EDSGN100H Design
Project #1
PROGRESS Report

ELECTRIC TOOTHBRUSH DESIGN

Introduction to
Engineering Design
EDGSN 100H

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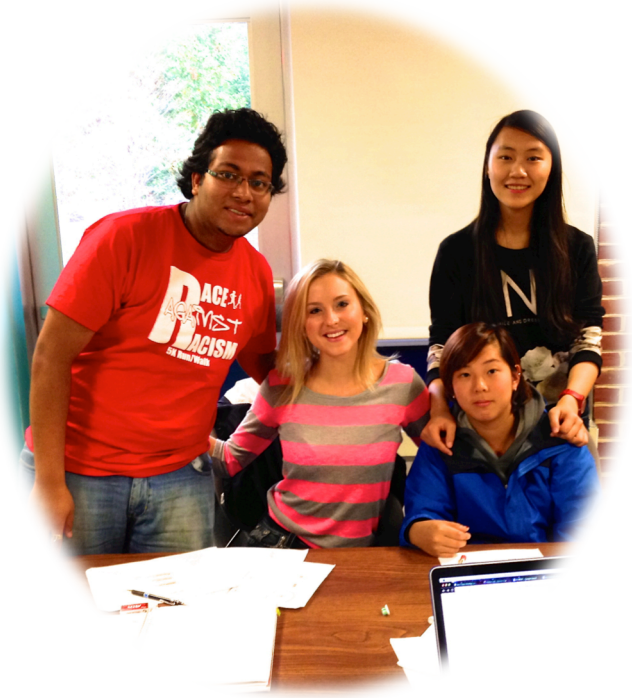
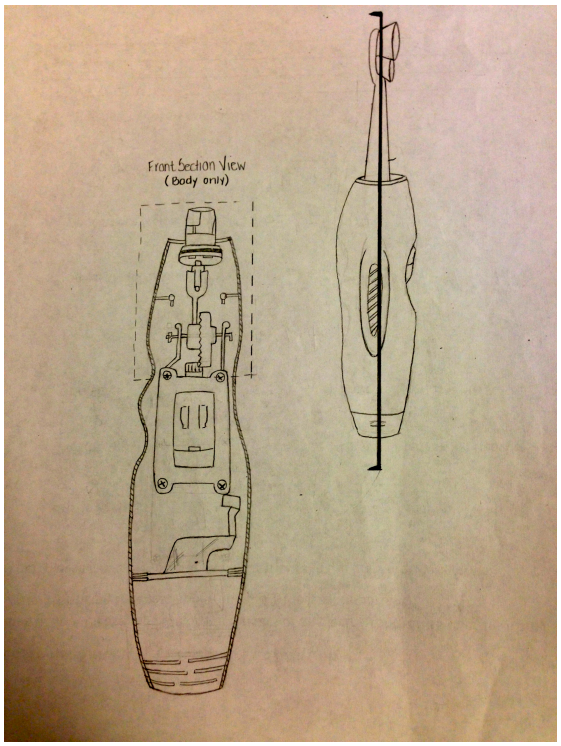


Submitted to:
Professor
Christopher Smith
Date:
10/20/2013

Executive Summary:



Our objective was to design a product that addresses our initial problem statement, while tending to our customer's needs. The product developed, an electrical toothbrush, was created through the use of the engineering design process consisting of multiple steps ranging from external research to sketching and dimensioning. Through external and internal research, we discovered new concepts such as angled bristles, tongue-scraping devices, and molded body designs. We implemented these findings in our concept generation, and then used Pugh charts to vote on a final concept to be prototyped. With the assistance of our House of Quality, we were able to come to a final concept selection, thus producing a final design. Our selected design was drawn out in isometric, frontal, backside, right, and left views. The inside functioning and mechanics of the toothbrush were explained in great detail. Finally, the drawings were then fully dimensioned, and a **section view** was created.

ELECTRIC TOOTHBRUSH

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1.0 Introduction

The electric toothbrush is a universal tool, which has been used worldwide by many different genders, ethnicities, and age groups since 1954. The toothbrush itself is crucial to maintaining good hygiene, and appropriate dental care. After exploring in depth the multitude of different electrical toothbrushes currently on the market, along with the needs of customers who purchase electrical toothbrushes, our team has concluded that changes can be made to perfect the quality of the product being sold. We were given an electrical toothbrush that is currently on the market, then analysed, dissected, and examined the product in order to gain insight regarding the electrical toothbrush components. We then were able to develop a product, which meet the requirements of the general public and customers who were surveyed. We accomplished this by changing and modifying aspects of the pre-existing toothbrush that we were given. The customers we surveyed aged from 17-40, and consisted of both genders. Our toothbrush was created to appeal to this age range, considering we based our model off of the requests from the customers.

In sections to follow, we will discuss the design process used to produce a successful prototype. First, we will examine the costumer needs. Then we will discuss certain external searches, which contributed to our design (such as websites, articles, and reviews.) We'll continue the procedure by addressing the concept generation process and our concept selection. Lastly, the detailed design will be presented! This will include pictures, diagrams, and materials to give the customer or company a better understanding of the product.

We began the design process by identifying the problem through the use of a problem statement. Next, we addressed the customer needs to determine how to "fix" the given problem.

1.1 Initial Problem Statement

Our task is to analyse the current offerings in the market and design an electric toothbrush that will better meet the needs of the targeted population.

2.0 Customer Needs Assessment

We began the researching process of the design project by conducting a survey that evaluated the opinions of 32 individuals regarding what they expected of an electrical toothbrush. Our participants aged from 17-40 years old, making them our targeted population for our particular toothbrush design. We asked the participants to rank the different qualities of a toothbrush using a scale of 1-7 (with 1 being the most important attribute). The qualities listed on the survey: bristle texture, weight, grip, cost, durability, appearance, and noise. The results of this survey were crucial to our design, because they allowed us to make a hierarchy of the customer's needs and demands regarding their toothbrush.

After analyzing the recorded data, we concluded that the bristle texture was the most important feature to customers. The findings of the data are listed as follows:

Toothbrush Attribute:	Number of Voters who ranked the Quality Number 1:	Percentage:
Bristle Texture	16	50.00%
Weight	0	0.00%
Grip	1	3.13%
Cost	7	21.88%
Durability	3	9.38%
Appearance	5	15.63%
Noise	0	0.00%

Since bristle texture seemed to be the most important quality based on the data, we had the same customers rank what type of bristle texture they would prefer. The options listed were soft, medium, and stiff. This would give us an idea regarding how delicate to make the bristles when creating our toothbrush. We then asked all of our customers to state whether they preferred rubber grippers, or a smooth plastic body. This is what we found:

Bristle texture	Number of Voters who preferred this quality	Percentage
Soft	8	25.00%
Medium	21	65.63%
Stiff	3	9.38%

Grip	Number of Voters who preferred this quality	Percentage
Rubber	30	93.75%
Smooth Plastic	2	6.25%

2.1 Hierarchy of Customer Needs

A hierarchy, or ranking, of the customer's needs is a significant component to the design process because it gives us (as the engineers) an understanding of what is most important to buyers. It also tells us what is less important and does not require as much emphasis. By viewing the multiple charts presented containing the survey results, the hierarchy of customer needs was established. The hierarchy is depicted below:

Ranking:	#1	#2	#3	#4	#5	#6	#6
Feature:	Bristle Texture	Cost	Appearance	Durability	Grip	Weight	Noise

By analysing the charts regarding the specific bristle textures, it is evident that customers prefer a medium stiffness. The hierarchy is as follows:

Ranking:	#1	#2	#3
Stiffness of Bristles:	Medium	Soft	Stiff

Finally, the hierarchy of the grip is simple:

Ranking:	#1	#2
Grip:	Rubber Grippers	Smooth Plastic Body

To conclude, the bristle texture was the most important component when considering the design of our electric toothbrush. Medium stiffness of bristles was the most popular choice, according to our survey data. Cost also held importance, as did appearance. In contrast, weight and noise did not seem to matter to customers nearly as much. Which means our focus steered towards the bristles of the toothbrush, its cost, and its appearance as opposed to its weight or noise level.

