

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1 BACKGROUND

1.1 Introduction

This project consists of creating a dental triturator that will be battery powered. This device is used by a dentist or dental student to shake and mix a capsule made up of amalgam and glass ionomer sealant. This capsule contains liquids and metals used for teeth fillings. The problem with current triturator is that it requires electricity. Our client frequently travels to third world countries to give dental services to people in need. The problem is some of the places they go to do not have electricity. Our job is to design and build a dental triturator that does not require mains electricity to mix the dental capsules. This new triturator will help improve the lives of the users and many people in third world and foreign countries.

1.2 Project Description

This section highlights the current problem and description of the project. The following is the original project description provided by the sponsor.

> *''A dental triturator is used to mix the components of dental capsules before certain dental procedures and they are usually powered by electricity. When dental hygiene students travel internationally, often times there is no electricity and/or the powered triturations are not compatible with international outlets. Collaboration between NAU's Dental Hygiene (DH) Dept and NAU Mechanical Engineering Dept (CHHS and CEFNS) have created this Spring 2017 capstone project for 3-5 mechanical engineering students to create a human powered mixer that can shake a capsule for 10 seconds''[1] .*

1.3 Original System

The original system for this project is an AC powered dental triturator called the Wig-I-Bug. A dental triturator is used to mix a capsule filled with amalgam and glass ionomer sealant. This specific capsule is mixed for a 10 seconds at "approximately" 4000 rpm to ensure that the capsules are properly mixed. This sealant is then used to fill cavities or holes in teeth[2].

1.3.1 Original System Structure

The dental triturator contains a motor, shaft, and rotational components that convert electrical energy to shake the capsule in a semi-linear motion. There are plastic bands that act as arms to hold the capsule in place. Figure 1, shown below, contains the components of the original triturator. The triturator only allows one capsule at a time to ensure the mixture has the right viscosity. The internal components are some kind of metal or alloy and the cover and buttons are plastic.

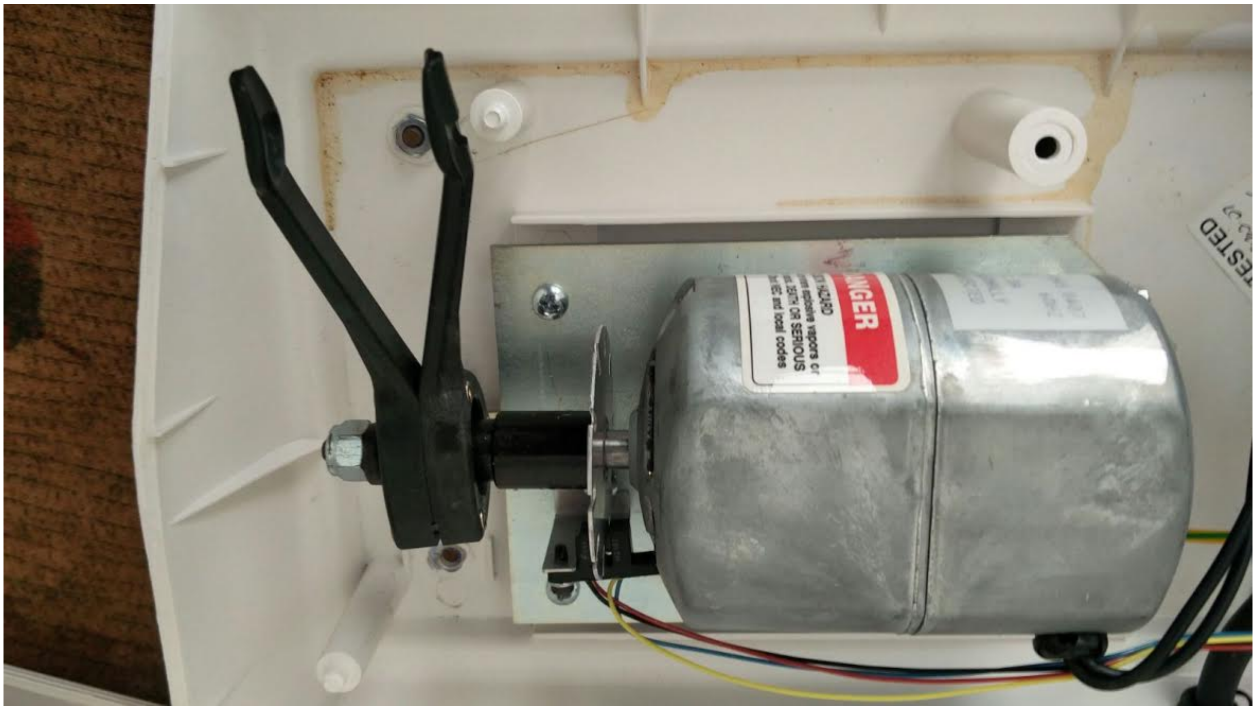


Figure 1: Original Dental Triturator Components

1.3.2 Original System Operation

The team observed the active operation of the existing triturator while meeting with our client. We noticed that the motion was not directly linear but almost a figure eight motion. It was a non circular motion since a circular motion would separate the components of this capsule. The motion of the device was quick and the capsule was shaken for about 10 seconds. The capsule was then put into a tool and the components were squeezed out as a liquid. If the triturator does not do its job correctly then the capsule components remain unmixed or overmixed and it can not be used.

1.3.3 Original System Performance

The function of the dental triturator is to shake a capsule at 4000 rpm for approximately 10 seconds. When we observed the triturator, we timed it for 10 seconds but could not directly measure the rpm's. The FujiTriage capsule calls for 4000 rpm but we estimate that the triturator may not always reach this requirement. Each capsule weighs around 2 grams and the triturator weighs on average 5 kilograms. The power requirements for the triturator are 115V and 60Hz. We assume a negligible amount of power is used for the buttons and lights so the majority of power is directly converted to the capsule. The triturator has a high efficiency since it is small and there is not many parts. The energy required to properly mix the capsule is about 300 joules, calculation shown in Appendix B.

1.3.4 Original System Deficiencies

The only deficiency with the dental triturator is that it is dependant on electricity. The Dental Hygiene Department wants a triturator that can be easily transported and used in countries that may not have electricity.

2 REQUIREMENTS

This project required us to engineer a dental triturator that is manually or battery operated. The current dental triturator is run on electricity(AC power) and this resource is not always available in other countries. The Dental Hygiene Department wants a triturator that can be run off of manual power such as a hand crank or DC electric power such as small battery. The triturator needs to function the same as the current triturator so that the user can do their job properly. The triturator will be engineered using the requirements below so that it can produce the proper results for the Dental Hygiene Department.

2.1 Customer Requirements (CRs)

This section contains the customer requirements that are based off of what our client wants from the design. Lightweight, easy transportation, and homogeneous mixture are the top customer requirements so we gave them a ranking of 5 out of 5. The triturator will be lightweight so the user can carry it onto a plane, bus, or car. Also, it will fit in a small bag for easy carry. The triturator will have shake a capsule into a homogeneous mixture in order for the filling to be used, so this must be ranked with the highest weighting.

Easy operation and reliability are the next customer requirements with a ranking of 4 out of 5. This project is not meant for a single person so we are going to make it easy to operate for any person who uses it. The triturator has to work every time it is needed and this will confirm that we develop a reliable design to satisfy our customer.

The last customer requirements are quality of parts, cost, and easy maintenance with rankings of 3 out of 5. Aesthetics is also a requirement with a ranking of 2 out of 5. The triturator will have a few different parts and they may break or need to be changed in a few years. Maintenance on the device should be easy for all users and the parts should be easy to locate. The team will stay under budget by developing a triturator with low cost parts and fabrication. The quality of the parts have to satisfy the users and will have a lifespan of at least 1 year of moderate use. Aesthetics are ranked last since we do not need a good looking design in order for it to work.

Table 1: Customer Requirements

Customer Requirements	**Weighting**	**Justification**
Lightweight	5	Request of the client to ease traveling
Easily Transportable	5	Travel is necessary, the device must be able to fit on a plane or bus
Homogeneous Mixture	5	The capsule must be properly mixed to ensure proper procedure
Reliability	4	The device must work every time it is needed
Easy Operation	4	Anyone should be able to use it
Quality of Parts	3	Parts should not break or bend
Cost	3	Cost cannot exceed $350
Easy Maintenance	3	Operators must be able to change a broken part with ease
Aesthetics	2	The device should not have internal parts visible
Battery Life	2	The device should last long enough to provide efficient final product

2.2 Engineering Requirements (ERs)

This section contains the engineering requirements. The engineering requirements represent how well the design meets the customer needs and are used to measure different aspects and functions of our final design. Our customer requirements were used as a basis to choose our engineering requirements.

The first of the requirements are weight, energy, and cost. The weight is important for transportation and the amount of energy is crucial to determine if the design will mix the capsules properly. Cost is both an engineering and customer requirements since it is necessary to keep the final design cost under $350. The next requirements are dimensions, material strength, and the number of parts. The dimensions are simply the design size and it is designed to fit in a carryon bag for easy transportation. The material strength needs to be strong and durable in order to withstand unexpected drops and normal expected usage. Number of parts corresponds to the total number of parts in our design. We want to minimize the part number in order to obtain easier maintenance. The last requirements contain manufacturing time, life expectancy, and ambidextrous. Manufacturing time corresponds to the time it takes to obtain or 3D print the parts. Life expectancy is how long the parts and device battery lasts under normal usage. Ambidextrous means the device can be used by anyone left or right handed.

Below, is a table of the engineering requirements, targets, and rationale for each.

Table 2: Engineering Requirements

Engineering Requirements	**Target**	**Rationale**
Weight	8 pounds	To minimize the weight during transportation
Energy	300 Joules	To properly mix the capsule components
Cost	$350	The device must be affordable and within budget
Dimensions	L-7in W-10in H-16in	Must fit inside the dimensions for a carry on bag at all airlines
Material Strength(Tensile)	50 MPa	Must not wear under normal conditions
Number of Parts	7	To minimize maintenance and wear
Manufacturing Time	5 days	Must have available parts
Life Expectancy	3 years	Must be long lasting
Ambidextrous	L/R Handed	To ensure that anyone can use it

2.3 Testing Procedures (TPs)

The testing procedures discuss how the team will test and measure each engineering requirement for our design. The testing procedures are described below:

1. A digital scale will be used to take the initial and final weight of the device.
2. To measure the energy of the device, calculations are done according to the design specifications we use. A viscometer will be used to test the viscosity of the homogeneous mixture. This test will be done using the original device and our device to ensure physical properties are similar and to verify our calculations.
3. The cost of the final design and all parts will be documented and represented in our final budget.
4. A measuring tape will be used to measure the dimensions of the different parts of the device.

5. Since the material we are using, ABS, has already been tested and measured we can reference the existing tensile strength. We will 3-D print our ABS parts and test them in hot weather and test durability by throwing them a distance of 5 meters.
6. The number of parts for our design will be measured by simply counting the parts and referencing the bill of materials.
7. Manufacturing time will be measured by how long our parts take to be 3D printed. We are also ordering parts online that are already available so shipping time will also be used in our calculated time.
8. Life expectancy can be measured with existing data we have about our materials and testing them accordingly. It will be an estimate since we do not have much time to test the total life expectancy. The life expectancy of the toothbrush will be tested by letting it run continuously until it loses charge and continue this process for at least 1 week.
9. To measure if the device is ambidextrous, we will simply let both a left handed and right handed person use the device.

2.4 Design Links (DLs)

The design links describe how the design meets each of the engineering requirements. The design links are listed below:

1. The weight of the design must be less than existing systems which is roughly 10 lbs. The final design’s total weight is projected to be less than 5 pounds, including all spare parts. Since the final design weight is less than existing systems, it will meet this requirement.
2. The energy required to mix a capsule properly is 300 Joules. With calculations for the final design, we are expecting to meet this requirement.
3. Required cost for the final design to be less than $350. The design is going to cost less than $100, so it does meet the cost requirement.
4. We are basing the dimension of our device and all spare parts on the maximum dimensions for a carryon bag for flying. The maximum dimensions for a carryon bag is 9” x 14” x 22”. Our design is going to fit inside of a carryon bag of dimensions 7.3" x 6.5" x 4.5".
5. The tensile strength of Acrylonitrile Butadiene Styrene (ABS) is about 46 MPa. We are designing the material to handle drops and normal wear and tear since the design will not be under much stress during operation. Since there is not a large stress on the component, a tensile strength of 46 MPa will meet our requirement.
6. The users want the design to be simple and have minimal parts for easy care and maintenance. The design will only have 2-4 components, which will meet our requirement.
7. The manufacturing time for the device is fast and efficient in order to give users enough time to receive the parts needed. The toothbrush can be purchased at nearly any store and there will be a spare handy. The main component can be 3D printed in less than a few days. Given these times, our design will meet this requirement.
8. The life expectancy the design should be long lasting in order to be reliable for the clients. Given lifetime observations, Electric Toothbrushes typically last for some years

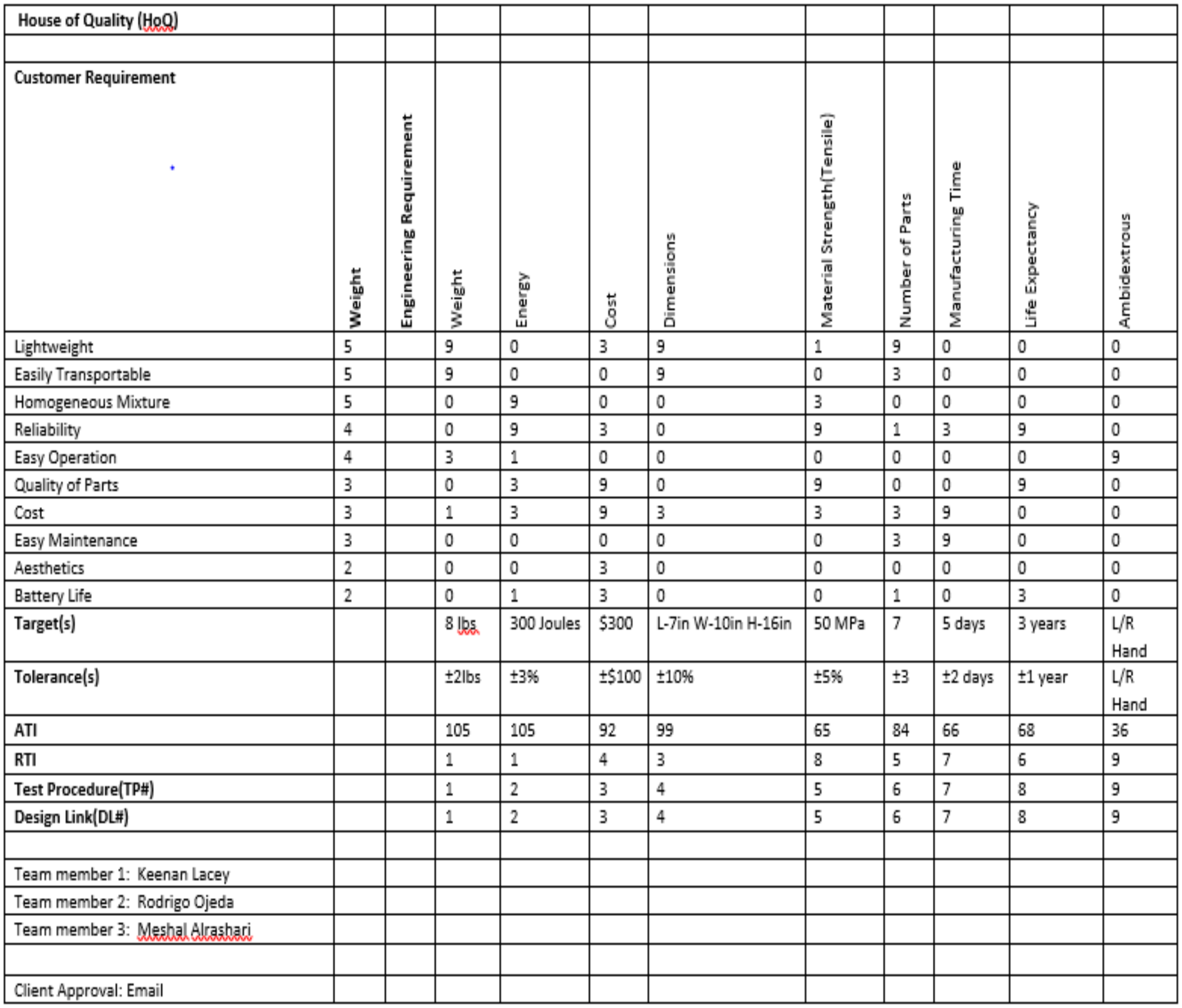
under normal use and batteries can last up to 2 weeks with normal use. The 3D printed design is expected to last 3 years, based on testing, with normal use. The overall design is estimated to last at least 2 years under normal use which meets our requirement.

9. The device is to be used by anyone and easy to use. Since it is not left or right hand dominant, it will be ambidextrous and will meet the requirement.

2.5 House of Quality (HoQ)

The house of quality shows our customer requirements, engineering requirements, and appropriate weightings. The HoQ shows how each engineering requirement relates to each customer requirement. We completed the weightings for each requirement with the approval of our client, shown in Appendix: A. The most important requirement is the weight of the device then followed by the energy required to mix the capsule. These engineering requirements are what the customer wants most out of the design. They will be the main focus to complete the design but other requirements must be considered and implemented.

