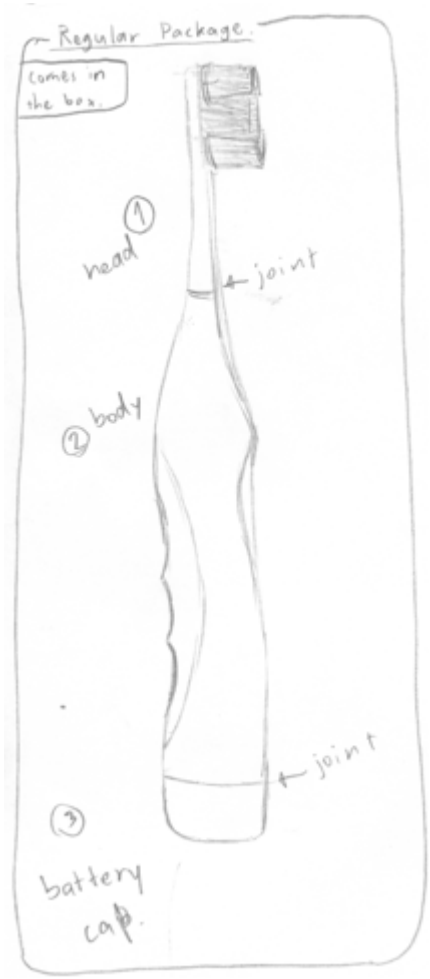
EDSGN100
Design Project #1
Redesign A Toothbrush

Design Team 3
Fang Shu - fis5096@psu.edu
Haavard Andersen - hha5045@psu.edu
Pranay Megchiani - pmm5346@psu.edu
Worawich Chaiyakunapruk - wqc5138@psu.edu

Submitted to: Prof. Christopher Smith
Date: 10/20/2013



Executive Summary

The group faced a challenge of designing an electric toothbrush superior to a given model toothbrush, and one that meets the needs of people of all ages. Through a detailed research and concept generation processes, several concepts were created that provided a basis of our final design. A final toothbrush was designed to include features that provide effective dental care, and address all listed customer needs to meet our goal.

Table of Contents

1.0 Introduction 3
1.1 Initial Problem Statement 3
2.0 Customer Needs Assessment 3
2.1 Hierarchy of Customer Needs 4
2.2 Revised Problem Statement 5
3.0 External Search 5
3.1 Literature Review 5
3.2 Patent Search 6
3.3 Benchmarking 7
3.4 Design Target 8
4.0 Internal Search 8
4.1 Concept Generation 8
4.2 Concept Selection 10
5.0 Final Design 12
5.1 Design Drawings and Parts List 12
Figure 2: 12
Figure 3: 13
Figure 4: 14
Figure 5: 14
5.2 Bill of materials 15
6.0 Conclusion 16
References: 17
Appendix 18
A: Custom Survey Questions 18
B: Concept Designs 18

1.0 Introduction

The task at hand is to redesign an electric toothbrush, a product that some see as a necessity in daily life. Given a sample Oral-B electric toothbrush, we are to build upon it and design an improved device that meets the needs of the end users. The problem is tackled using devices such as a RPM meters and sound meters. Access to such technology helps proceed through the design process, in which external research, benchmarking, concept generation, and prototype designs are all used to design a final product and solution.

1.1 Initial Problem Statement

Manual toothbrushes have been found to clean their teeth with 80% less effectiveness than those who use electric toothbrushes (Cosmic Smile, 2011). Therefore electric toothbrushes should be used to provide a more consistent and thorough cleaning of the mouth and gums. However, not all customers choose to use electric toothbrushes, and carry on with inefficient oral care. This is because the available products may not meet the needs of most customers, hence why they choose to revert to manual toothbrushes. This causes us to design an improved electric toothbrush that caters to a greater audience (of all ages) by using the designs of current products as a foundation.

2.0 Customer Needs Assessment

The initial problem requires the product to meet the general customer needs. To solve this problem, the first step is to assess the general customer needs of our target audience. This is accomplished by using a custom survey (See Appendix A), which is dispersed via email and social networking sites. Three questions are included in the survey, two of which request written answers, where as one question is a multiple-select, multiple choice question that asks the respondent to select important features in a descending order of importance. The participants are teenagers, adults and all those who regularly use social media networks from around the world. Data gathered through this method culminated in a set of customer needs that were interpreted through the respondents' responses.