2.2 Revised Problem Statement

By conducting a costumer survey and analyzing the data presented, we were able to modify our initial problem statement to create a more specific problem statement. We decided to target people aged from 17 – 40 years old when making our specific toothbrush design. In order to meet the needs of our targeted costumer, we will design an electric toothbrush that focuses on the comfort level while brushing teeth, which includes the stiffness of bristles, the angle of the bristles, the shape and material of the toothbrush which makes it easy for costumer to hold and use, etc. We also are going to focus on the appearance of the toothbrush, including the color palette, size and shape of the toothbrush. A tongue scraper will be added to the toothbrush, to add variation and multipurpose to the electric toothbrush. All of these changes shall be made while keeping the cost of the toothbrush reasonable and affordable.

3.0 External Search

Continuing on with our design process, we conduced external searches that ultimately contributed to our concept generation. It is important to perform external searches when inventing a new product because it allows the team to gain outside information and further investigate other toothbrushes on the market. Through the use of patents, literature, lead users, experts, and benchmarking, our team was able to create a broader concept generation with various ideas and solutions to the initial problem. We began the external search process with literature review, consisting of several Internet articles and websites.

3.1 Literature Review

In order to build a high-functioning electric toothbrush that competes with other toothbrushes currently on the market, we realized a characteristic or design that other toothbrushes lacked was crucial. This would set our toothbrush apart from other electric toothbrushes on the market. We conducted online research that provided additional information regarding the tooth, and where the plaque is stored. These studies expanded our minds regarding how effectively toothbrushes clean, and how we can make the toothbrush clean even more efficiently. We found that:

“Dental plaque forms first in-between teeth and along the gumline, so it is important to focus on these areas during brushing by directing your toothbrush bristles toward your gums at a 45 degree angle just like you would with a manual toothbrush. You should be able to feel the bristles along your gumline.” (Frey, 2011, Para.7)

We can conclude by this statement that a toothbrush containing actual bristles angled 45 degrees would make it easier for the customer to rid their dental plaque, without having to awkwardly bend their wrist to achieve this goal. In order to build a better-functioning electric toothbrush, we decided to model our bristles in accordance with this new research study. Our next challenge was to choose which way the angle should go, which bristles should be angled, and what the bristles would ultimately look like. We designed three differently angled bristles, which were added to our concept selection process and further reviewed later in the design process.

Another concept that was brought up within our team discussion involved the tongue, and how tongue cleaners are now on the market. We considered adding a tongue scraper or cleaner to the toothbrush, making the electric toothbrush a two-in-one cleaner. (Cleaning the teeth, as well as the tongue.) In order to validate the need for a tongue cleaner, we conduced online research yet again. We found that:

“Tongue brushing, in contrast to tooth brushing, is really more of an option than a necessity. Brushing our teeth actually breaks up the plaque that forms in everyone's mouth, rather than removing germs. During the day, bacteria, which are always present, colonize the food particles that remain in your mouth after eating. The accumulation of food and bacteria produces plaque, which takes approximately twenty-four hours to form. Thorough brushing at least once a day keeps the bacteria from sticking — that's the key to healthy teeth. The main purpose for tongue brushing is to remove these same stuck food particles before they cause odor.” (Alice, 1999, Para. 2 & 3).

We were able to determine that the tongue brush eliminates odor and bad breath, while the toothbrush itself rids plaque. In order to maintain a clean and odorless mouth, we decided it was crucial to add a tongue brush to our toothbrush. Our next challenge involved where to place the tongue cleaner, what materials were needed to make the tongue cleaner, the shape of the tongue cleaner, and the cost of the addition. We developed different options and models for the tongue cleaner, and placed them in our concept generation. They were further reviewed and considered during concept selection.

Finally, we investigated the importance of color. It was necessary for us to gain insight on the topic of color, and what colors were popular in the world of the toothbrush. Our customer needs data suggested that appearance of the toothbrush was generally important to customers. Thus, we used external searches to discover what color appealed to users. According to a research poll found online conducted by Deal of The Day, the most popular toothbrush color was blue, followed by pink. We took this information into account during concept selection, and had our team member’s vote on different shades of blue and pink, along with other attractive and appropriate colors.

These external searches discovered through the use of the Internet were used to develop different models and designs of our electric toothbrush. These designs were then placed into a chart, which would generate our ultimate concept selection through the process of voting and compromising as a design team.

3.2 Patent Search

Our next step in the external search process involved researching patents that exists for other common toothbrush models. This step is crucial; it will allow our team to determine the key technologies used in the making and design of an electric toothbrush. A chart of the Art-Function Matrix for the Electric Toothbrush is depicted below, containing the patent numbers that were found through external research:

Table 4. Art-Function Matrix for Electric Toothbrush

ART / FUNCTION	Moving Bristle Head	Tongue Cleaner	Toothbrush Body	Electric Motor	body shape	Screw-on Battery lid
Brush Teeth	US 6000083 US 7225494					
Clean Tongue		US 8359693				
Cover Motor and inside			US 6178579 US 6932216 US 6189693 US 6178579			
Drive the Devices				US 20130221776 EP 2536980		
Comfort to hold					US 6360395	
Cover Battery						CN 203000270 EP 0427688

3.3 Benchmarking

Our third step in external searching involved investigating similar products, including a competing design team containing our fellow classmates (Design team 5). We then were able to compare these results to our personal customer needs, and attempt to meet our customer's needs while maintaining an affordable cost, and matching our competitors and what they have to offer. We then rated each product on a numeric five-point scale: 1- strongly disagree, 2- disagree, 3- neutral 4- agree, 5- strongly agree. The charts of our benchmarking data is listed as follows:

Table 5. Benchmarking of Products

Toothbrush	Avg. Noise Level (db.)	Oscillation Speed (Hz)	Cost (USD)
Design Team #5	70.9	85.61	7.99
Crest Spin Brush Pro (1)	81.9	99	8
Crest Spin Brush Pro (2)	79	56.85	8
Colgate Motion (1)	135	99	7.49
Colgate Motion (2)	78.5	18.4	7.49
Oral B Cross Action (1)	88.4	40.2	6.99
Oral B Cross Action (2)	35.8	39.4	6.99

Table 6: Rating the Products:

Toothbrush:	**Noise Level**	**Oscillation**	**Cost**	**Appearance**	**Easy to Hold**	**Weight**	**Clean Properly**
Design Team #5	4	4	3	X	X	X	X
Crest Spin Brush Pro (1)	3	4	3	4	4	2	4
Crest Spin Brush Pro (2)	3	3	3	2	2	2	3
Colgate Motion (1)	1	4	3	3	4	4	3
Colgate Motion (2)	3	1	3	3	5	4	4
Oral B Cross Action (1)	2	1	4	2	4	5	3
Oral B Cross Action (2)	5	1	4	5	3	5	4

The data for design team 5 in the last four columns was unable to be obtained considering their design had not been completed during the time of our benchmarking.