Table 3. House of Quality



House of Quality (HoQ)											
Customer Requirement	**Weight**	**Engineering Requirement**	Weight	Energy	Cost	Dimensions	Material Strength(Tensile)	Number of Parts	Manufacturing Time	Life Expectancy	Ambidextrous
Lightweight	5		9	0	3	9	1	9	0	0	0
Easily Transportable	5		9	0	0	9	0	3	0	0	0
Homogeneous Mixture	5		0	9	0	0	3	0	0	0	0
Reliability	4		0	9	3	0	9	1	3	9	0
Easy Operation	4		3	1	0	0	0	0	0	0	9
Quality of Parts	3		0	3	9	0	9	0	0	9	0
Cost	3		1	3	9	3	3	3	9	0	0
Easy Maintenance	3		0	0	0	0	0	3	9	0	0
Aesthetics	2		0	0	3	0	0	0	0	0	0
Battery Life	2		0	1	3	0	0	1	0	3	0
Target(s)			8 lbs	300 Joules	$300	L-7in W-10in H-16in	50 MPa	7	5 days	3 years	L/R Hand
Tolerance(s)			±2lbs	±3%	±$100	±10%	±5%	±3	±2 days	±1 year	L/R Hand
ATI			105	105	92	99	65	84	66	68	36
RTI			1	1	4	3	8	5	7	6	9
Test Procedure(TP#)			1	2	3	4	5	6	7	8	9
Design Link(DL#)			1	2	3	4	5	6	7	8	9
Team member 1: Keenan Lacey											
Team member 2: Rodrigo Ojeda											
Team member 3: Meshal Alrashari											
Client Approval: Email											

3 EXISTING DESIGNS

Existing designs are devices on the market that have a similar function to our device. There is a paint shaker that shakes paint in a similar way we need to shake our dental capsule. An eggbeater device uses manual power to rotationally mix all the cooking ingredients. A Sawzall moves its blades in a similar motion that we need to move our dental capsule.

3.1 Design Research

Research has been done by an examining similar systems and searching the web. For the examination of similar systems portion of this report, the team used the original dental tritrator. After extensive research, the team chose three existing devices that are similar to the same system used by the electrical dental titrator.

3.2 System Level

A dental tritrator is a device that mixes components of a dental capsule. Today, it can be found in almost every dental clinic. Three different devices that have a similar motion to the dental tritrator were studied, these devices are a paint mixer, egg beater, and sawzall. First, the paint mixer works with the necessary semi-linear motion which is the goal of our device. Second, the egg beater provides the concept of using the manual method to mix food. Finally, the sawzall provides a back and forth movement that can be used to accomplish our goal.

3.2.1 Existing Design #1: Paint Mixer

Below, Figure 2, displays a gas powered paint mixer. If paint is left still the ingredients will separate. This is why paint must be mixed before use. This paint mixer requires 3.2 cfm at 70 psi pressurized air to shake the paint in a semi-linear motion. The paint can is heavy so it requires more gas than a capsule would. Air is used as a gas in a small combustion engine that pumps a piston in order to achieve the figure 8 motion. This device can be used as a foundation for our project, since it works in a similar motion to our original system.

Figure 2: Paint Mixer [3]

3.2.2 Existing Design #2: Egg Beater

This design moves in a rotational or circular motion. This is an egg beater made from the company XOX. In the description, it says they have combined the idea of the egg beater and the smooth movement crank from a fishing rod. The device is human powered, so this means the speed of the crank differs. This design works by using the spinning holder and spin it. Then the metal in the bottom will rotates. This device related to our project because of its light weight.

Figure 3: Egg beater[4]

3.2.3 Existing Design #3:Sawzall

The sawzall is an existing design that is used to cut different materials. The reason the sawzall is relevant to our project is because the movement of the Saw is back and forth. This movement can be used for our project. This device powered by rechargeable batteries.

Figure 4: Sawzall[5]

3.3 Subsystem Level

In this section the team describes the system and subsystems of the existing designs we found. Each system and subsystems is explained how they work and why they are relevant to our project design.

3.3.1 Subsystem #1: Paint Mixer

The paint mixer has multiple sub-systems. They consist of the base, the air motor, and the air feed system. Each subsystem was observed to find out how it works.

3.3.1.1 Existing Design #1: Base

The base is a really important in this model because it holds the whole system together. In this particular model the base needs to be very sturdy because a gallon of paint weighs 11.3 pounds. When the paint is shaken it emits a tremendous moment and force that the base has to withstand.

3.3.1.2 Existing Design #2: The Air Motor

The air motor is the most important subsystem in this item. Pressurized air is used as the working gas for the system. The air motor converts the power of the air into a kinetic energy. This kinetic energy is then used to shake the paint in a semi-linear motion.

3.3.1.3 Existing Design #3: Air Feed System

Air feed system is important because it allows the source of energy to enter the Paint mixer. There is a valve to manage the intake of the air on the motor. There is also a filter to keep contaminants from entering the motor.

3.3.2 Subsystem #2: Egg Beater

Egg beater contains several subsystems that make it work. The subsystems are a plastic handle, crank, and beaters. This system does not require electricity to function and this is why it can help influence our design.

3.3.2.1 Existing Design #1: Handle

A plastic handle is attached to the crank with a carved stainless steel block. The plastic handle is a source that is used to generate human energy into kinetic energy. This is done by rotating the handle using human power to make the egg beater work.

3.3.2.2 Existing Design #2: Crank

The crank is the most important subsystem in the egg beater, and without it the entire device can not function. The most significant thing about the crank is the faster the crank rotates, the faster the beaters will rotate. This conversion of human energy is why it is related to this team's project.

3.3.2.3 Existing Design #3: Beaters

The beaters are the conclusion of the device, because they beat the eggs. They are made of stainless steel for safety reasons. The function of the beaters is achieved by rotating them in a high speed circular movement. The team has decided to convert the movement of the beaters from a circular way to a back and forth way. With this method, the team will find a key of success to the project design.

3.3.3 Subsystem #3: Sawzall

The sawzall has a few main subsystems. The main ones are the Electric motor, the ANC gear drive, and the blade.

3.3.3.1 Existing Design #1: Electric motor

The motor needs to produce high power and reliability so it has to be electrically powered. The sawzall conducts heavy duty cutting therefore the saw has to have much force and torque supplied to its motor. A rechargeable battery is what fuels the motor.

3.3.3.2 Existing Design #2: ANC Gear Drive

The ANC Gear drive allows for the power of the electric motor to be converted into the back and forth motion of the saw. The gear drive is a set of gears and bearings that convert rotational motion from the motor to a linear motion.

3.3.3.3 Existing Design #3:The Blade

The blade is the simplest of the subsystems, but essential for the purpose of this device. The blade is what is used to cut the materials. The blade is where the linear motion is translated and we can observe the operation.

4 DESIGNS CONSIDERED

This section contains ten designs we have considered to engineer a final product. We will explain the function and the parts of each design. We will also discuss the advantages and disadvantages of each design. The designs we have chosen are the best designs that the team has generated and meet our Engineering requirement and customer requirement . We will also explain the black box model and functional decomposition chart in this section to better understand the purpose of our design.

4.1 Design #1:Gear design

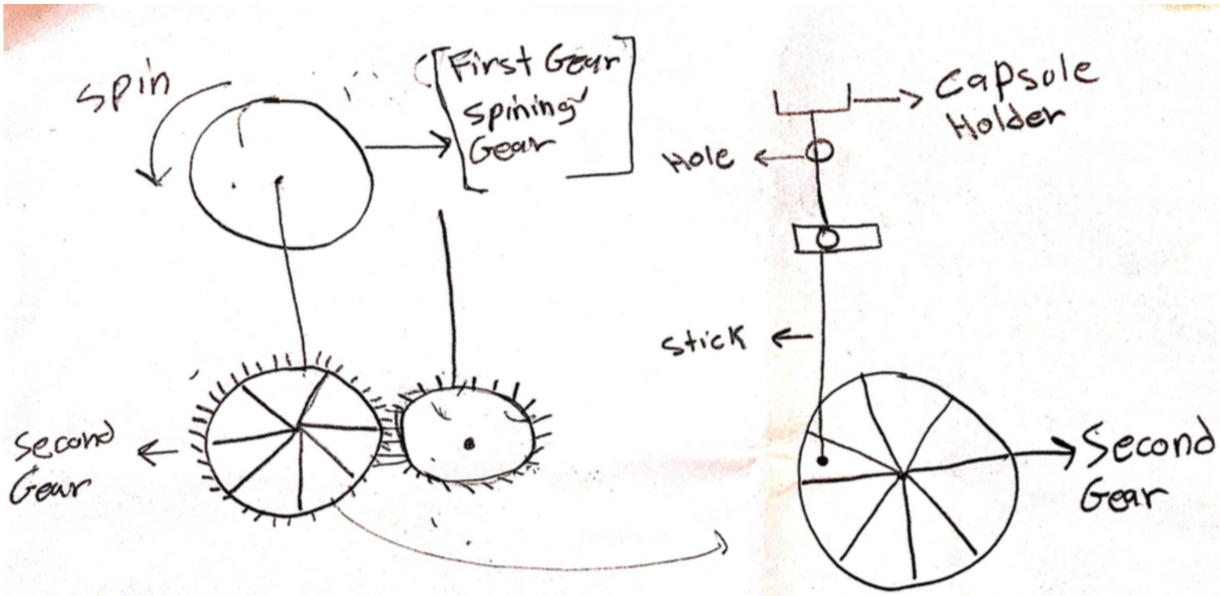


Figure 5: Gear Design

The Gear design, shown above, has three gears. The first gear is the spinning gear. Also, the first gear is attached to the second gear by a stick to spin the second gear. There is a third gear which is connected to the second gear. The purpose for the third gear is to increase the rotational speed of the second gear. So this design will be in a box with holes in the above of the box. So, the second gear will have a two screw, the first screw is attached in the gear and the other is attached to the square and that square will have the second screw move right and left while spinning. When that screw is going right and left, it will move the top stick the and the holder of the capsule will shake in a semi-linear movement. The advantages of this design is we can reach our desired speed with gears and it is easy to use. Disadvantages are the weight and the time to shake the capsule can be limited.

4.2 Design #2:Quick Return Design

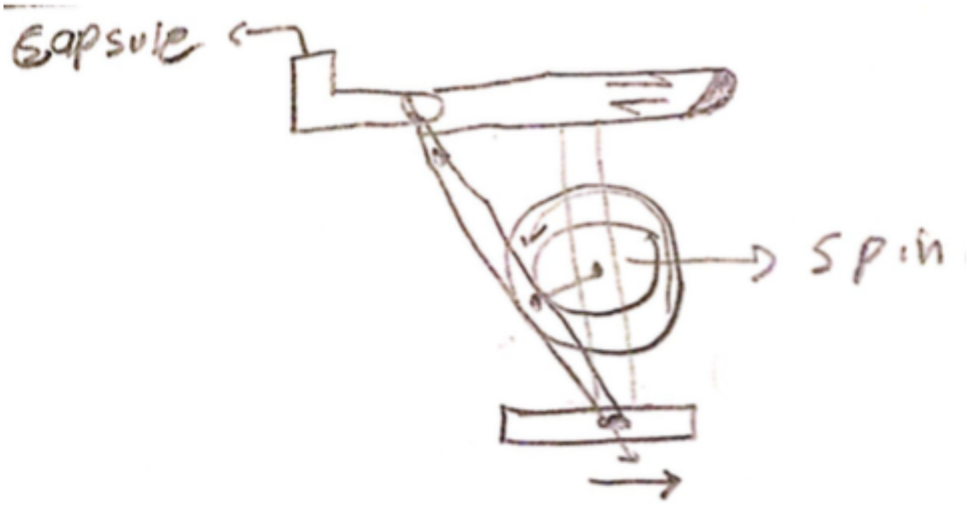


Figure 6: Quick Return Design

This design contains a spinning gear in the middle of the design. The spinning gear has a screw on it that attaches to a rod. While spinning the gear the rod will move in a semi-linear motion. Also connected to another rod that makes the top holder move right and left “back and forth” movement. The advantage of this design is we can use any materials that can reach our engineering requirements like weight and quality. The disadvantage of this design is the speed to shake the capsule since we cannot add more gears.

4.3 Design #3: Spinning Gear Design

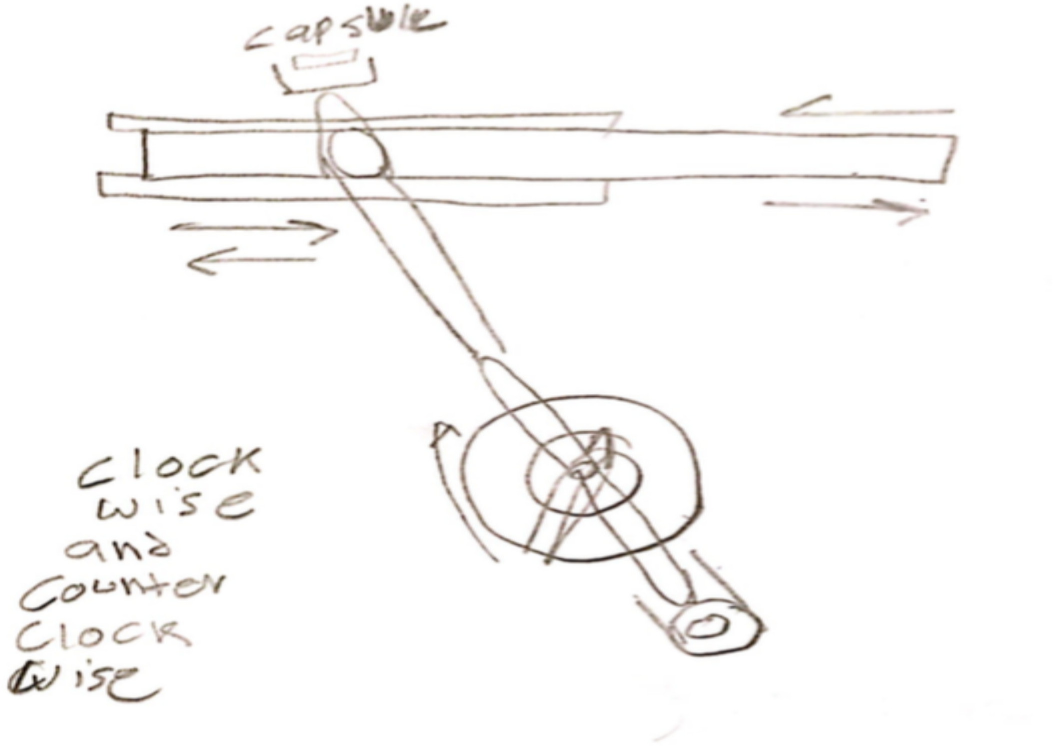


Figure 7: Spinning Gear

This design is called the spinning gear design. This design is similar to the second design. However, this design has the semi-linear motion movement which is not in the quick return design. The spinning gear has a screw in the middle and that screw is connected to a rod. The advantage of this design is we can change the angle of the screw which will make the capsule shake in different lengths. However, the disadvantage of this design is that it is complicated to replace broken parts.

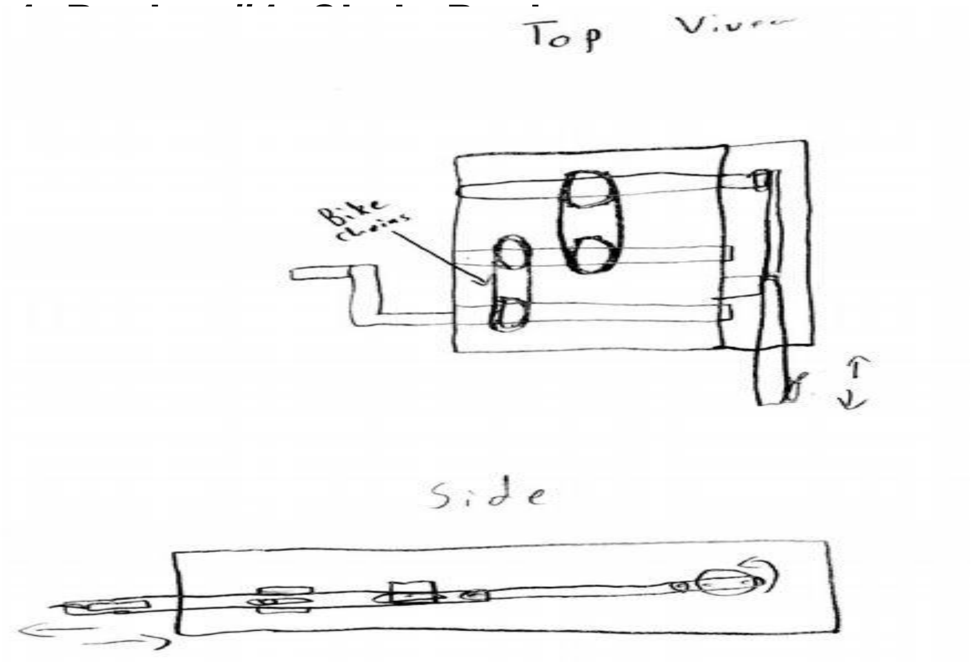


Figure 8: Chain design

This design called the chain design. This design can he used for both hands “left and right”. This design has two chains as shown in the figure above. It has three shaft on it. The purpose of using three shaft and two chains is to increase the speed of the shaking capsule. The top shaft is connected to the shake capsule. The advantage of this design is the team can increase or decrease the speed as the team can reach the required speed. The disadvantages of this design it will be a heavyweight design which our client while travel abroad seas and carry the project in a carry on luggage.