Table 1:

Initial Customer Needs
The toothbrush is durable
The toothbrush can reach all areas of the teeth.
The toothbrush is long lasting.
The toothbrush head assists the user in cleaning his or her teeth.
The toothbrush can also clean the user's tongue.
The toothbrush is easy to use.
The toothbrush is portable

2.1 Hierarchy of Customer Needs

Once interpreted from the survey results, the customer's needs are then placed in order of descending importance to the customer. This step is of great importance, as it guides the rest of the create process by giving certain features a certain priority within the final design. This therefore gives the group a more focused mindset on the designs of the product by providing important design specifications. The hierarchy is based off the popularity of each response from question 1 of the survey (See Appendix A); therefore the feature that was mostly commonly selected, was recognized as the most important customer need.

Table 2: Hierarchy of Customer Needs

Level of Importance	Customer Need
1	The toothbrush is easy to use.
2	The toothbrush can reach all areas of the teeth.
3	The toothbrush head assists the user in cleaning his or her teeth.
4	The toothbrush is long lasting.
5	The toothbrush is durable
6	The toothbrush is portable
7	The toothbrush can also clean the user's tongue.

2.2 Revised Problem Statement

Given the hierarchy of customer needs, it is easier to create a problem statement that allows the group to recognize and respond to a more concise and focused problem:

Manual toothbrushes have been found to clean their teeth with 80% less effectiveness than those who use electric toothbrushes (Cosmic Smile, 2011). Therefore electric toothbrushes should be used to provide a more consistent and thorough cleaning of the mouth and gums. However, not all customers choose to use electric toothbrushes, and carry on with inefficient oral care. This is because the available products do not have an easy method of operation, and fail to reach all areas of the mouth, and clean the surface of the tongue. Furthermore, the product should also have a durable body in order to extend the product's life. Due to such needs not being met, customers choose to revert to manual toothbrushes. This causes us to design an improved electric toothbrush that caters to a greater audience (of all ages) by using the designs of current products as a foundation.

3.0 External Search

3.1 Literature Review

The electric toothbrush is clearly not a new invention, as it was invented by Philippe Woog in 1954. Therefore there would be little purpose in completely reinventing the electric toothbrush, as analysing current technologies would provide a better foundation for designing an improved product. One such technology is the "double head" electric toothbrush (USD $65), which helps the user brush the front and back of a tooth at the same time (Cosmetics & Toiletries & Household Products

Marketing News in Japan 25.2, 2004). This is an especially effective feature, as some users may not brush all sides and areas of the teeth with maximum effectiveness. Another fascinating feature is the ultrasonic brush head. This brush head vibrates at 1.6MHz to extract food particles and plaque from the teeth, and massage gums (Cosmetics & Toiletries & Household Products Marketing News in Japan 26.10, 2004). While this may be a more consistent and reliable method to ensure complete cleansing, it does cost USD $170, which is beyond what most customers would spend on a toothbrush. Another innovative concept that was generated in the past is Gillette's "triple brushing mode", which uses multiple rows of bristles for deep penetration of the gaps between the teeth (Cosmetics & Toiletries & Household Products Marketing News in Japan 26.12, 2004). This assists the user in removing plaque, and in cleaning the surface of the tongue. As seen within the survey, this concept thoroughly meets the requirements of our customers. The last noteworthy concept that the group came across was the "double movement head", which uses bristles that rotate and move back and forth. The use of individual sets of bristles allows one set to remove food particles and plaque from between the teeth, while the second set cleans the gums (Cosmetics & Toiletries & Household Products Marketing News in Japan 25.7, 2004). This design, allows the user to brush all the teeth and gums with optimal results at an attractive price of USD $14. Overall, the mentioned technologies all use innovative techniques to provide thorough cleansing devices, which is the primary purpose of a toothbrush and a need of our customers.

3.2 Patent Search

Prior to producing designs, a patent search of electric toothbrush components is conducted to recognize registered works and prevent any breaches of copyright infringement policies.

Table 3: Art-Function Matrix for Electric Toothbrushes

Function	**Article**			
	Electric Toothbrush Head	**Oscillatory System**	**Motor Unit**	**Toothbrush Handle**
To Rotate and Brush Teeth	US 689698			
To rotate the bristles		US 8525373 B2		
To provide kinetic energy to the oscillatory system			US 8558430	
To allow the user to hold the device during operation				US 8549691 B2

3.3 Benchmarking

Four different products are benchmarked to the same criteria in order to compare designs and quality of current products.