The oscillations for the Colgate Motion (2), and the Oral B toothbrushes were below average, leaving them with a score of 1. The Colgate Motion (1) had an absurd noise level, causing it to receive a score of 1 under this particular department. Our team strongly agreed with the appearance of the Oral B Cross Action (2), ranking the appearance a solid 5! Based on the rating of the competition, our team clearly is in a general agreement with Crest Spin Brush Pro (1), along with Colgate Motion (1).

3.4 Design Target

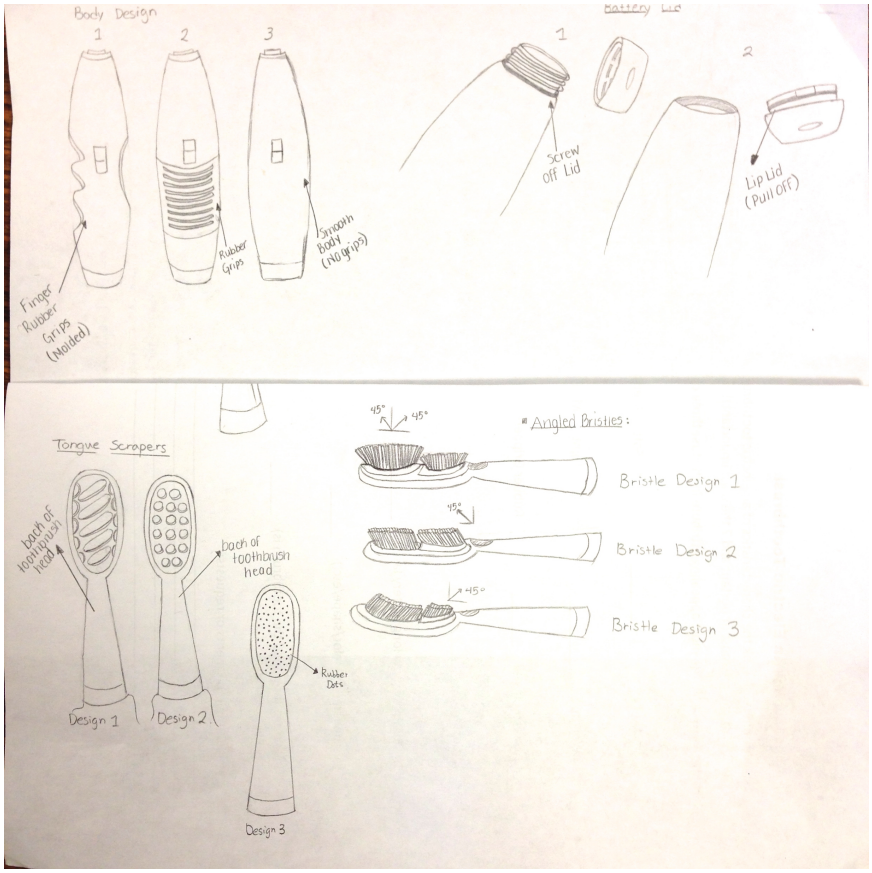
The external researching part of the design process gave us insight to what is currently on the market. It provided us with adequate information on our competition. It allowed our team to think outside of the box to generate possible solutions to the problem while exceeding the standards of our competitors. Thus, we were able to develop concepts for a design that will function above and beyond the normal standard. By using a Pugh Chart and voting system, we were able to finally come to a concept selection. This selection process would not have been possible without the use of our external searching, followed by our internal searching.

4.0 Internal Search

Our next step in the design process involved internal searching, consisting of brainstorming and mind mapping. During internal searching, all judgement had to be suspended in order to accomplish the development of multiple concepts and ideas. Criticizing, condemning, and complaining all had to be banned in order to productively work as a team. Our design team proved successful at internally searching, and produced a wide range of concepts and designs.

4.1 Concept Generation

Our concept generation included team brainstorming, discussion, research, and analysis. We used the technique of mind mapping to express our ideas to one another through the use of sketching.



Our team came up with three ideas for the body: the body with the shape that is modelled to fit the costumers hand (covered with rubber grips), the body only with rubber grippers, and the smooth body with no grips at all. Those three ideas were generated based on research and discussion within our team, along with analysing the survey data previously conducted.

Then, in order to enhance the convenience of the toothbrush lid to meet the needs of our costumers, we decided to make a few changes to the battery lid. All of our team members agreed that it is difficult to open the battery lid. We came out with two designs: a lip lid that has to be pulled off, and the screw off lid.

Moreover, by conducting external research, our team discovered that bristles with an angle clean the tooth more proficiently. Our team collectively decided that angled bristles were a must, however we faced the challenge regarding which way the angle should face. We brainstormed multiple possibilities. As a result, we came out with three concepts: the bristles angled to the right 45-degrees, angled bristles to the left 45-degrees, and bristles angled both to the right and left 45-degrees.

After externally researching ideas regarding the toothbrush, we came upon the concept of a tongue scraper to eliminate bad breath. We looked further into this idea, and unanimously decided to add a tongue-scraping device to our model of the electric toothbrush. We generated three different designs: a tongue scraper with extruded rubber of an oval shape, extruded rubber in large circles, and extruded rubber dots in a large quantity.

Finally, we addressed color in our concept generation process. Our survey told us that appearance was important to our costumer's, so we externally searched popular toothbrush colors. We also internally searched to generate ideas regarding what colors we personally favored. The colors we generated are as follows: Turquoise, Navy, Purple, Green, Grey, Royal Blue, and Pink.

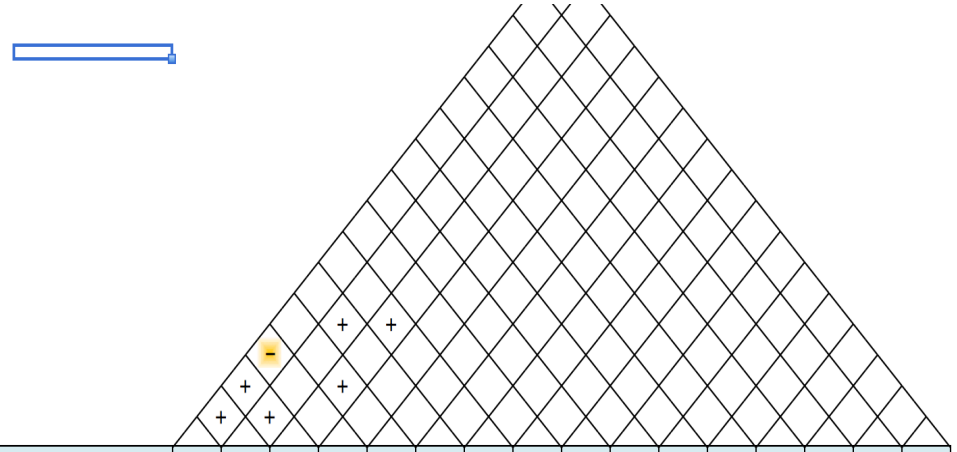
4.2 Concept Selection

Once the surveys, research and brainstorming were complete, our team was able to come to an ultimate concept selection. Through the use of Pugh charts, we were able to determine which features met the customer's needs most sufficiently. Pugh charts are designed to allow engineers to solve problems by evaluating, rating, and comparing different options and alternatives. Each of our team members rated each concept, and then a final concept was selected (based on a majority vote) for each feature on the toothbrush. We established our individual votes by analyzing the data obtained in a diagram we created known as the House of Quality. The House of Quality acted as an organization method for our team, to arrange our customer needs, functional requirements, our competitors (benchmarking data), etc. We used the information provided in this structure to cast votes on a final concept selection, thus producing the most practical and efficient toothbrush on the market for our particular customers!