4.5 Design #5: Battery Operated Design

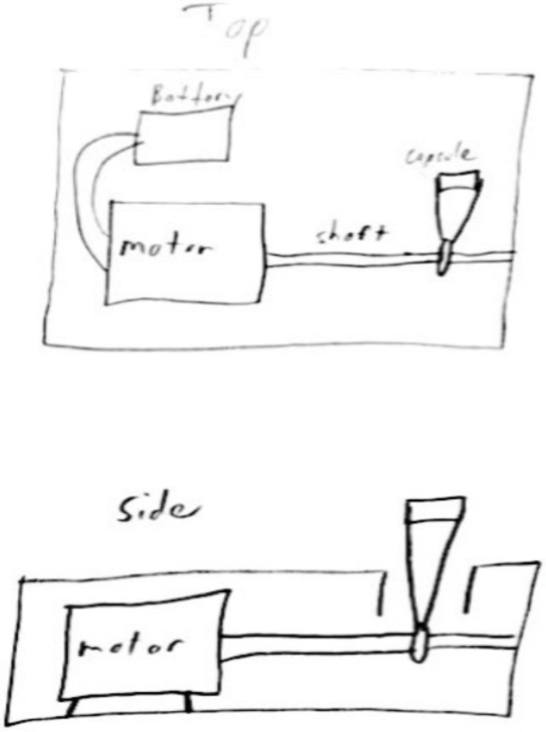


Figure 9: Battery Operated Design

This design is inspired on the original system of the project. This design will use batteries to function. The batteries are connected to the motor and then the motor turns the shaft. This shaft then shakes the capsule in a figure eight motion by using a certain component. The ideal speed is for the shaft to turn at 4000 rpm. The advantages of this design is it is battery powered and can reach our goal of 4000 rpm. The disadvantages of this design is that it would need a lot of power, so it would also require a lot of batteries. This would make the design heavy.

4.6 Design #6: Compressed Air Design

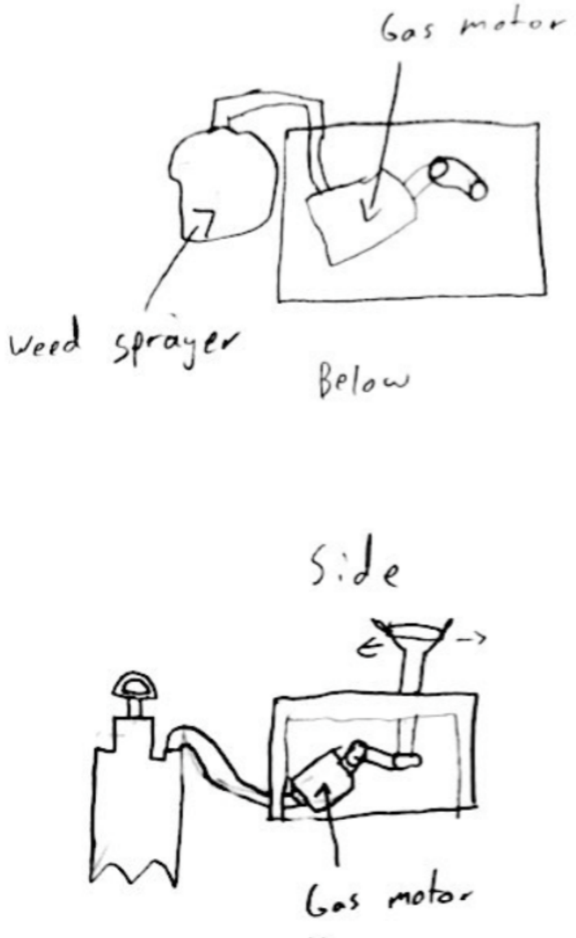


Figure 10: Compressed Air Design

This design is inspired on the background research of the paint mixer. We would use a type of weed sprayer to load up pressurised air into a tank. The weed sprayer has a pump that is used to raise the psi inside the tank. Some of the weed sprayer tanks can have pressurized air up to 90 psi. The pressure needed to run this air motor is 70 psi. In this design you would pump the air into the tank then the motor would shake the capsule. The advantage of this is the shaking process would be very efficient. The disadvantages are that this design would be very large and it would be hard to transport it on an airplane.

4.7 Design #7: toothbrush design

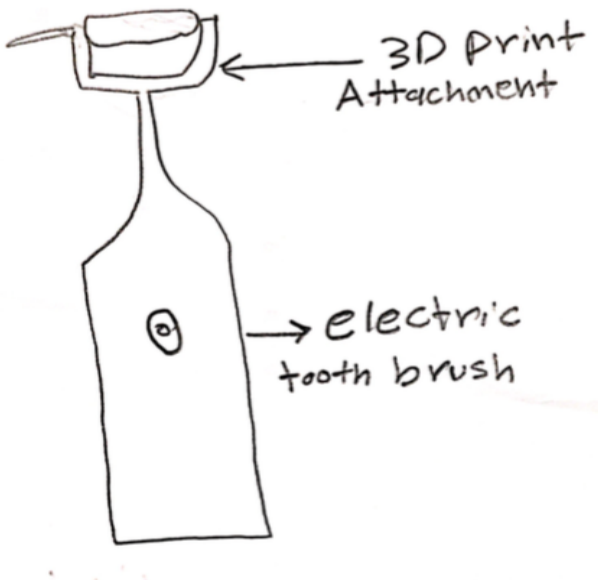


Figure 11: Toothbrush Design (Outside)

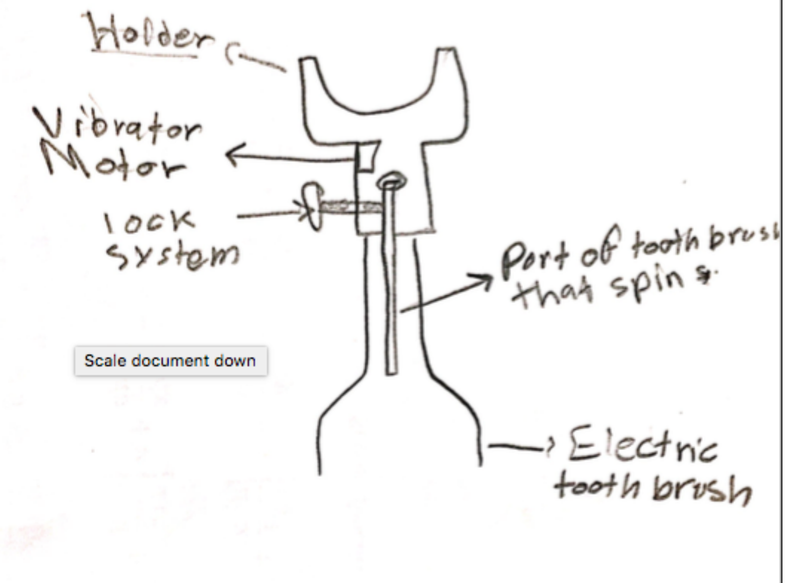
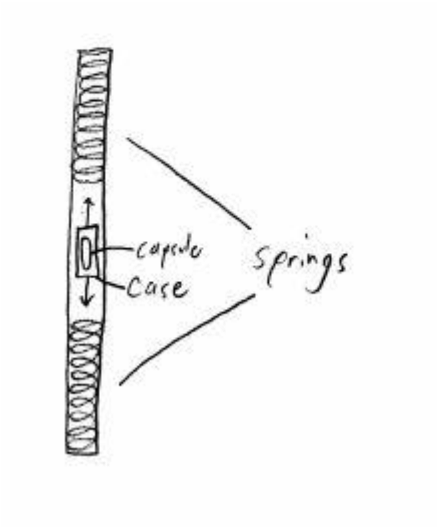


Figure 12: Toothbrush Design with the vibrating system(inside)

Research on an electric toothbrush has been made into this design. This design will shake the capsule by vibrating it as simply as an electronic toothbrush. The toothbrush has a semi-circular movement which that will mix the capsule differently than other designs. The idea is to use a vibrator motor and lock system in the toothbrush. The lock system will lock the the holder on the part that spins which shown in the above figure. The vibrator motor will vibrate the capsule's holder, and a human hand can turn it left and right then the capsule will be mixed. So, the advantages of this design are light weighted, easy to use, and a small size. The disadvantages of this design are non-fixable parts, hard replaceable parts and electricity used in this design.



4.8 Design #8: Springs Design

Figure 13: Springs Design

This design is the springs design. This design consists of a round tube, 2 springs, and a protective case inside the tube to place the capsule. The idea of this design is to place the capsule inside a tube with springs and shake it up and down. The springs will bounce the capsule back and forth with spring energy and since it is human powered it will be a semi-linear motion. The advantages of this design is that it is lightweight, easy to use, and cost efficient. The disadvantages are that the capsule may not get mixed properly because of the operator and then it can not be used.

4.9 Design #9: Clapper design

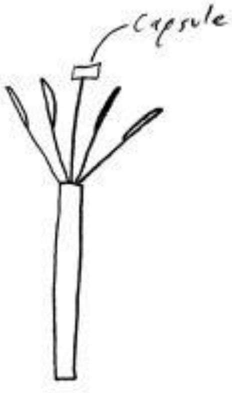


Figure 14: Clapper Design

This design is called the clapper design. It has five clappers and a rod holder. This design works by shaking the rod left and right and the capsule will be mixed. The clappers will supply the energy to the capsule to mix the components. The advantages for this design is lightweight and small size so that will makes it easy to transport. The disadvantages for this designs is it might not reach our capsule requirement which is the speed in a semi-linear motion for 4000 RPM.

4.10 Design #10: Two balls design

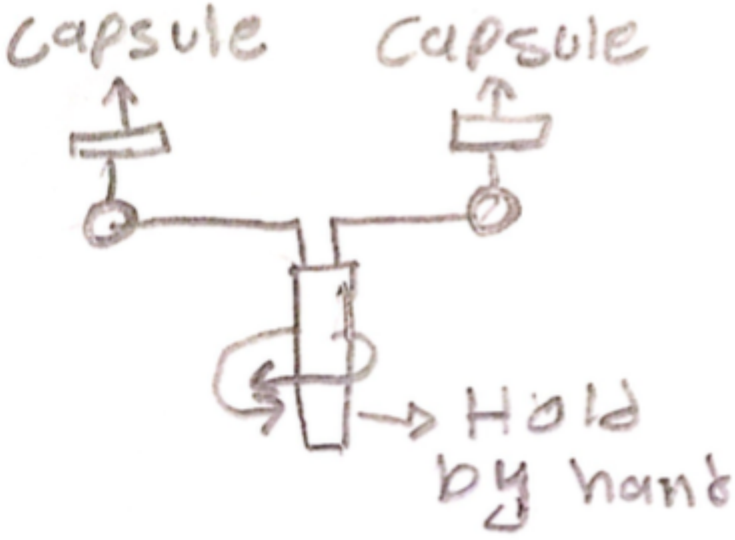


Figure 15:Two Balls Design

As shown in the figure above, the team has considered a design containing two balls. This design is basically a hard rod with two connected ropes. The two ropes are attached to the balls. This design works by holding the hard rod and turn right and left by both hands. The advantages of this design are low cost and it can shake two capsules at the same time. The disadvantages of this device is people who use this design must use their both hands to make the capsules mixed.

4.11 Black box and Functional Model

This section illustrates our black box and functional model. Our black box model shows the basic operation of what our device needs to do. That is to mix ingredients and produce a homogeneous mixture. The functional model shows what goes into mixing the capsule. It starts with a hand and human energy or electricity. The hand is used to hold the device and turn it on. Once activated the electricity or human energy will convert to linear motion and produce heat, noise, and energy. These models helps the user understand what the device is going to accomplish.

Figure 16: Black Box model

5 DESIGN SELECTED

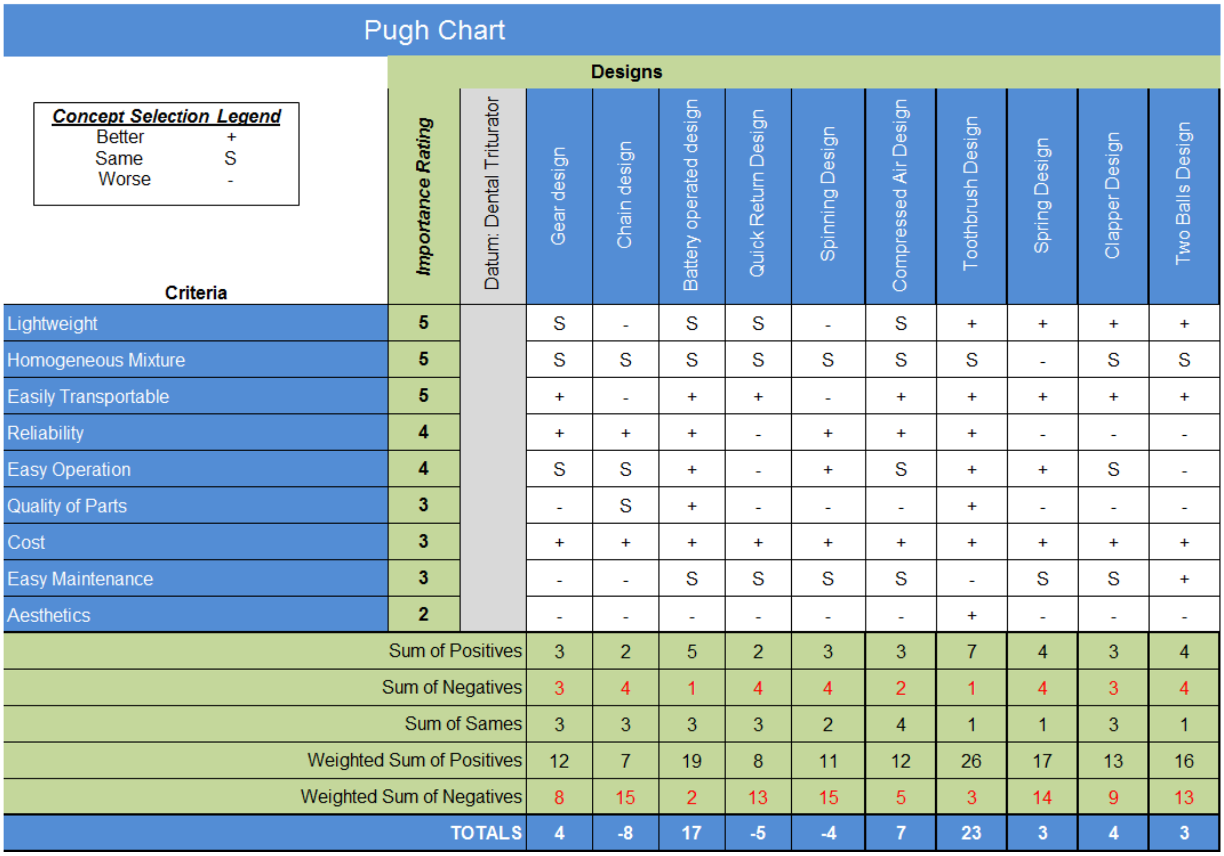
After much research and design ideas for making a dental capsule shake and mix based on the engineering requirements and customer requirements, the team has decided to chose the toothbrush design as the final design. In the following section the team will discuss the design in details.

5.1 Rationale for Design Selection

5.1.1 Pugh chart

The designs from section four were evaluated with a Pugh chart to determine the top ideas. As shown in the table below the team has provided the ten designs in the chart. Also, as shown, the pugh chart has the team’s customer requirements as the criteria. The designs were compared to the original design. After analysis, the team has chosen the top three designs based on their best total scores. For the first design, which is the toothbrush design, it got 23 points. The second design, which is the battery operated design, has 17 points. The third design is the compressed air design which has 7 points. These three designs will be presented in the team decision matrix.