Table 4: Benchmarking of 4 Products

Feature	Oral-B PULSAR	Crest Spinbrush	Colgate	Sonicare
Packaging	Pre-etched cardboard backside allows easy opening, oversized.	Multilingual instructions: English, Spanish and French, flashy front side with transparent plastic cover, highly detailed instructions and warning included.	Not recyclable, easy to open, display of brush and tongue cleaner, brand and name is obvious, clearly shown what batteries are needed but not that they are included.	Packaging was easily opened, very organized, all pieces were displayed well and did not scatter upon opening. The description on the back was detailed and informative.
Aesthetics	White, mazarine and light blue base with a green, yellow, blue and white brush.	Attracts target market (children-boys), colorful and has the design of on the "The Avengers: Captain America" on the package and the toothbrush itself.	Looks bad and no color; boring.	Simple colors most white and blue, does not include a creative color scheme. Generic color scheme and product design.
Ease to clean	Easy to clean, the flexibility features allow access to the rear of the brush.	One piece, fairly easy to clean (on/off switch can get toothpaste stuck under it)	Simple cleaning because brush is easily detachable. Instructions on cleaning hard to find.	The brush is easy to clean because it is flat and has no holes or grooves. Although in the intersection of the two connecting parts the creases could easily get toothpaste on and in them, which could be difficult to clean.
Convenience of on/off switch	Simple, easy to use, very handy.	Too big even though it attracts kids' attention; it bumps with the hands during its usage	Turning on is easy, turning off is slightly harder	The switch requires a firm amount of force to turn the power on. It may be very helpful to reduce the force needed, or to change the power button to a switch. It is a blue rubbery button.

3.4 Design Target

The external research has exposed several innovative and effective features that exist in today's electric toothbrush market. Features such as double-heads, ultrasonic heads, triple brush heads, and double movement heads have all been concocted to improve the effectiveness of cleaning one's mouth, and providing excellent oral care. However, some of these features cause the respective toothbrushes to be priced well beyond the reach of most customers, and therefore cannot all be included in the final design. Furthermore, the benchmarking has simply reconfirmed that current products today are not all simple to use, as some have switches that need "force" to function. This is simply not convenient for children and the elderly, who may find great difficulty in operating such a necessary item. This research has therefore given the group a greater understanding of the capabilities of current toothbrushes, while also recognizing the reality of including such innovative concepts in the designs.

4.0 Internal Search

4.1 Concept Generation

Concept #1 (See Appendix B) is an electric toothbrush which builds on a sturdy design with replaceable batteries and bristle-heads to ensure that it lasts long without having to replace the main body. It features functions such as a hinge battery cap, which allows for easy replacement of batteries, no risk of losing the cap, and is opened simply with a pinch of the rear sided lever. There is a single on off button, which upon pressing it, goes in and stays, turns on the toothbrush motor, something that stays on until the second press which allows the button to completely protract. The main bristle-heads has 4 rows and three columns, where every other row respectively moves horizontally and vertically. Replacement heads include circularly rotating heads, but can potentially be used for any number of designs with the same adapting socket.

Concept #2 (See Appendix B) is an agile electrical toothbrush with a long neck to allow reach in far areas of the oral cavity. High friction rubber base allows for a solid grip that grants the user maneuverability at all times. The battery screw cap lets the user replace batteries making it flush mounted for increased comfort. Rounded front edges avoid damage to the gums. The on/off button simply snaps between two positions, one that cuts the circuit and one that opens it. The circular brush rotates while the square brush oscillates vertically to remove plaque and bacteria from different angles. The oscillating parts are sealed to the brush head with a small rubber seal, loose enough to not harm the actual oscillation, but tight enough to stop fluids from entering the brush capsule. This keeps the brush hygienic.

Concept #3 (See Appendix B) is a toothbrush optimized for cleaning the entire oral cavity. It does this through two main features. When brushing your teeth with the inner bristle, the outer bristle brushes the gum, a very important part of brushing your teeth according to the ADA. The size also naturally lets the toothbrush serve as an effective tongue cleaner. The inner bristle rotates while the outer bristle oscillates

vertically. This brush also has a replaceable head, primarily intended for replacements that allow full access at hard to reach places.