Correlations	
Positive	+
Negative	−
No Correlation	

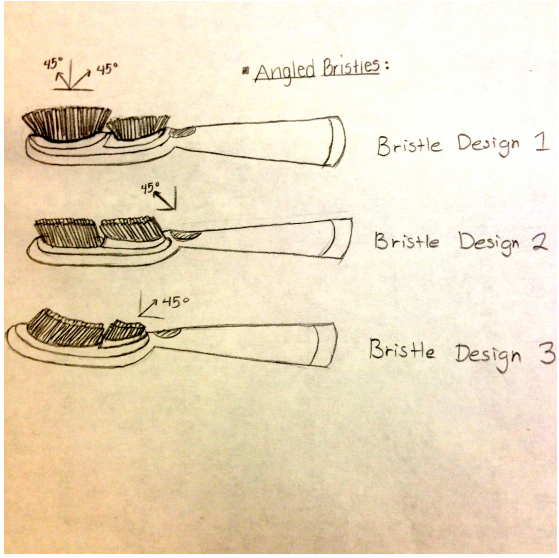
Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



Row #	Weight Chart	Relative Weight	Customer Importance	Maximum Relationship	Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Customer Competitive Assesment								
					Direction of Improvement	▲	▲	◇	▼	◇	◇	▲																		
					Functional Requirements / Customer Requirements (Explicit and Implicit)	Durability	Appearance	Economical.	Weight	Should be Soundproof	Grip	Bristle Texture										Our Product	Competitor # 1: Crest Spinbrush Pro	Competitor #2: Crest Spinbrush Pro 2	Competitor #3: Colgate Motion 1	Competitor #4; Colgate Motion 2	Competitior #5: Oral B Cross Action 1	Competitior #6 : Oral B Cross Action 2	Competitor #7: *Design Team 5*	Row #
1		10%	4	9	The toothbrush should work for a longer time.	●																4	4	4	4	4	5	5	4	1
2		22%	6	9	It should cost less.		○	●			○											4	3	3	4	4	5	5	4	2
3		12%	5	9	It should look good.	▽	●	○	▽	▽	●											5	4	2	3	3	2	5	3	3
4		3%	2	9	It makes a lot of noise					●												3	3	3	1	4	3	5	x	4
5		2%	3	9	Easy to hold						●											5	3	2	4	5	4	3	x	5
6		51%	7	9	Clean Properly							●										4	4	3	3	4	3	4	x	6
7		1%	1	9	It is very Heavy				●													3	2	2	4	4	5	5	x	7

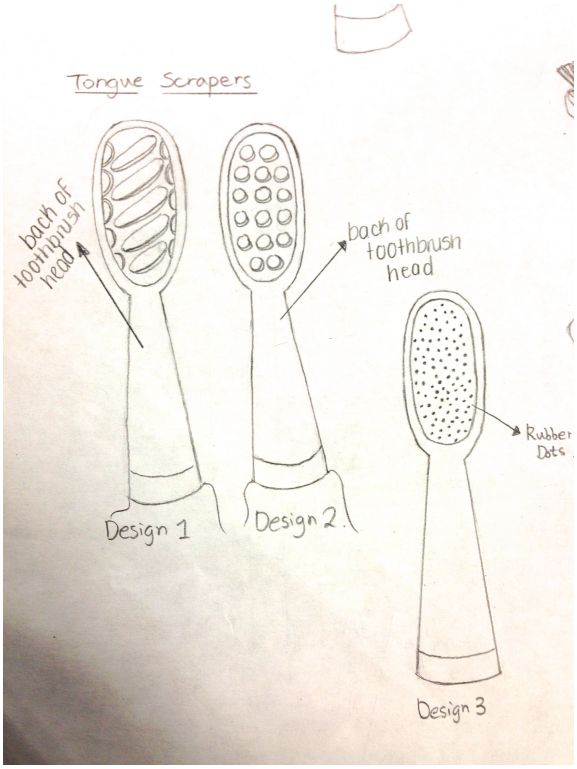
Bristle Texture: Angled Designs



Team Member	Design 1:	Design 2:	Design 3:
Hahyoung	X		
Liana	X		
Sisi	X		
Akshat	X		

Clearly, the team unanimously voted for design one, which depicts the bristles as being angled in both directions with a 45-degree angle. This design includes bristles that can clean all areas of the tooth, reaching angles on both the right and left side of the tooth. This design proves to be the most efficient.

Tongue Scraper Designs

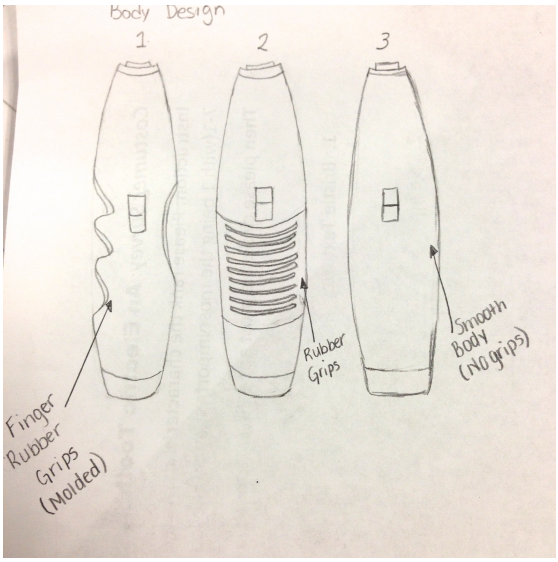


Team Member	Design 1	Design 2	Design 3
Hahyoung			X
Liana			X
Sisi			X
Akshat			X

Our team collectively agreed on design concept number three, which shows the tongue scraper as tiny rubber dots which are extruded from the back of the toothbrush head. We believed that this model would clean the tongue most efficiently, and be the less expensive way to add a tongue cleaner to our electric toothbrush.

When analysing the effectiveness of a tongue cleaner, we related it to a general cleaning device: a scrubbing brush. When using a scrubbing brush, if you have larger bristles in a fewer quantity far apart, it will not clean as well compared to a brush with multiple tiny bristles, closer together. We brought this analogy into our tongue scraper device, believing that smaller rubber dots closer together would be more efficient as opposed to design 2 (larger rubber dots further apart.)

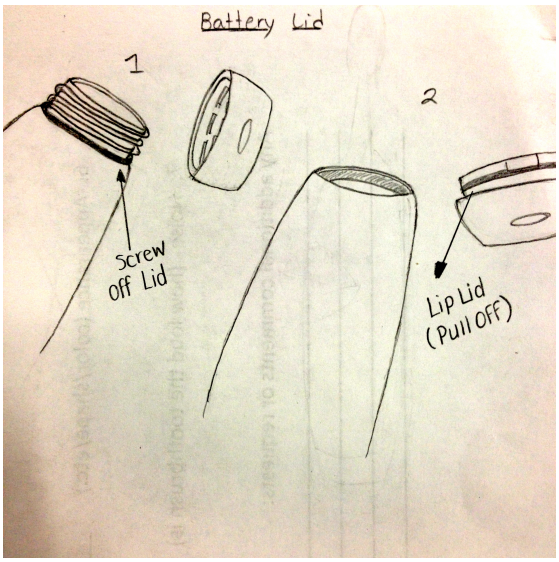
Toothbrush Body Designs



Team Member	Design 1	Design 2	Design 3
Hahyoung	X		
Liana	X		
Sisi	X		
Akshat	X		

Our team unanimously agreed on design concept one, which depicts the body as being moulded to fit the customer's hand. This allows for comfort and stability when holding the toothbrush. The mould also contains rubber grippers to avoid slippage and dropping of the toothbrush while in use.