Table 4 : Pugh Chart



Pugh Chart

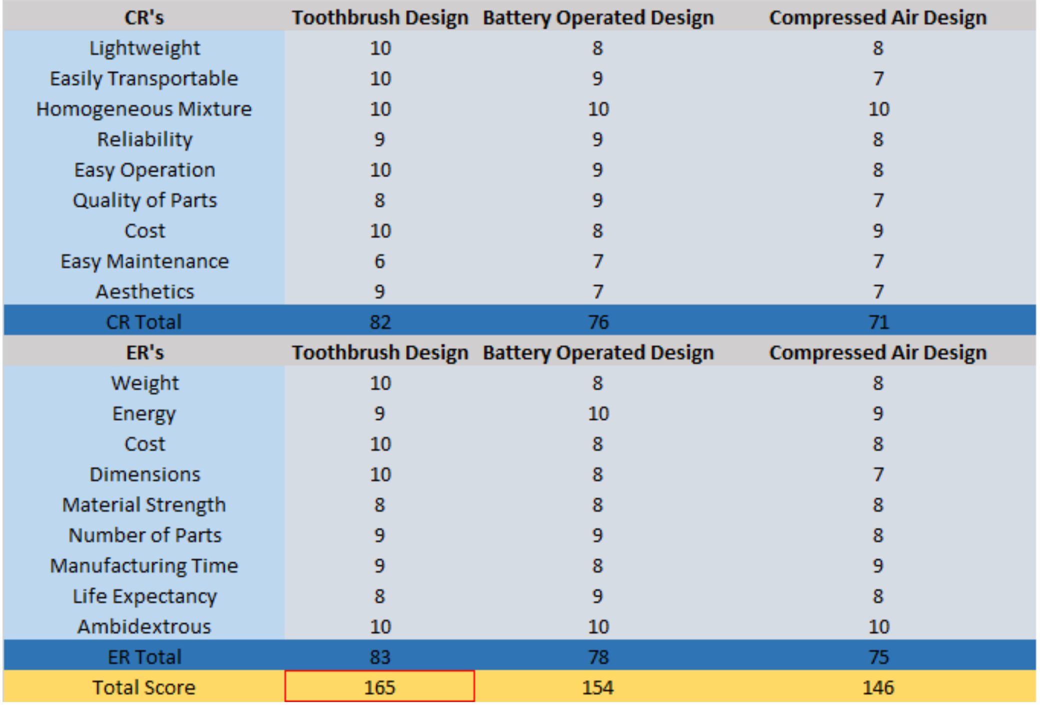
Concept Selection Legend
Better +
Same S
Worse -

Criteria	*Importance Rating*	Datum: Dental Triturator	Gear design	Chain design	Battery operated design	Quick Return Design	Spinning Design	Compressed Air Design	Toothbrush Design	Spring Design	Clapper Design	Two Balls Design
			Designs									
Lightweight	**5**		S	-	S	S	-	S	+	+	+	+
Homogeneous Mixture	**5**		S	S	S	S	S	S	S	-	S	S
Easily Transportable	**5**		+	-	+	+	-	+	+	+	+	+
Reliability	**4**		+	+	+	-	+	+	+	-	-	-
Easy Operation	**4**		S	S	+	-	+	S	+	+	S	-
Quality of Parts	**3**		-	S	+	-	-	-	+	-	-	-
Cost	**3**		+	+	+	+	+	+	+	+	+	+
Easy Maintenance	**3**		-	-	S	S	S	S	-	S	S	+
Aesthetics	**2**		-	-	-	-	-	-	+	-	-	-
Sum of Positives			3	2	5	2	3	3	7	4	3	4
Sum of Negatives			3	4	1	4	4	2	1	4	3	4
Sum of Sames			3	3	3	3	2	4	1	1	3	1
Weighted Sum of Positives			12	7	19	8	11	12	26	17	13	16
Weighted Sum of Negatives			8	15	2	13	15	5	3	14	9	13
TOTALS			**4**	**-8**	**17**	**-5**	**-4**	**7**	**23**	**3**	**4**	**3**

5.1.2 Decision Matrix

With the results from the pugh chart, a decision matrix was done for the three top designs by using the customer requirement and engineering requirements and to compare the three designs in the table below. These requirements are ranked on a scale from 1 to 10. For 1 means that the requirement is unsatisfied, for 10 means that the requirement is satisfied. Results show that the toothbrush design has the top score. That means the toothbrush design is the best design and that's the reason for this design to be the final device to pursue.

Table 5: Decision Matrix



CR's	Toothbrush Design	Battery Operated Design	Compressed Air Design
Lightweight	10	8	8
Easily Transportable	10	9	7
Homogeneous Mixture	10	10	10
Reliability	9	9	8
Easy Operation	10	9	8
Quality of Parts	8	9	7
Cost	10	8	9
Easy Maintenance	6	7	7
Aesthetics	9	7	7
CR Total	82	76	71
ER's	Toothbrush Design	Battery Operated Design	Compressed Air Design
Weight	10	8	8
Energy	9	10	9
Cost	10	8	8
Dimensions	10	8	7
Material Strength	8	8	8
Number of Parts	9	9	8
Manufacturing Time	9	8	9
Life Expectancy	8	9	8
Ambidextrous	10	10	10
ER Total	83	78	75
Total Score	165	154	146

5.1.3 Final design

The team has used the decision matrix and other data to choose the toothbrush design as the final product. The advantages of this design is the easy of use, lightweight, easily transportable, inexpensive parts, and small size. The disadvantages of this design are it is not easy to maintain, electricity(batteries) used on this design, and non-flexible and hard to find replaceable parts. The toothbrush itself can not be maintained by the user, so a whole new one will need to be purchased when a problem occurs.

5.1.4 CR's and the Final Design

The team's design has satisfied all of the customer requirements. The first and the most important customer requirement is light weight. The final design weight is approximately 0.242 lbs which is under our target weight of five pounds, and the lightest out of all the designs. The second requirement is easily transportable and this depends on the design's weight and dimensions. The design as mentioned is 0.242 lbs and 1.65 x 2.25 x 10.00 inches so it is easy to transport.[6] Also, the design has an easy operation because it is going to be just one button to turn it on and mix the capsule. In Appendix B, Equation 4 shows the energy for the design is calculated to be enough to mix the capsule properly. The bill of materials (table 6) shows a final design cost of $81.87 and the budget is $350 for the final design. So, the design has a cheaper cost than offered and meets the cost requirement. The requirements met by this design surpassed all other designs and that is why it is the best choice moving forward.

5.2 Design Description

The final design proposed is the electric toothbrush design, shown below in Figure 17. A full diagram of our final design is in Appendix D. This design has three main components, the extension, the timer relay module, and the electric toothbrush. The electric toothbrush acts as a base while the extension is where the capsule will be placed. The electric toothbrush transfers its energy to the extension and mixes the capsule. The timer relay module controls the amount of time that the electric toothbrush operates. It will automatically shut off the toothbrush when the time specified is expired.

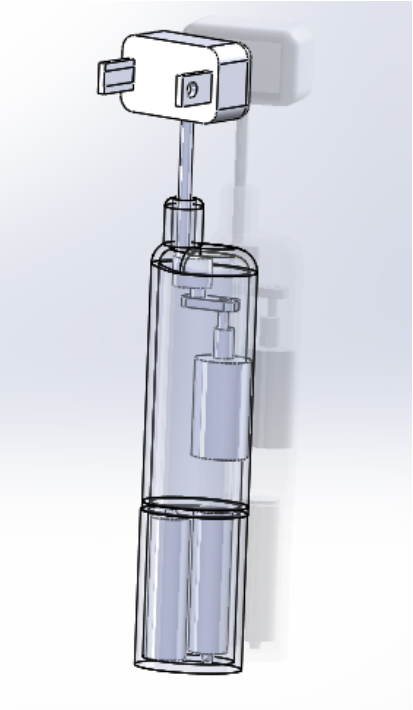


Figure 17: Current Toothbrush Design

5.2.1 Extension Model and Case in SolidWorks

Shown in Figure 18 is a model of the attachment piece designed. This figure shows all the dimensions in inches. This piece will fit on top of the electronic toothbrush. The piece will be 3D printed and the material we will be using for this is Acrylonitrile Butadiene Styrene (ABS). This is a great material because it is a inexpensive and a durable plastic. It has a glass transition of 105 °C (221 °F) , Typical Injection Molding Temperature is between 204 - 238 °C (400 - 460 °F) . Also, 98 °C (208 °F) for Heat Deflection Temperature (HDT) at 46 MPa (66 PSI). Also, It would stay two hours at 180°F to be dried. It has 46 MPa (6600 PSI) Tensile Strength and 74 MPa (10800 PSI) Flexural Strength[7]. Tensile strength will be our limiting factor for this material. The heat deflection temperature is when the material starts to lose it strength which can cause premature failure. As shown in Figure 18, the bottom view has an opening that is shaped in a semicircular way. This part will be placed on the metal shaft of the electric toothbrush. This particular shaft moves in a semicircular motion. It is not seen in Figure 18 but there is a hole in the back of this part. The hole will have a screw. This screw will tighten into the metal shaft thus creating stability between the extension and the toothbrush. This stability is key to transmitting the energy of the shaft to the capsule. Figure 5 in Appendix D shows a picture of our prototype. Figure 19 shows a model of the case. The case is made of the same material as the attachment part as is used to protect the components of the device. It is made up of 2 parts, the base and the cover. It can be removed to provide maintenance to the device.

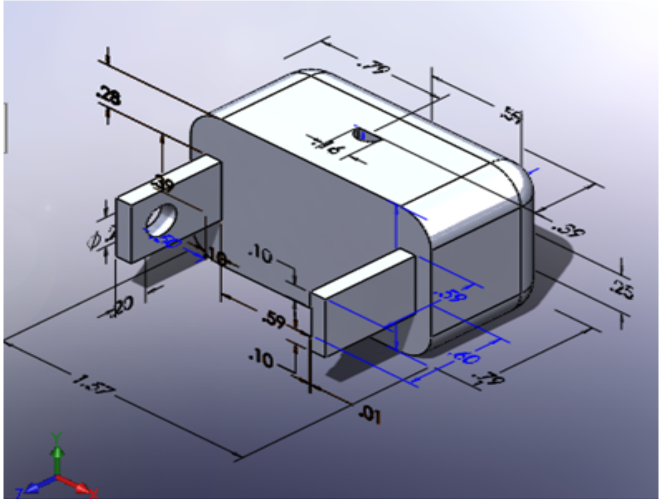


Figure 18: Capsules holder design

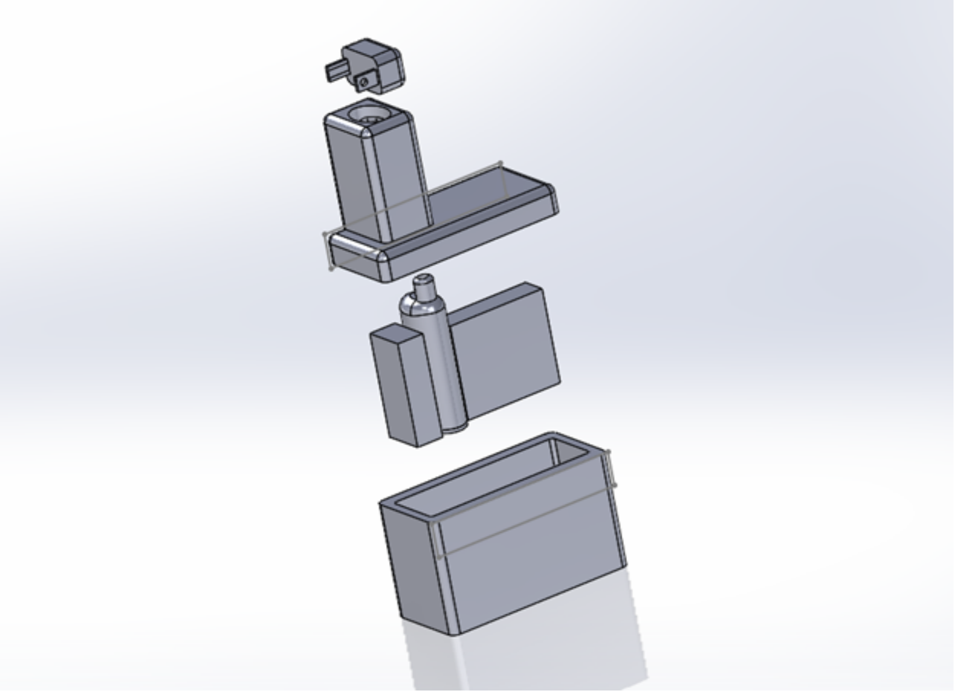


Figure 19: Exploded view final Assembly

5.2.2 Electric Toothbrush

The second component of our design is the electric toothbrush. The electric toothbrush is not design by the team but we know it is the key to the success of our project. Table 1 in Appendix C is the bill of materials of our design project. Figure 1 in Appendix D shows an extruded version of our electronic toothbrush. Each component is different and has a different function. Figure 3, shows all the different components and what number is used to describe them. This figure also has a ruler so each component can roughly be compared to inches and centimeters. Parts 11, 12, and 10 are the outside parts of the toothbrush they are the base that hold the rest of the pieces together. Part 9 is the brush itself but for our project we won't need it. Parts 8 are the batteries used for the toothbrush. It uses two double AA batteries. Part 7 is the on and off switch of the toothbrush. Part 6 is the motor, (shown in Figure 6). At the end of the motor there is a little plastic tip that is used to convert the rotational energy to semi rotation. Part 5 and 3 act as a case where part 4 transmits the motors rotational energy to the metal shaft (part 2). The end of the shaft of part two is flat. One can see this more clearly in Figure 7 of the appendix C. Part 4 resembles a figure eight and is made of plastic. Part 1 is attached to the metal shaft and acts as a stopper to keep the shaft steady.

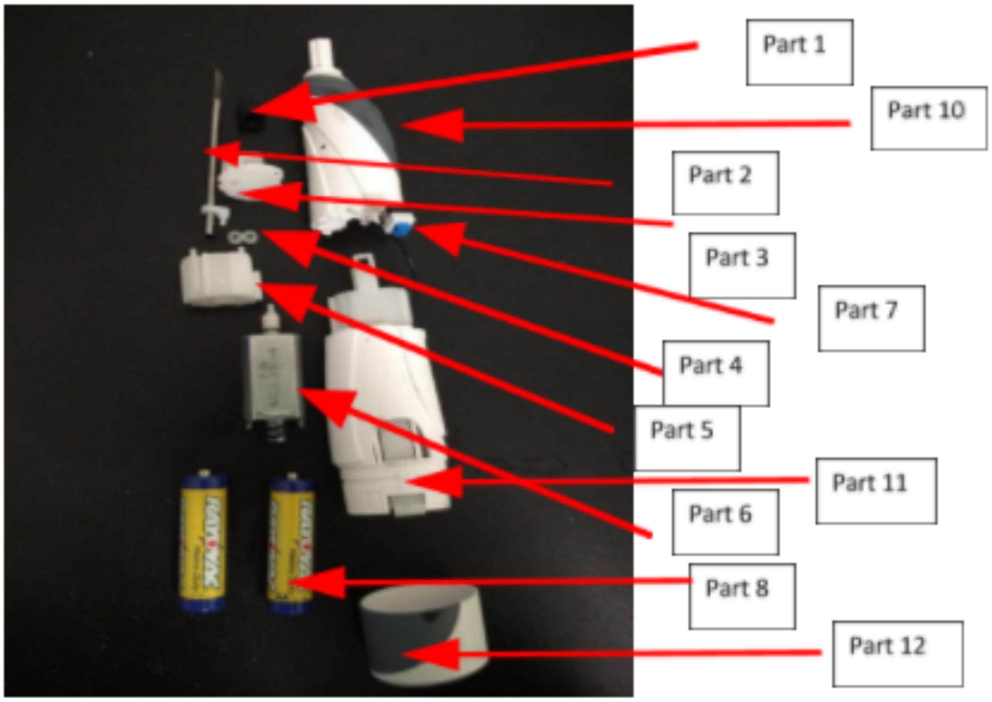


Figure 20: Toothbrush assembly

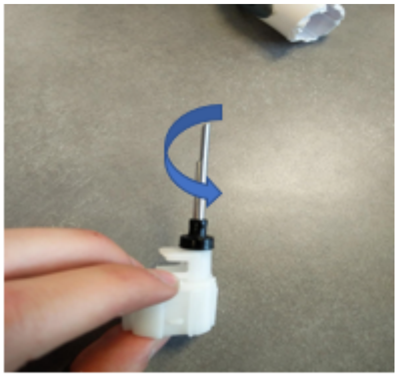


Figure 21 : Toothbrush Shaft

Figure 22: Part 4

5.2.3 Timer Relay Module

The timer relay module is used to turn off the motor after a certain amount of time. Figure 23 shows the module used and the wiring diagram for that module. The module is set to a time of 12 seconds based on testing. This time ensures a mixed capsule and a viscosity similar to that off the original machine. This module is not programmed from a computer so the functions can be changed at anytime with ease.

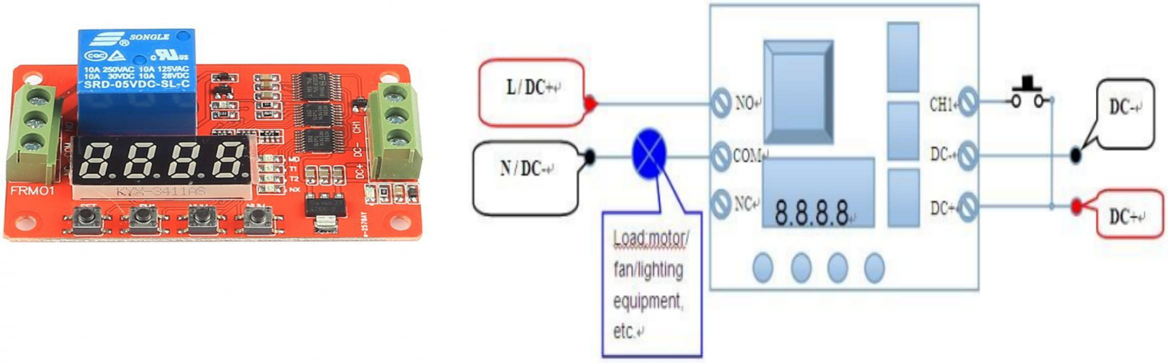


Figure 23: Timer Relay Module and Wiring Configuration

5.2.3 Design Explanation

The metal shaft in Figure 21 rotates in a semicircular way. This is crucial to the mixing of our capsule because we need to shake it in a semi linear pattern for it to work. If we try to mix the capsule using rotational motion this will only be detrimental to the mixture of the capsule. Rotational motion tends to separates mixtures which is the opposite of what we want to accomplish.

The hardest part of this design is converting the motors rotational energy to the shafts semi-rotational motion. Although part 4 is very small it is the key in converting the motors rotational energy to the semicircular energy. Figure 24 shows how parts 1,2,3,4, and 6 are assembled. This assembly shows where the rotational motion is changed to semicircular motion. The plastic tip that is attached to the motors shaft attaches to one of the holes of part 4. The toothbrush metal shaft (part two) has a little plastic piece that attaches to the other hole of part 4. As the motor spins in a circle it pushes part 4 up and down thus making the metal shaft only side to side. This creates the semi-rotational motion.

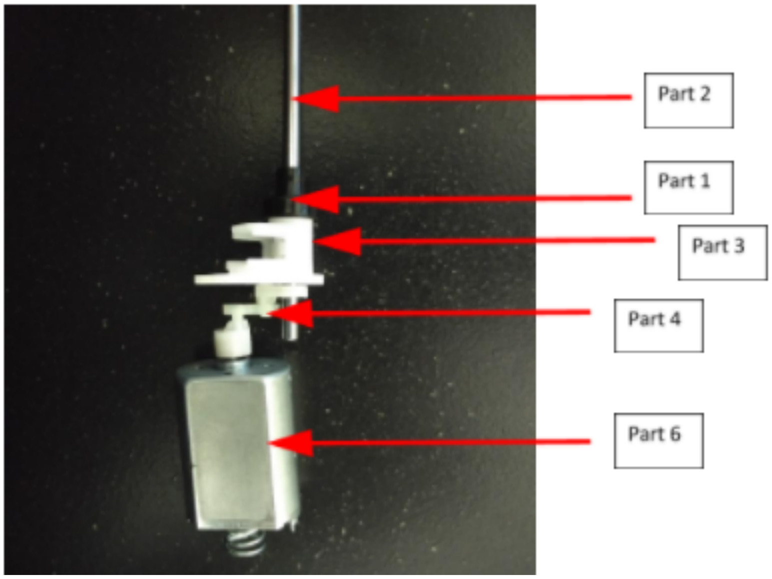


Figure 24: Shaft Assembly

5.2.4 Calculations

To find the energy needed to mix the capsule properly, the original system was first observed. The Wig-I-Bug is the original system so a reverse engineering method was necessary to find out what was on the inside. The motor's power requirements are 115 V and 1 amp (AC). This motor transfers the power to a shaft and then a manufactured piece where the capsule is secured and shook in a figure 8 motion. Since the motor directly transfers its power to the capsule the team calculated the basic electric power equation P = V*I*PF, where P is power, V is volts, I is amps, and PF is the power factor. Doing this calculation, Figure 23 **,** the capsule gets about 345 Joules of energy from this device.

$$P = 115V * 1A * 0.3 = 34.5 \text{ Watts} \qquad \text{(Eq.1.1)}$$
$$E = 34.5 \text{ Watts} * 10s = 345 \text{ Joules} \qquad \text{(Eq. 1.2)}$$

Figure 23: Power and Energy Equation 1

Now, looking at the specifications given by the GC FujiTriage company for this specific capsule, they state that the capsule should be mixed for 10 seconds at “approximately” 4000 rpm. Using the Wig-I-bug and the power equation P = (T*Speed)/9.5488 the energy required is about 290 Joules, Figure 24 . Since triturators are similar in size and speed, the designated energy is a minimum of 300 Joules to mix the capsules properly.

$$P = 0.0693Nm * 4000 \text{ RPM} / 9.5488 = 29.03 \text{ Watts} \qquad \text{(Eq. 2.1)}$$
$$E = 29.03 \text{ Watts} * 10s = 290 \text{ Joules} \qquad \text{(Eq. 2.2)}$$

Figure 24: Power and Energy Equation 2

5.2.5 Results

The final proposed design for the project is a high Hz output electric toothbrush. The toothbrush shaft performs a single plane motion along a half circle. Most electric toothbrushes have a frequency of 200-400 Hz and 24,000 - 48,000 movements per minute [8]. The design chosen contains a 350 Hz frequency in order to mix properly. To calculate the energy the used equation was the power equation P = (T*Speed)/9.5488. Tests will be done to make sure that the capsule can be mixed for more than 10 seconds. Appendix B shows the calculations done to find the rpm and Hz. Figure 4, in appendix B, shows the calculation executed by the team. According to these calculations 308 Joules will be transferred to the capsule in ten seconds from our design. To get the capsule to mix properly we need to transfer only 300 joules. Therefore these calculations supply the design will work.

6 PROPOSED DESIGN

The proposed design is an electric toothbrush with a Hz output of 350 Hz. The calculations in Appendix B assume that only a 350 Hz output or higher output toothbrush will meet our minimum energy requirements. We tested our design and it meets the requirements of successfully mixing the dental capsules.

6.1 Device Assembly

For the proposed design, the capsule needs a minimum of 300 Joules to mix the components. In addition to the toothbrush, Figure 25, shows a layout of the final assembly. The goal was to 3D print the extension to make the capsule attach more easily to then be shaken. The design requires six 1.5V AA batteries to be powered[9]. Two for the motor and four for the timer relay module. Since the design is smaller, this type of toothbrush can fit aboard in carry-on luggage. The device is enclosed in a 3D printed case to protect its components.

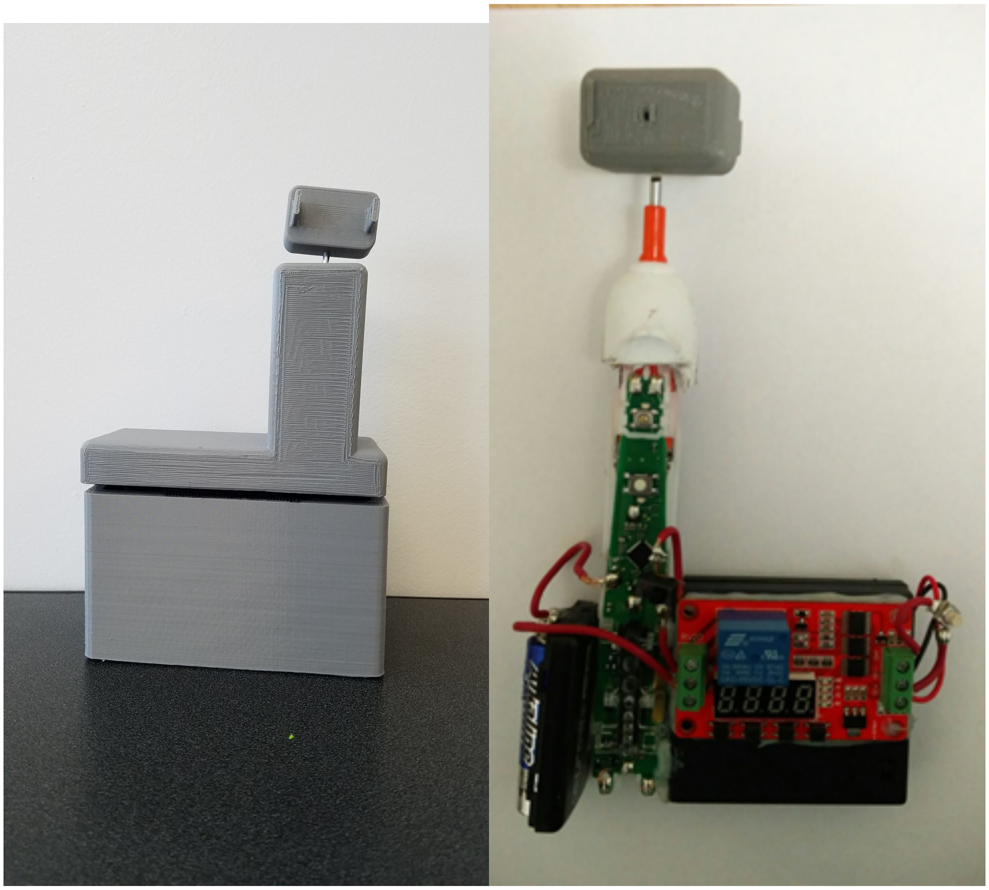


Figure 25: Final Device Assembly With and Without Case

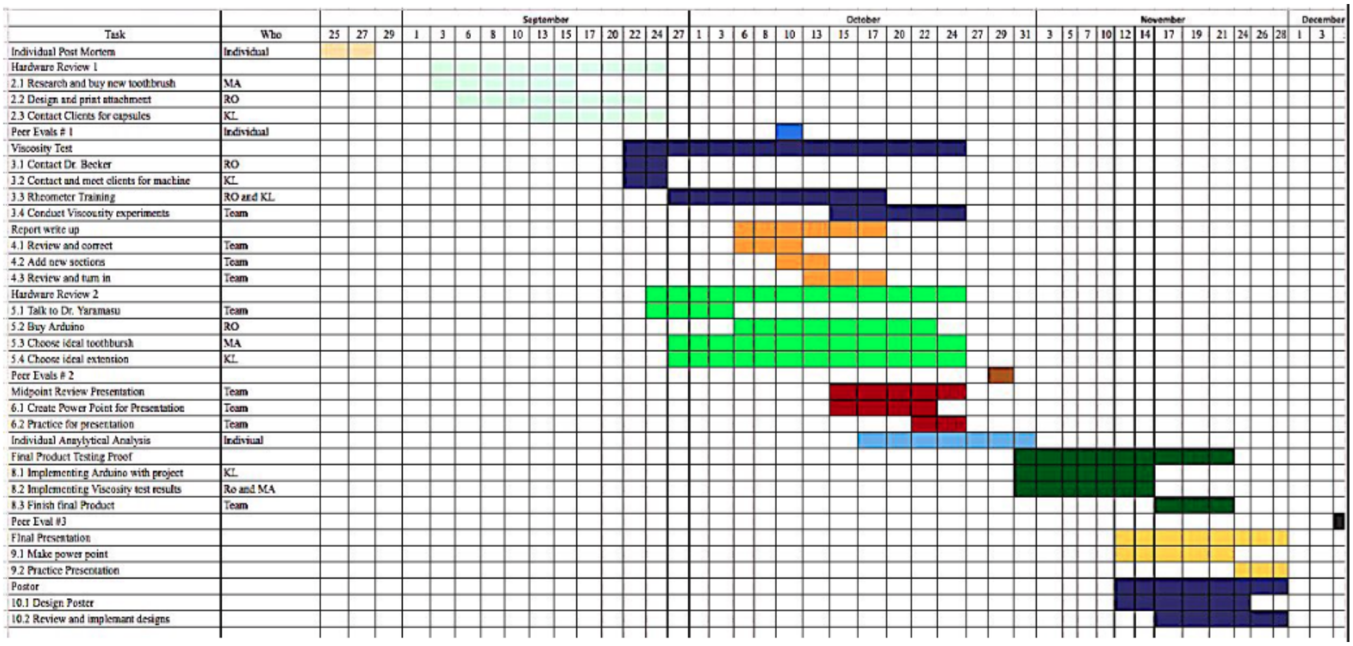
6.2 Budget and Schedule

Shown in Table 6, is the bill of materials for the design and total budget. Testing will require $100 and $35 for the prototype. The testing process will be in which toothbrush performs best for the team design to make the components mix. In order to test the output of the device, multiple brands of the batteries will be tested. Battery life will also be tested. Also, the capsule holder will be tested using our engineering requirements.

Table 6: Bill of materials

Material	Cost
Electric toothbrush [6]	$84.38
AA Batteries x8 [7]	$6.53
Timer Relay Module	$6.99
3D Printing “attachments” (Four)	$3.64
3D Printing Case	$19.90
Battery Cases	$9.00
Electric Trigger	$1.35
Prototype	$35
Testing	$100
Total funds available	$1000
Anticipated final cost	$216.87
Final Design Cost	$131.79

The schedule overview for this project is shown below in Figure 25. With the final design prototype we can test the device. This project will be completed in the fall 2017 semester. The first step is to meet with the faculty advisor. After the meeting, the final design will be modified or built according to requirements. Progress and changes will be presented to the faculty, clients, and students. At the end of next semester we will test our final design and send it to the clients to use.



Task	Who
Individual Post Mortem	Individual
Hardware Review 1	
2.1 Research and buy new toothbrush	MA
2.2 Design and print attachment	RO
2.3 Contact Clients for capsules	KL
Peer Evals # 1	Individual
Viscosity Test	
3.1 Contact Dr. Becker	RO
3.2 Contact and meet clients for machine	KL
3.3 Rheometer Training	RO and KL
3.4 Conduct Viscousity experiments	Team
Report write up	
4.1 Review and correct	Team
4.2 Add new sections	Team
4.3 Review and turn in	Team
Hardware Review 2	
5.1 Talk to Dr. Yaramasu	Team
5.2 Buy Arduino	RO
5.3 Choose ideal toothbursh	MA
5.4 Choose ideal extension	KL
Peer Evals # 2	
Midpoint Review Presentation	Team
6.1 Create Power Point for Presentation	Team
6.2 Practice for presentation	Team
Individual Anaylytical Analysis	Indiviual
Final Product Testing Proof	
8.1 Implementing Arduino with project	KL
8.2 Implementing Viscosity test results	Ro and MA
8.3 Finish final Product	Team
Peer Eval #3	
Final Presentation	
9.1 Make power point	
9.2 Practice Presentation	
Poster	
10.1 Design Poster	
10.2 Review and implemant designs	

Figure 25: Fall 2017 Schedule Overview

7 IMPLEMENTATION

This section includes changes made to our design and the manufacturing of any parts included in final design. Changes to the prototype have been decreasing size of shaft hole on the attachment part and the electric toothbrush previously chosen. Manufacturing done for our project is 3D printing our device and ordering necessary parts that are already manufactured.

7.1 Manufacturing

The manufacturing process of our device is simple and fast as of right now. The parts that take the longest to manufacture are the attachments that are 3D printed. These usually take anywhere from 3-5 days to print. All other hardware used is already manufactured. The electric toothbrush can be ordered online or found in most supermarkets for quick pick up. The arduino and solar panels are ordered from Amazon and have a usual shipping time of 2-4 days. Since all our parts are easy to receive and find there is no major concerns with our manufacturing times. The concerns with manufacturing we have is the 3D printed attachment. This part may have an error so we will print many of them to ensure there will be no major error. If there is a major error that shows up during viscosity testing, the team may consider using Aluminum for the attachment part.

7.2 Design Changes

The team chose to use ABS material for our final attachment part since it is easy to print, light, and inexpensive. The testing so far has been successful for this product. To test further, the material will be thrown hard at the floor and tested for approximately 24 hours of run time. The problems encountered were the shaft hole was smaller than expected and had scrap material in it. Since the material is flexible, we easily pushed the toothbrush shaft onto it. This problem is not major and simply can be solved by cleaning the hole and making it larger or smaller depending on the final toothbrush shaft size. If ABS does not have an acceptable life expectancy after all testing the team may consider using Aluminum for the part.

8 TESTING

The testing plan for the final product was to use the testing procedures and design links from the appropriate sections in Chapter 2. The significant testing procedures was the viscosity testing using the rheometer and the life expectancy. All other testing procedures were completed with simple calculations, a simple measurement, or a reference. The results in Table 7 shows that all requirements were met based on tested results.

To test for viscosity a machine called rheometer is needed. This machine is very expensive and requires training. After contacting Dr. Becker, the team set up an appointment with one of his grad students to start the training. Figure 26 is a picture of the rheometer. The rheometer has many different attachments that are required for different sets of tests.

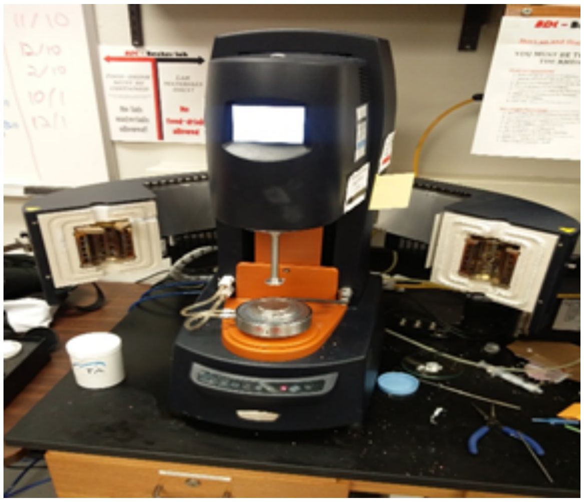
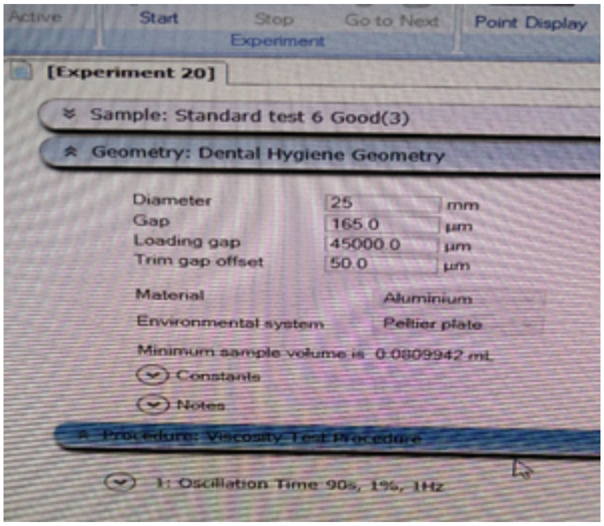


Figure 26:Rheometer

Test development:
The hardest part of this experiment is trying to control all the different variables that can skew the results of the tests. One of the most important parts of this experiment is making sure the software is setup properly and correct. The software has three different tabs for each experiment. All tabs must be set up properly before proceeding to the tests. The first tab is the name of the test and where it gets saved as shown in Figure 9. The second tab consist of the geometry of the tools being used as shown in Figure 10. The third tab is the Viscosity test procedures.