Battery Cover Designs



Team Member	Design 1	Design 2
Hahyoung	X	
Liana	X	
Sisi	X	
Akshat		X

In regards to the lid of the battery cover, ¾ of our team voted in favour of the screw off lid. The three members that preferred this design believed that the screw off lid would be most efficient because it would be easiest to remove. The model of the Spinbrush that we dissected earlier in the design process had a lid with a lip (design 2) and the lid was extremely hard to remove. This is why we ultimately chose design 1, containing a screw off lid, in hopes that the customer could remove the lid with less effort and more ease. Akshat, on the contrary, wished to stick to the lip lid because he believed that the lid was not a problem to remove considering the lid is hardly ever removed and the batteries are not changed often enough to be of concern. After much discussion, we persuaded Akshat into considering the first design. He agreed, and we selected design one (containing the screw off battery cover.)

Color Selection:

Team Member:	Turquoise	Navy	Purple	Green	Grey	Royal Blue	Pink
Hahyoung	X	X		X			
Liana	X	X					X
Sisi	X	X	X				
Akshat	X				X	X	

As a team, we collectively decided to choose three different colors for our toothbrush model. We plan on producing our toothbrush design in three various colors for our range of customers. Each member of our team voted on three colors, as depicted above in the Pugh chart. Clearly, turquoise proved to be the favourite option regarding color. Navy also contained a majority vote, with ¾ of our team members agreeing on navy as a color for our toothbrush.

The third color for our toothbrush was hard to determine based on the Pugh Chart, considering each member chose a different third color. In order to solve this problem, we created a second Pugh Chart regarding color selection. This time, each member chose two colors. The chart is as follows:

Team Member:	Green	Grey	Royal Blue	Pink
Hahyoung	X	X		
Liana		X		X
Sisi	X			X
Akshat		X	X	

Based on the results attained from the second Pugh Chart, we chose grey as our third and final color for our toothbrush design.

In conclusion, our team used various methods to come to a concept selection that we all agreed on. Through the use of our House of Quality, sketches, and verbal persuasions, we were able to create a final prototype of the design of our choosing.

4.3 Prototyping and Design Reviews

For our prototype we decided to create sketches to communicate our ideas. We combined our concept selections into one final prototype consisting of the favorited features under each category (lid, color, bristles, tongue scraper, etc.) This prototype was dimensioned, perfected, and reviewed, ultimately becoming our final design!

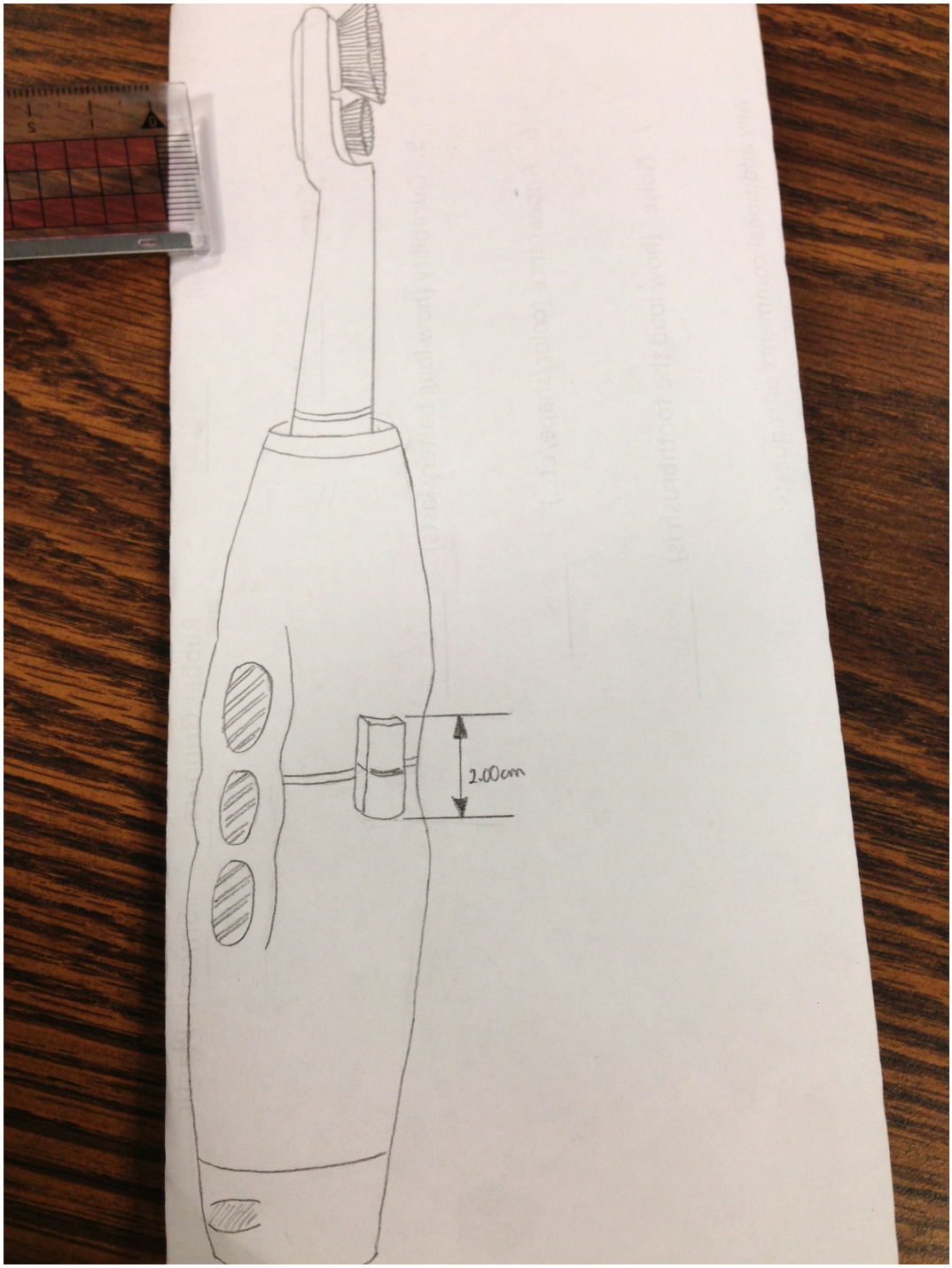
5.0 Final Design

We combined our 45-degree angled bristles (in all directions), our dotted rubber tongue scraper, our molded rubber-gripped body, and our screw off battery cover into a final toothbrush design. We then chose to create the design in three separate color schemes: turquoise, navy, and