In the Figure 27 the second tab, the gap is set to 165 micrometers. This is the space between the two plates that come together during the experiment. The gap controls the amount of ml sample you need. Each capsule is supposed to have .12ml of material but the reason we chose .08ml for this experiment is because, the amount of material we can extract from each capsule varies. We decided to undershoot this number because we know from each capsule we can always get at least .08ml of materials. We measure .08ml of material by squirting the capsule into a syringe. The other factors shown in this tab are chosen by the properties of the top plate. The third tab shows Oscillation time of 90s, 1%, and 1Hz. The Oscillation time is how long we want the experiment to run. The 1% and 1Hz are factors recommended to us by the grad student.



[Experiment 20]

Sample: Standard test 6 Good(3)

Geometry: Dental Hygiene Geometry

Diameter 25 mm
Gap 165.0 µm
Loading gap 45000.0 µm
Trim gap offset 50.0 µm

Material Aluminium

Environmental system Peltier plate

Minimum sample volume is 0.0809942 ml

Constants

Notes

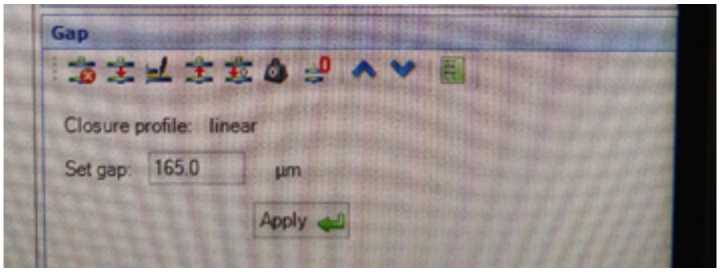
Procedure: Viscosity Test Procedure

1: Oscillation Time 90s, 1%, 1Hz

Figure 27: Experiment Tab Geometry

Procedure of test:
Before we could master the procedure, we had lots of failed attempts. One of the first failed attempts was that the test lasted too long. This let the paste cure completely, and made it extremely difficult to take it off from each plate. Learning from this we decided to time our experiment. Two minutes after the capsule was activated we stopped all testing and pulled the plates apart. Cleaning each plate was much easier because the paste had not cured completely. Once a capsule is activated it starts a curing process that takes two minutes and a half to complete. Due to this the viscosity of this paste changes with time. That is why it was extremely important we started the testing of each paste at the same time after activation. The time we choose to do this was 67 seconds.

For each test, first we activated the capsule and stated a timer. We then put the capsule into the designated machine. Once it had been shaken we used the tool from Figure 29 to squirt the capsule into a syringe. Using this syringe, we placed .08ml of paste onto the rheometer. Once second 55 hit on the timer we pressed on apply on the computer. Figure 28 shows this apply button. This lowered the top plate onto the material. At second 67 we hit enter and started the testing. Once the timer hit two minutes we stopped the testing and brought the top plate up. After this we cleaned the plates and stored the data in a separate file. During each test, we had to be fast and precise in order to get the best data.



Closure profile: linear

Set gap: 165.0 µm

Figure 28: Apply button

Figure 29: Squeeze tool

Results:

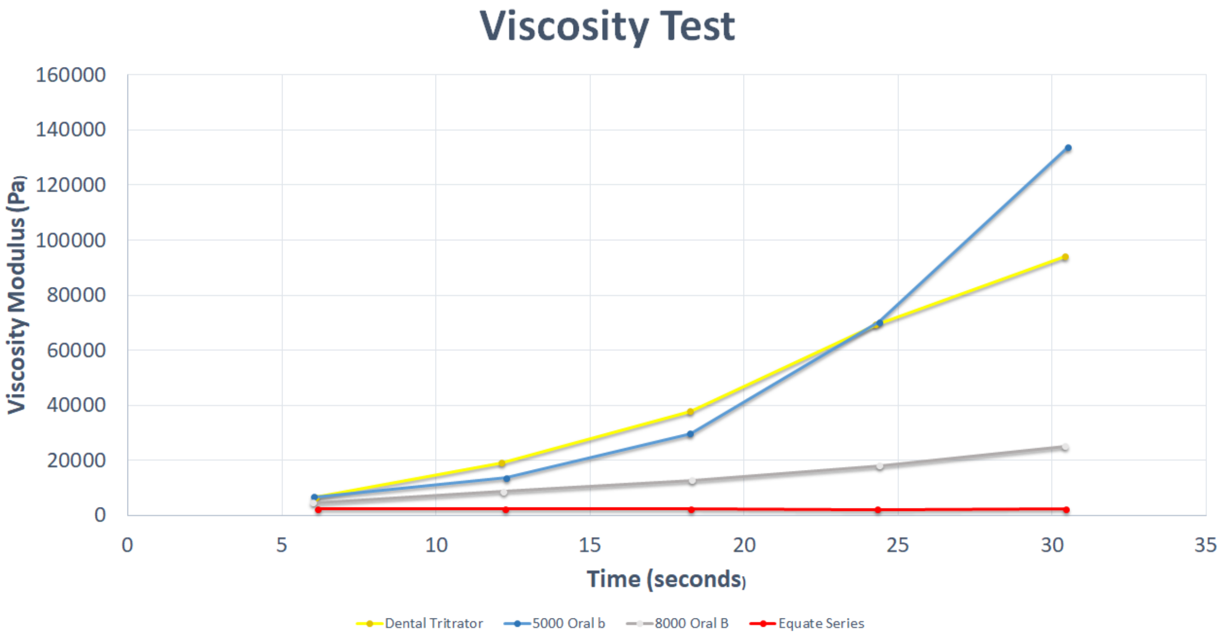
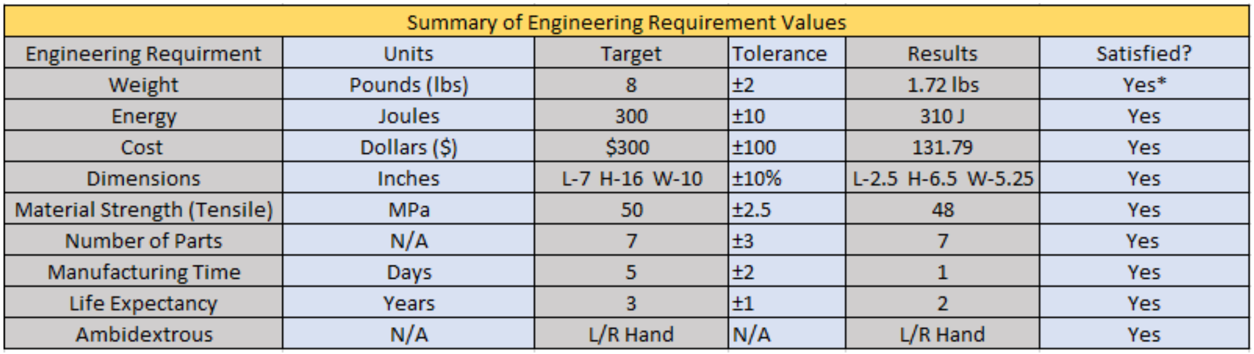


Figure 30: Viscosity test results

After the team ran the viscosity testing the team found that the Oral B 5000 was the best choice for our project. The yellow line shows the results of the viscosity testing for the Standard titrator. The blue line shows the results of the Oral B 5000 toothbrush, the grey shows the results of the Oral B 8000, and the red shows the results of the *Equate Series.* As seen in the Figure 30 the Oral B 5000 toothbrush had the closest viscosity values to the Standard dental Titrator compared to the other toothbrushes. The team thought the Oral B 8000 was going to have the best results because it is the most expensive toothbrush, but this toothbrush has a feature where if the motor is exposed to too much stress it will turn off. So we could only run the 8000 Oral B experiments using the lowest powered mode. This affected its results because the viscosities were relatively low compared to the standard titrator. The Equate Series was the least powerful toothbrush hence the results on the graph reflected that.

Life expectancy testing was done by using data on the toothbrushes, arduinos, and common 3D printed parts. The expectancy of the batteries is approximately 1 week under normal usage. The motor and timer relay could last anywhere from 3 months to 5 years, based on product data. The weight was done by weighing the device fully assembled. The energy calculations were done using the frequency of the device. Calculations are shown in Appendix B. Tensile testing was not done physically. There have been tests done on the material previously so those values were referenced. Number of parts were done by counting all components that make the device function but not including the batteries since they assemble inside the device. Manufacturing time was done by averaging the time it took for each part to print. The ranges were 4 hours to 24 hours. Measurements were taken of final device in Solidworks and with a measuring tape. The final cost of the device was considered with taxes, batteries, and 4 attachments. This value was calculated to be $131.79.

Table 7: Summary of Engineering Requirement Values



Summary of Engineering Requirement Values

Engineering Requirment	Units	Target	Tolerance	Results	Satisfied?
Weight	Pounds (lbs)	8	±2	1.72 lbs	Yes*
Energy	Joules	300	±10	310 J	Yes
Cost	Dollars ($)	$300	±100	131.79	Yes
Dimensions	Inches	L-7 H-16 W-10	±10%	L-2.5 H-6.5 W-5.25	Yes
Material Strength (Tensile)	MPa	50	±2.5	48	Yes
Number of Parts	N/A	7	±3	7	Yes
Manufacturing Time	Days	5	±2	1	Yes
Life Expectancy	Years	3	±1	2	Yes
Ambidextrous	N/A	L/R Hand	N/A	L/R Hand	Yes

9 CONCLUSIONS

After research and analysis, a final design was chosen. An electric toothbrush with an attachment made out of ABS material will fit on the toothbrush shaft and the capsule will fit inside the attachment. This design best meets the proposed customer and engineering requirements. the team have been tested the design with three ways which are viscosity testing, attachment dropping testing and battery last testing.

9.1 Contributors to Project Success

The main contributor to the team’s success was the ability to work with each other and agree on many ideas. This is what helped make us bond more as individuals and communicate more efficiently. While working on the first conceptual ideas and assignments we all stayed on the same page and pushed each other to think outside of the box. This is how we came up with many of our ideas and move towards our proposed project.

The project purpose was to create a reliable dental triturator that can be easily transported and be used without electricity. The team has completed the purpose of the project but in a different way. We were in the beginning of the semester when we wrote the team charter and were not thinking about all the possibilities. After reconsideration, we decided to use electricity but not from the grid or outlet but from small batteries. The clients were hesitant at first but realized that batteries have benefits over hand or human powered device, meaning they don’t have to use their energy to get feedback.

The team goals are to have efficient meetings, get work in on time, and produce quality work. We also wanted to get an A in the class but some preparation and editing issues held all of us back from that goal. Our goal to have efficient meetings was achieved by never straying off topic and addressing the issues in front of us. We always tried our best to get our work in on time. The quality of work we provided was to the best to our ability at the time. We continued to grow throughout the semester and get better with our writing and overall work.

The ground rules laid down in the team charter was specific meeting times unless complications came up, do your share of work, split the work up equally, and redo any work that other team members thought was of bad quality. These rules were followed almost perfect by the team. If we had to change a meeting, the team agreed on a time later in the week. We all did our fair share of work and if someone was gone for a weekend one of the other team member took over for the time being. When that member came back they had to make up for being gone by contributing more the next time around. There was may discussions and changes done in our work because of non factual data or bad technical writing.

Coping strategies were followed by all team members and we all understood consequences for not doing our share of work. The only problems we had in the semester was members being gone or sick. We all understand these kinds of things happen and it never happened on a regular basis. We were all free to speak our mind and communicate freely.

The most positive aspects of the project performance was the final product cost and ability to work and communicate efficiently. Once we all agreed on the toothbrush idea and confirmed that it would work, we had a final product cost of less than 131.79$. This was substantially less than the anticipated cost of 300$. We were all excited to stay well under budget and to be able to experiment further on our project.

The tools we used to be successful was communication to keep all team members on board and understand the team goals. There was an occasional time when the goals were not being reflected and we had to be reminded that we should not take certain routes in our work. We were poised to complete our work at least 2 days prior to due dates so that we could have time to review and critique each other's work. This was a huge benefit because there were many issues fixed by using this methodology that would have caused substantial point losses.

9.2 Opportunities/areas for improvement

There are many opportunities that are existing in our project. Even though we felt that we did a great job and followed all our goals and procedure, there is still room for improvement. As previously stated, we changed the purpose a little bit from our team charter to what is now the team purpose. This was because of reconsideration and seeking better opportunities in the project. The continuous improvement method is used in all aspects of our project and we are always looking for different methods to improvise on in our work.

The most negative aspects of the project were time management and quality of writing. The team did great on most of the assignments but there was a couple of times that time management was bad. We took our time and advantage of having longer due dates. We did not do work when we should have and fell behind our own deadlines. This caused our quality of writing to decrease since we had less revision time and a closing deadline. We can improve in this by sticking to our plan of completing our work before the deadline to edit mistakes.

Some negative tools we used were implying our own thoughts and not doing as much research. We also did not use our peers and instructors as much as we should have. We all agreed on each other's thoughts most of the time and this allowed us to believe that what we were saying was factual. This was not always the case and later we had to spend more time getting other data or changing our writing. There were also a few times where we did not know the answer and searched online or implied something was false since we didn't have evidence. We could have and should have talked to our peers and mentors/instructors. So, we take a place to improve in these areas by not settling for answers and reviewing the facts available.
The team did not have any major issues. There was a handful of times that we did not communicate as well as we should of and this caused confusion with handling documents. Team meetings in the beginning were slow and not very productive since there was not much information to throw around. We improved in this area by using effective communication and using past meetings to improve the future ones.

Organizational actions to be used in the future will be better time management and rules to enforce this time management. We make the ground rules more efficient so that we get stuff done on or before the dates that are planned. By doing this, we are able to edit and revise documents multiple times thus upgrading our quality of writing. We also imply a system that changes the roles of each member in the group. One week a member will be the leader and in charge of the project flow/management, and the next week they could be the editor or the website developer. This make each member well rounded in all aspects of the project and give us more experience when editing or giving advice. This is not only help the team in the project but help us complete the project at the end of the year if someone is ill or out of town.

Technical lessons that The team learned during this project was the importance of citing and references, and the use of the engineering process. I know from previous writing and courses that sitting people is important, but The team never understood the importance it had on designing your own work. Many of the practices and processes we used were based on other people findings and previous work done. These references are here so that we don’t have to reinvent or recalculate many of the things already done. The engineering process is important to engineering design as we already know. But to understand and apply this to a real-world project is crucial. Without this process, there would be no boundaries or foundation to base our designs off.

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[5] *Sawzall*. Digital image. N.p., n.d. Web. http://toolguyd.com/blog/wp-content/uploads/2013/09/Milwaukee-M18-Fuel-Sawzall-Recip-Saw.jpg

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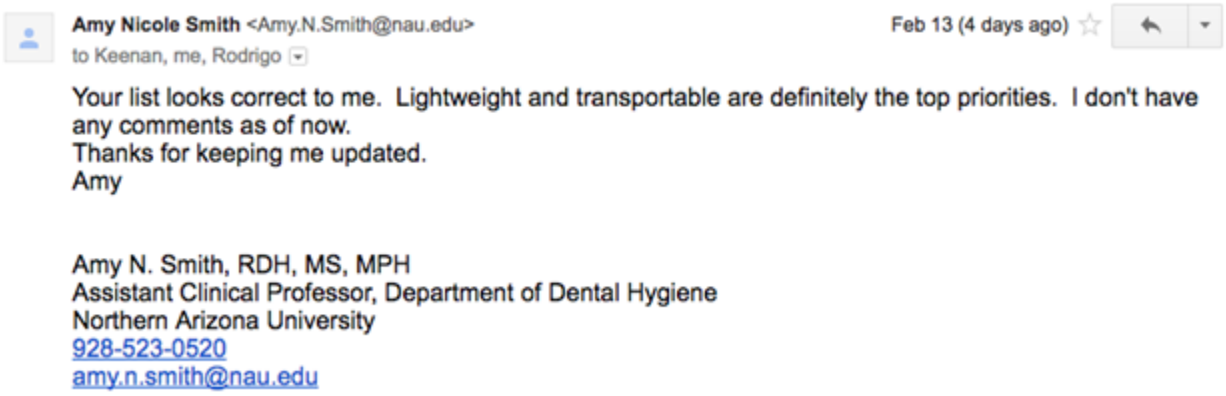
[9] "Amazonbasics AA Rechargeable Batteries (8-Pack) Pre-Charged - Packaging May Vary: Health & Personal Care". *Amazon.com*. N.p., 2017. Web. 24 Apr. 2017..

Appendix A: Client Approval



Amy Nicole Smith <Amy.N.Smith@nau.edu>
to Keenan, me, Rodrigo
Feb 13 (4 days ago)

Your list looks correct to me. Lightweight and transportable are definitely the top priorities. I don't have any comments as of now.
Thanks for keeping me updated.
Amy

Amy N. Smith, RDH, MS, MPH
Assistant Clinical Professor, Department of Dental Hygiene
Northern Arizona University
928-523-0520
amy.n.smith@nau.edu

Appendix B: Energy Calculations

The energy calculations below are used to find out how much energy output comes from the wig-l-bug and how much comes from the toothbrush. There is a minimum amount of energy calculated that is used to mix the capsules properly. Note: Equations 1 and 2 are done for the original system(wig-l-bug). Equations 3 and 4 are for the final design(electric toothbrush).

Equation 1(Power and Energy from the Wig-l-Bug Motor):

$$P = V*I*PF$$
$$V = 115 \text{ Volts}$$
$$I = 1 \text{ Amp}$$
$$PF = \cos(75) = 0.3$$
$$P = 115*1*0.3 = 34.5 \text{ Watts}$$
$$E = P*t$$
$$E = 34.5*10$$
$$E = 345 \text{ Joules}$$

Equation 2(Power and Energy from the Torque of the Motor):

P = (T*Speed)/9.5488
T = F*d
F = m*V/t
V = r*RPM*0.10472

V = 10.2mm*4000rpm*0.10472 = 4.27 m/s
F = 2.95kg*4.27m/s/10s = 1.26 N
T = 1.26N*0.055m = 0.0693Nm
P = 0.0693Nm*4000rpm/9.5488 = 29 W
E = 29W*10s = 290 Joules

Minimum Energy and Power requirements:
Emin = 300 Joules
Pmin = 300/10 = 30 Watts

Equation 3(Average Specifications for Electric Toothbrush):
Assumptions:
200-400 Hz (Range for electric toothbrush)
Hz = 60 RPM
350 Hz = 21000 RPM(Selected Toothbrush)

Equation 4(Power and Energy output from Electric Toothbrush):

P = (T*Speed)/9.5488
T = F*d
F = m*V/t
V = r*RPM*0.10472

V = 0.92mm*21000 rpm*0.10472 = 2.02 m/s
F = 0.091kg*2.02m/s/1s = 0.184 N
T = 0.184N*0.0762m = 0.014 Nm
P = (0.014*21000)/9.5488 = 30.8 Watts
E = 30.8*10 = 308 Joules-----Meets minimum requirement

These calculations conclude that a higher energy toothbrush is required. We will be doing our testing using both high and low energy toothbrushes to observe the difference in the viscosities.

Appendix C:

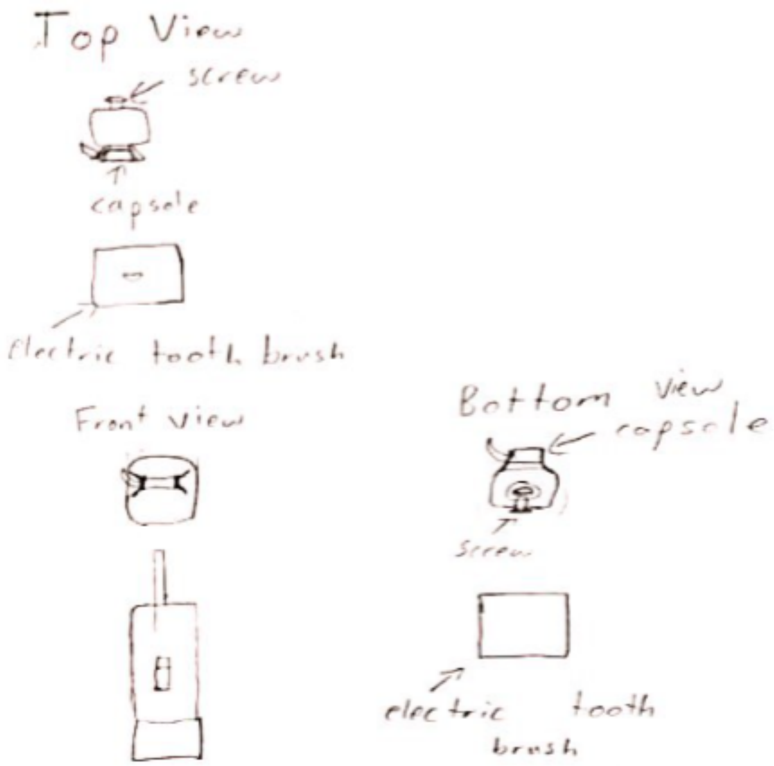


Figure 1: Final design Sketch

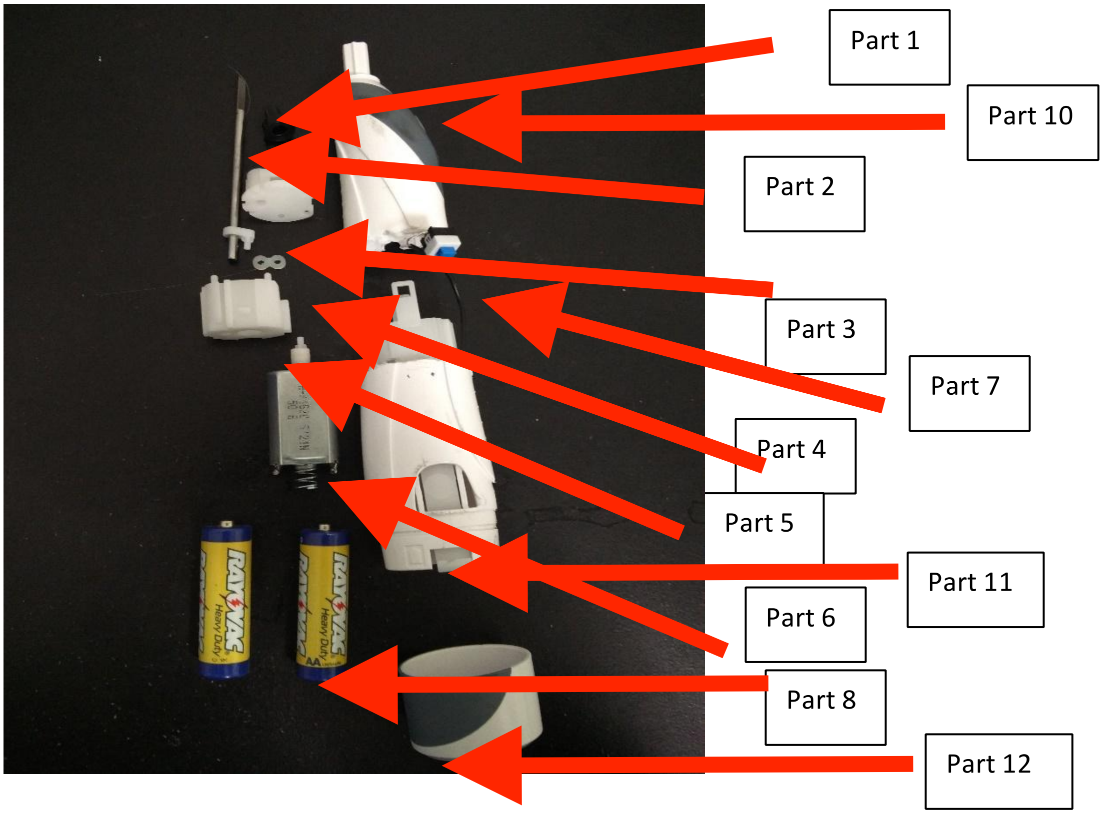


Figure 2: Extruded Figure 2: Picture of electric toothbrush

Figure 3: Electric Toothbrush parts

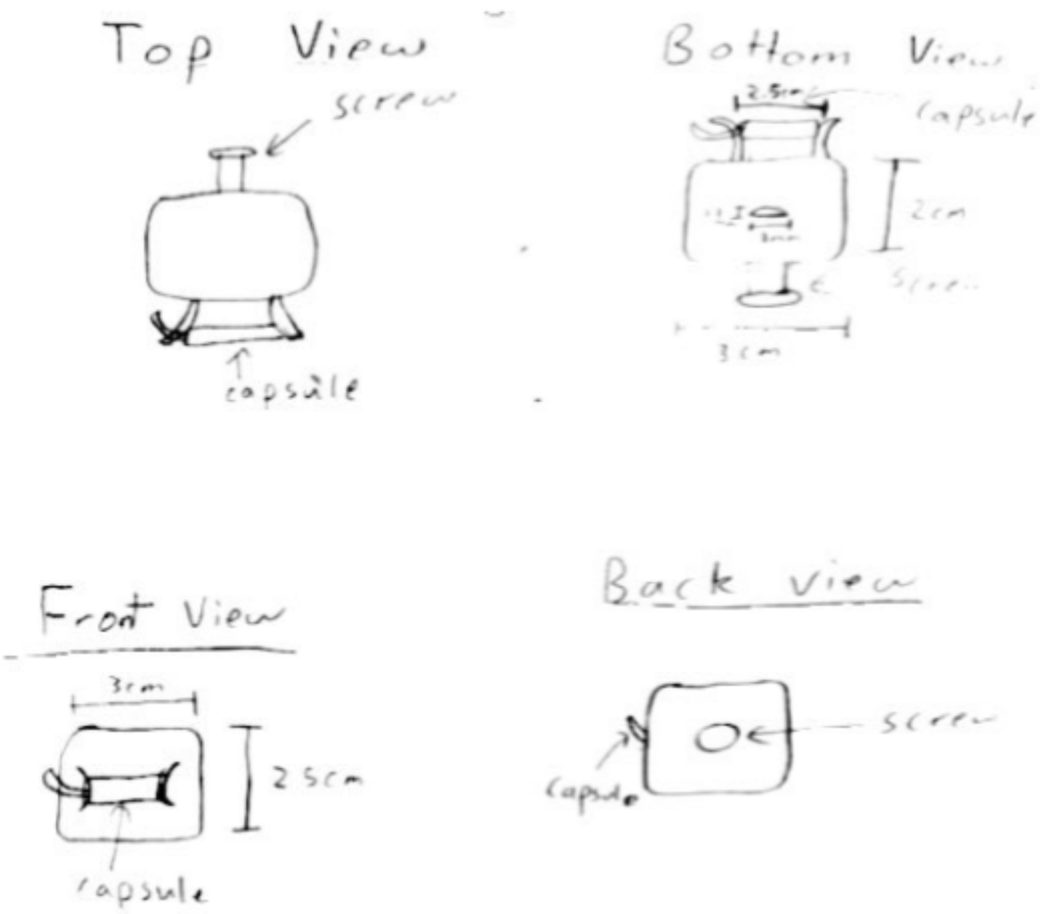


Figure 4: Attachment design

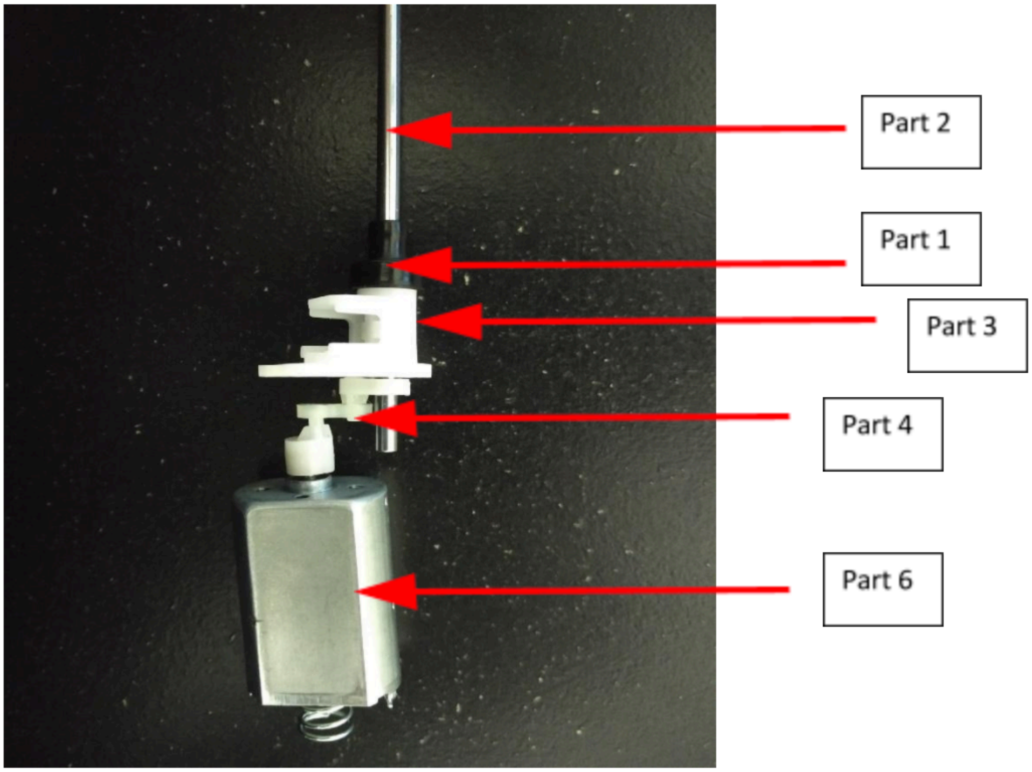


Figure 5: Assembly of Energy conversion

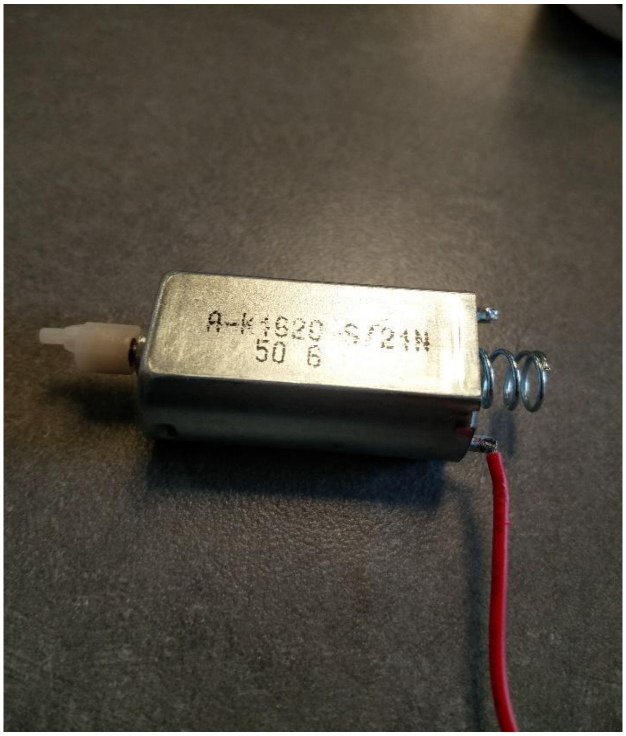
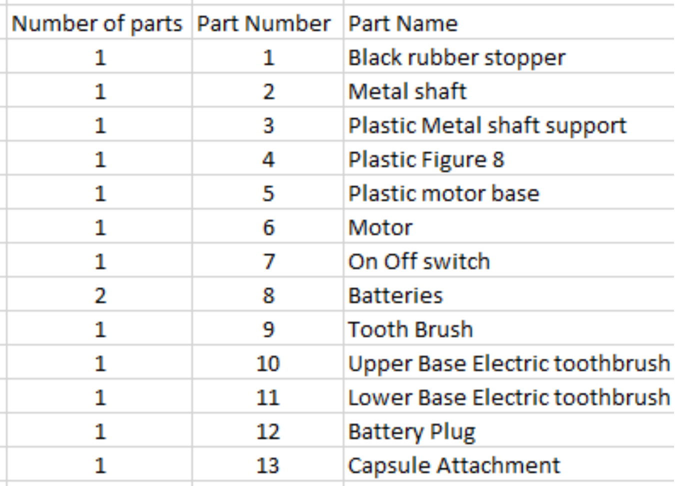


Figure 6: Motor

Figure 7: Metal Shaft

Figure 8: Part 4

Table 1: Bill of Materials



Number of parts	Part Number	Part Name
1	1	Black rubber stopper
1	2	Metal shaft
1	3	Plastic Metal shaft support
1	4	Plastic Figure 8
1	5	Plastic motor base
1	6	Motor
1	7	On Off switch
2	8	Batteries
1	9	Tooth Brush
1	10	Upper Base Electric toothbrush
1	11	Lower Base Electric toothbrush
1	12	Battery Plug
1	13	Capsule Attachment

Appendix D:

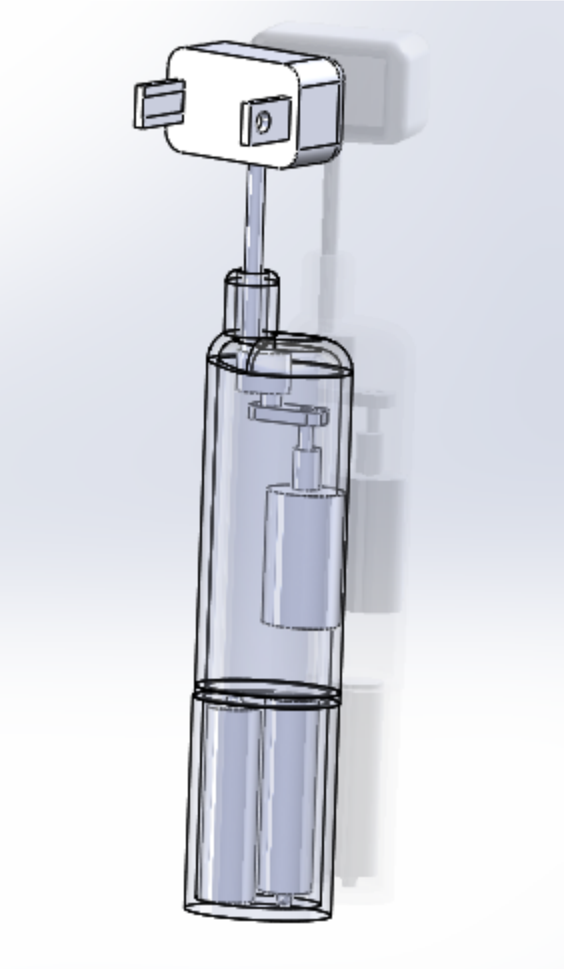


Figure 1: Toothbrush cad Design

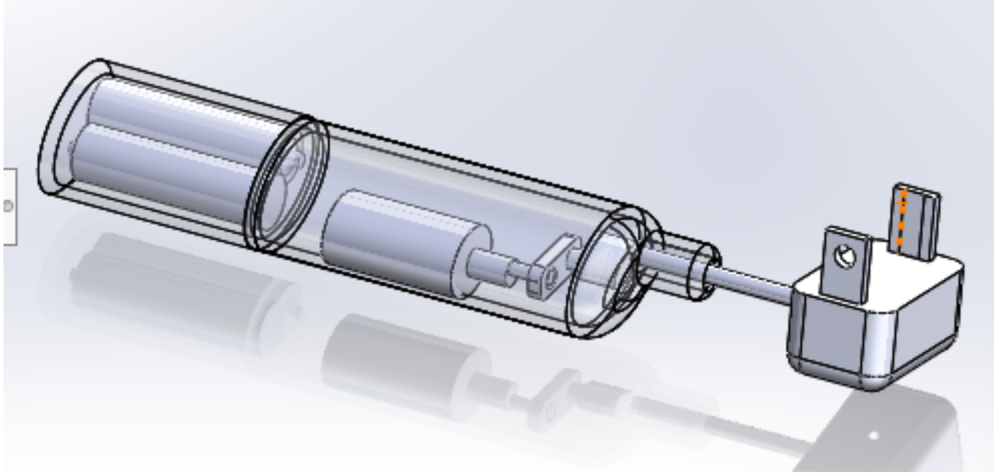


Figure2: Toothbrush cad Design (side view)

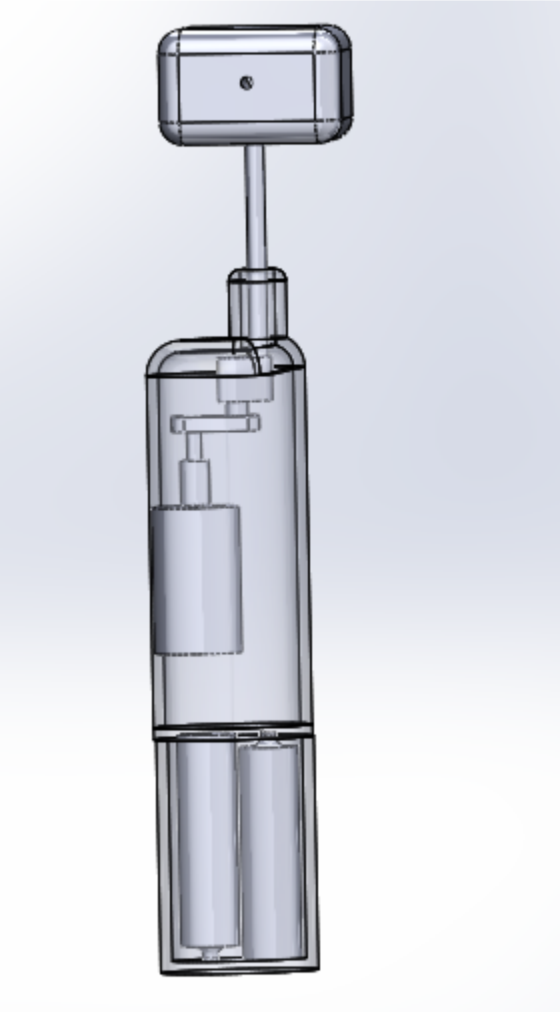


Figure 3: Toothbrush cad Design (Back view)

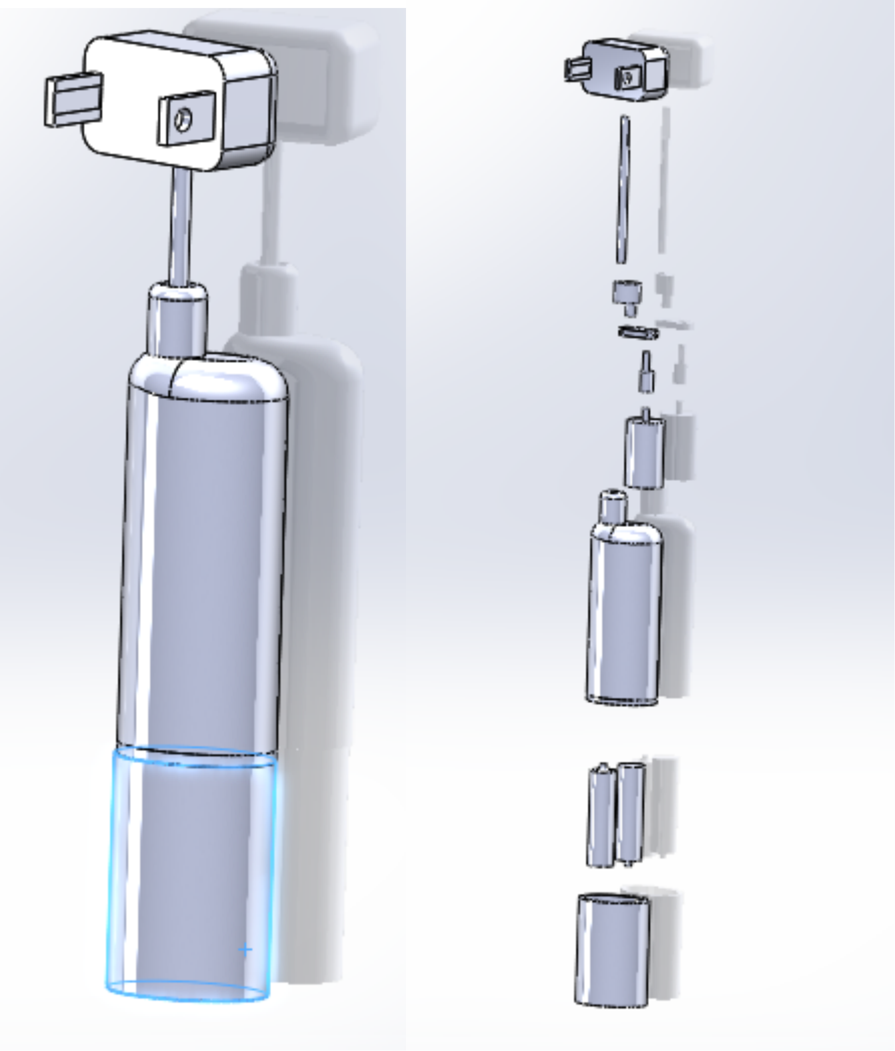


Figure 4: Cad design assembly

Figure 5: Prototype

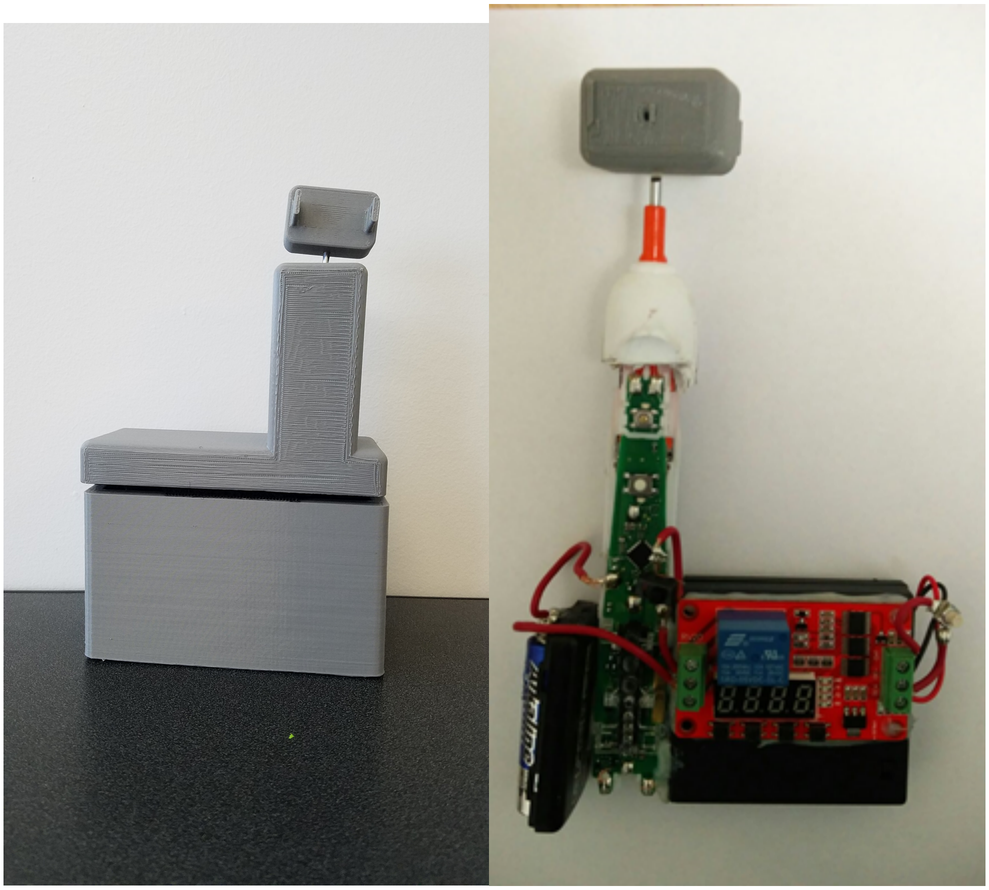


Figure 6: Final Device Assembly With and Without Case

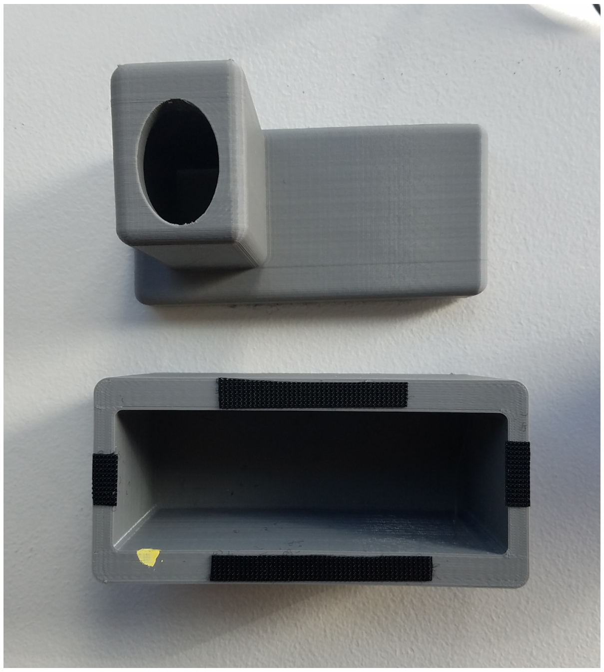
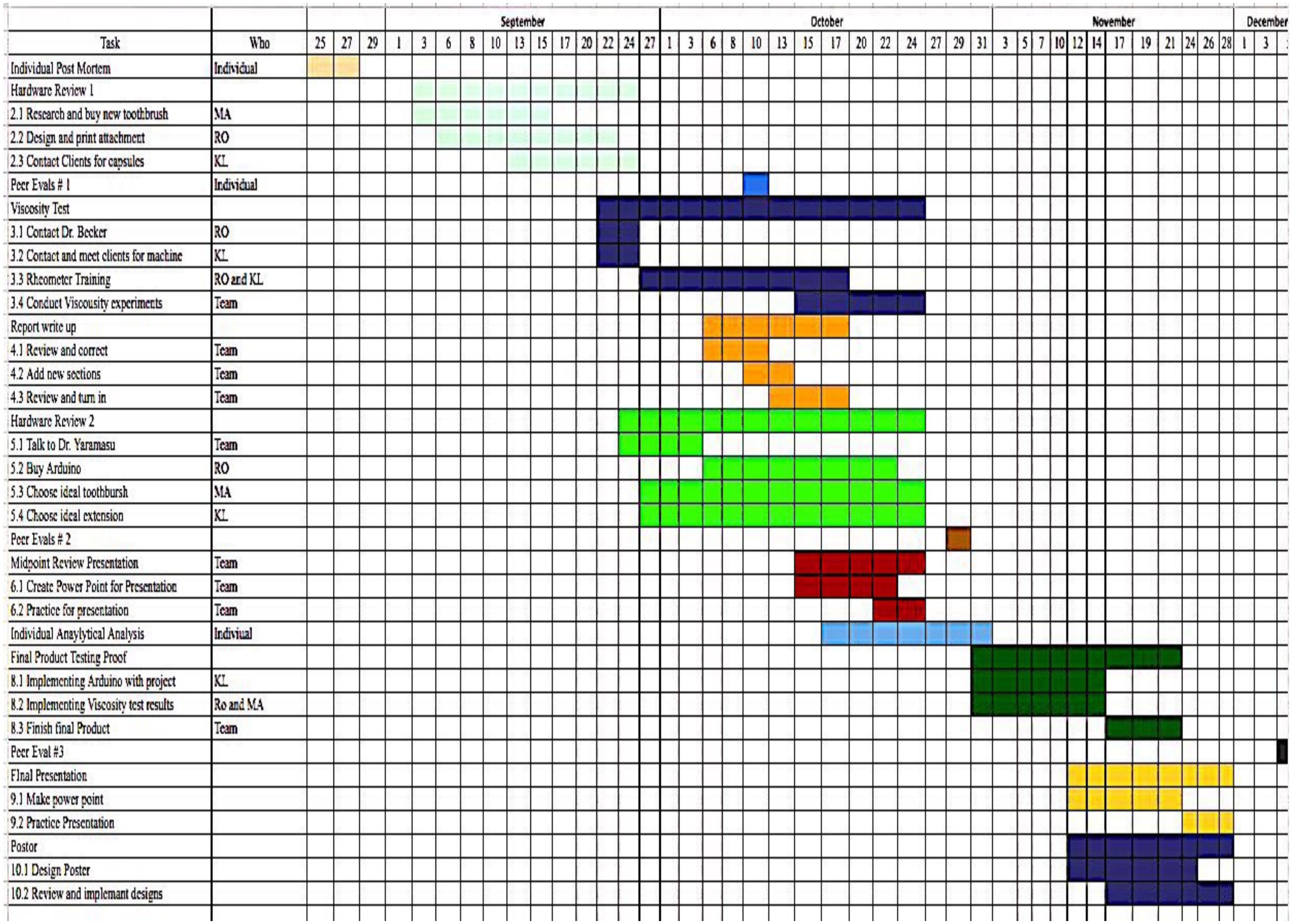


Figure 7: Base and Top Cover of 3D Printed Case

Appendix E: Fall 2017 Gantt Chart



					September											October														November												December		
Task	Who	25	27	29	1	3	6	8	10	13	15	17	20	22	24	27	1	3	6	8	10	13	15	17	20	22	24	27	29	31	3	5	7	10	12	14	17	19	21	24	26	28	1	3	
Individual Post Mortem	Individual	■	■																																											
Hardware Review 1					■	■	■	■	■	■	■	■	■	■																													
2.1 Research and buy new toothbrush	MA					■	■	■	■	■	■																																	
2.2 Design and print attachment	RO						■	■	■	■	■	■	■	■																														
2.3 Contact Clients for capsules	KL									■	■	■	■	■	■																													
Peer Evals # 1	Individual																				■																							
Viscosity Test														■	■	■	■	■	■	■	■	■	■	■	■	■	■																	
3.1 Contact Dr. Becker	RO													■	■																													
3.2 Contact and meet clients for machine	KL													■	■																													
3.3 Rheometer Training	RO and KL															■	■	■	■	■	■	■	■	■																				
3.4 Conduct Viscousity experiments	Team																						■	■	■	■	■																	
Report write up																			■	■	■	■	■	■																				
4.1 Review and correct	Team																		■	■	■																							
4.2 Add new sections	Team																				■	■																						
4.3 Review and turn in	Team																					■	■	■																				
Hardware Review 2															■	■	■	■	■	■	■	■	■	■	■	■	■																	
5.1 Talk to Dr. Yaramasu	Team														■	■	■	■																										
5.2 Buy Arduino	RO																		■	■	■	■	■	■	■	■																		
5.3 Choose ideal toothbursh	MA															■	■	■	■	■	■	■	■	■	■	■	■																	
5.4 Choose ideal extension	KL															■	■	■	■	■	■	■	■	■	■	■	■																	
Peer Evals # 2																													■															
Midpoint Review Presentation	Team																						■	■	■	■	■																	
6.1 Create Power Point for Presentation	Team																						■	■	■	■																		
6.2 Practice for presentation	Team																									■	■																	
Individual Anaylytical Analysis	Indiviual																							■	■	■	■	■	■	■														
Final Product Testing Proof																														■	■	■	■	■	■	■	■	■	■					
8.1 Implementing Arduino with project	KL																													■	■	■	■	■	■	■								
8.2 Implementing Viscosity test results	Ro and MA																													■	■	■	■	■	■	■								
8.3 Finish final Product	Team																																				■	■	■					
Peer Eval #3																																													■
FInal Presentation																																			■	■	■	■	■	■	■	■		
9.1 Make power point																																			■	■	■	■	■					
9.2 Practice Presentation																																								■	■	■		
Postor																																			■	■	■	■	■	■	■	■		
10.1 Design Poster																																			■	■	■	■	■	■				
10.2 Review and implemant designs																																					■	■	■	■	■	■		