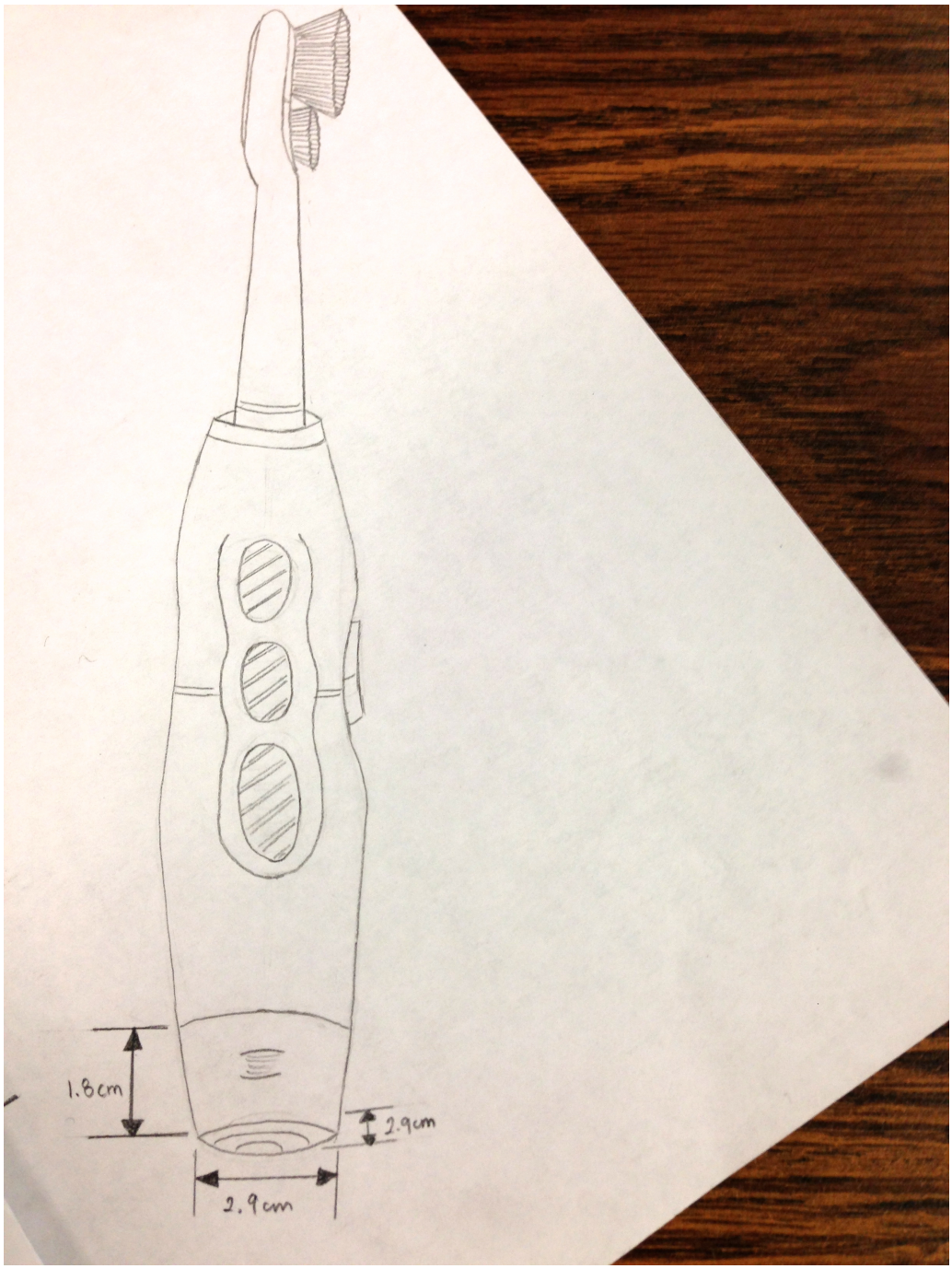
grey. We plan on producing three separate toothbrushes of the same model, just in different colors. The model that is used in all three colors is depicted below.

5.1 Design Drawings:

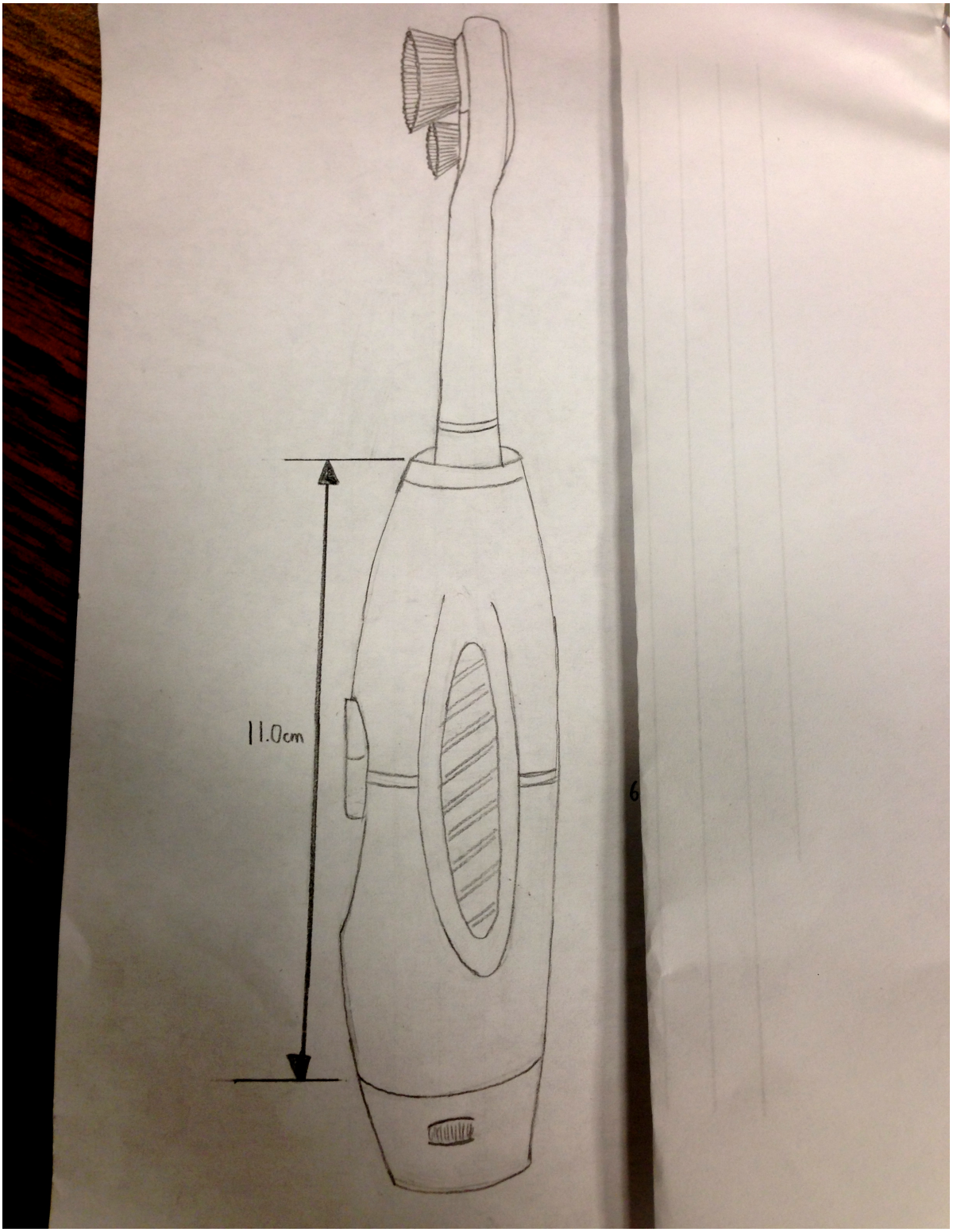
Isometric View:



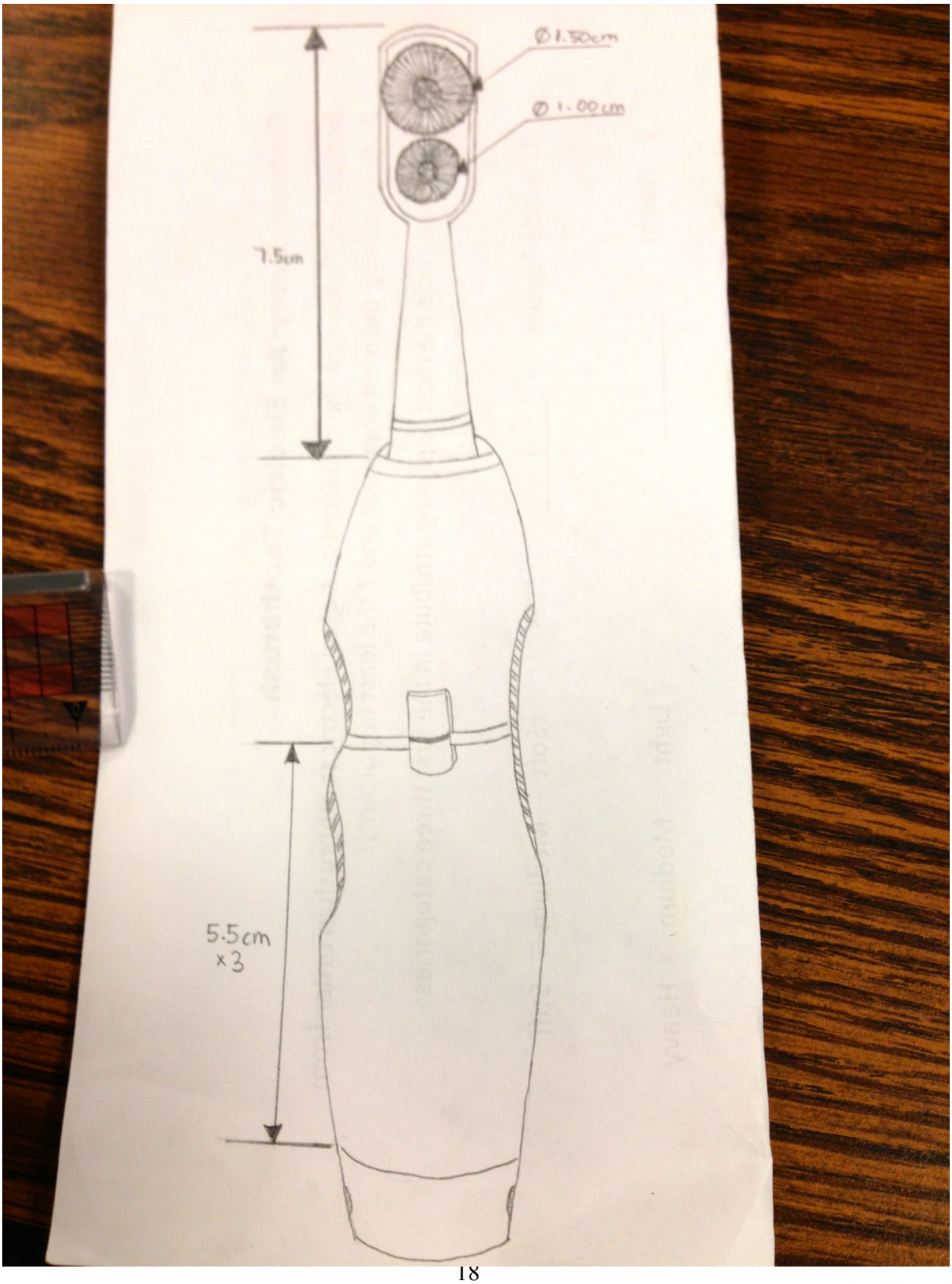
Left Side View



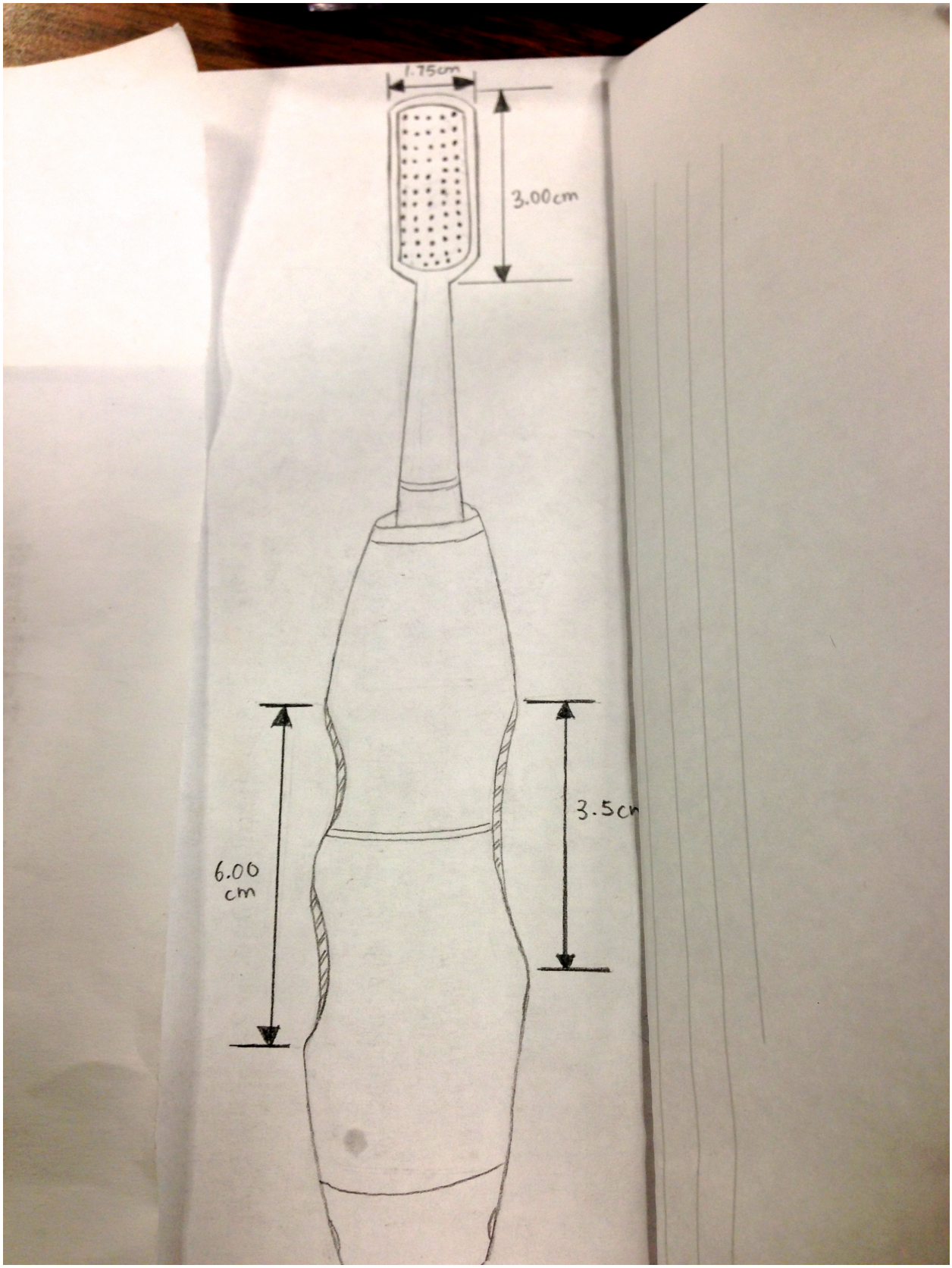
Right Side View



Front View:



Back View:



5.2 Bill of materials used in our model:

Part Number	Part Name	Qty	Function	Mass (oz.)	Material	Dimensions	Cost
1	**Brush Head** **(Including angled bristles)**	**1**	Cleans Teeth	.224	Plastic, containing bristles. Spring inside of the brush head.	1.5 cm in diameter (top) 1 cm in diameter (bottom) 7.5 cm in length	**$0.55**
2	**Battery Cover (twist off)**	**1**	Holds batteries securely	.384	Plastic and rubber. Springs located inside to hold the batteries.	4 cm in length 2.9 cm in width 1.8 cm in height	**$0.30**
3	**Back Cover of the Body (including rubber grippers)**	**1**	Acts as the handle or body (so the user can hold it)	.416	Plastic and Rubber (Rubber grippers)	11 cm in length 1.6 cm in width 0.8 cm in height	**$0.30**
4	**Front Cover of the Body (including rubber grippers)**	**1**	Acts as the handle or body (so the user can hold it)	.512	Plastic and Rubber (Rubber Grippers)	11 cm in length 1.6 cm in width 0.8 cm in height	**$0.30**
5	**Motor and Motor Holder**	**1**	Allows the toothbrush to run efficiently	.608	Metal	1.9 cm in length 1.7 cm in width 3.4 cm in length	**$1.20**
6	**Batteries**	**2**	Needed for the toothbrush to turn on	.81	Metal	0.51 cm in length 0.13 cm in diameter	**$0.50**
7	**Nuts, Bolts, Washers,**	**4**	Needed to hold the motor in place (to the body)	.02	Metal	0.025 cm	**$0.15**

5.3 How does it work?

Our team collectively decided to keep the same inside functions as the Spinbrush in which we previously dissected. We did not try to change the mechanism of how our electrical toothbrush works because this is one of the best concepts we can use, and it is a hybrid of two common mechanisms i.e. slide crank mechanism and the plastic crown wheel and pinion gear mechanism. The mechanisms of our electrical toothbrush are as follows:

In **Part A**, a winding pinion and a crown wheel are placed next to each other, pinion in a horizontal fashion and the wheel in a vertical way.

When the circuit is complete the pinion starts rotating due to the working of the motor. As the pinion starts to rotate horizontally, the crown wheel also starts rotating vertically.

Part B

The rotating crown wheel is attached to a slider crank which converts this rotatory motion to oscillatory motion. The slider crank is further connected to a slider link which oscillates due to the oscillatory motion.

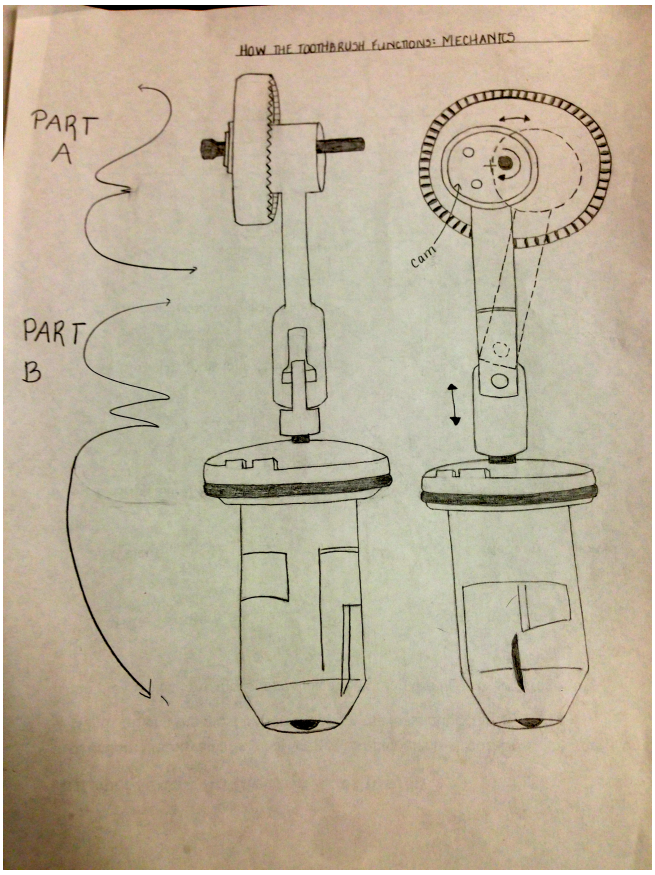
Part C

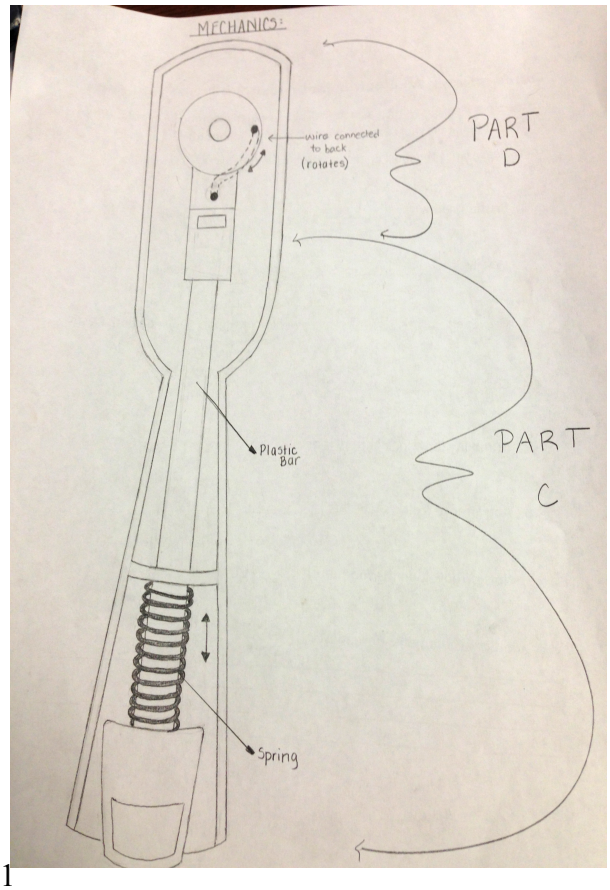
The oscillating slider link is internally connected to the lower brush head which also oscillates and does the function of cleaning the teeth.

Part D

The lower brush head is connected to the side of the top circular brush head with a thin and strong metallic wire. Due to this, when the lower brush head is oscillating the top circular brush head moves in a semicircular motion and performing the function of cleaning.

Photographs of the Mechanisms are as follows:





6.0 Conclusions

As a team, we analyzed the current offerings on the market and designed an electric toothbrush that would sufficiently meet our customer's needs for our targeted population ranging from 17-40 years old. We dissected a current model of an electric toothbrush, the Spin Brush, and improved the current design to match the criteria required by our customers. Through the design process, we were able to complete this assignment and solve our initial problem statement to the best of our ability; coming to a final design. We learned leadership, teamwork, and collaboration, while also becoming familiar with the design process through this assignment.

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