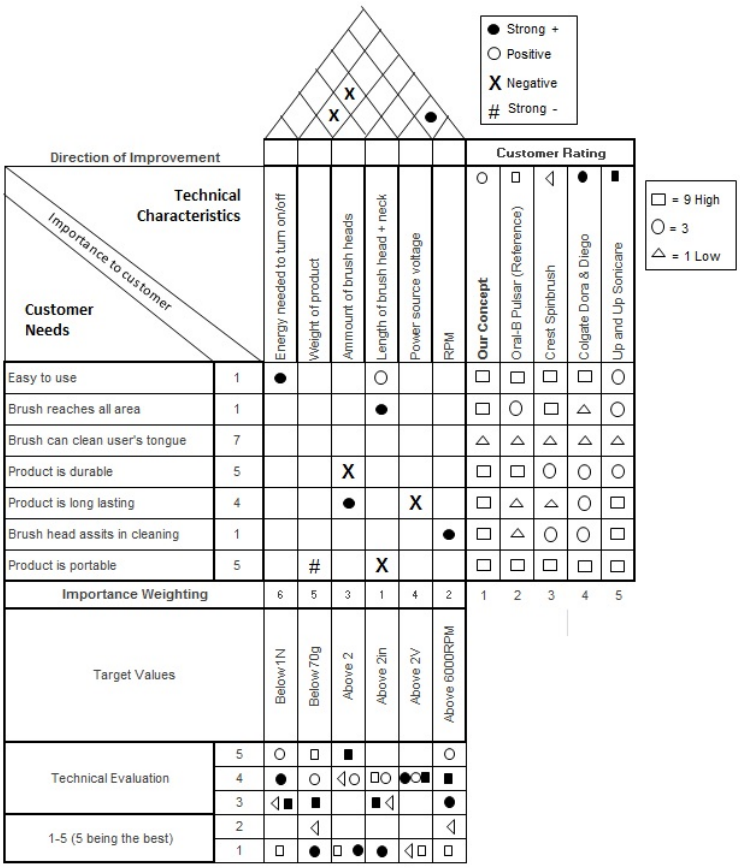
Concept #4 (See Appendix B) is an all-round brush that uses several oscillating parts to brush your teeth from multiple angles at once. The shape of the head is similar to the reference design, it increases surface brushed when applied correctly towards the teeth, it also has access to most of the oral cavity without any problems. According to the ADA's tooth brushing guide, the brush should be angled 45 degrees at the teeth in order to also brush the gum properly; this design works well with this principle as it has a straight edge and appropriately lengthened bristles.

Concept #5 (See Appendix B) is similar to the Oral-B pulsar in its way of function as a vibrating brush, but has a rear sided tongue cleaner with two main features. First of all it is used to brush your tongue, this removes bacteria that are the main reason for bad breath. The oval design of it will not majorly affect the effectiveness of the tongue cleaning as the tongue is very agile. However, the intention of the shape is to allow the user to brush the entire mouth to remove bacteria in an effective manor.

4.2 Concept Selection

First of all we used the House of Quality to combine the customer needs, metrics and benchmarking to get a proper overview of the concept selection stage.

Table 5: The House of Quality



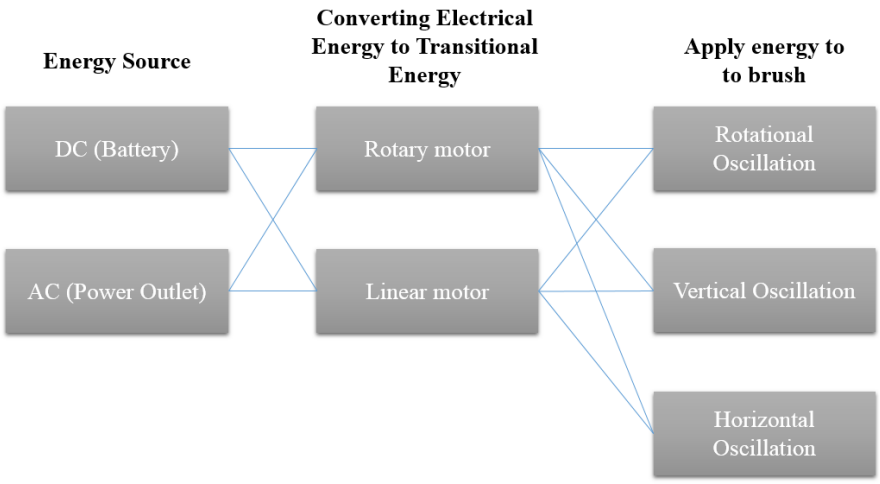
Going into concept selection, we decided to use the weighted chart to determine which designs we would use, drop or combine. The weighted chart is used by deciding percentage wise, how much each customer need is worth with the only limit being that the percentages of all customer needs add up to 100%. Furthermore you create a column for each of the concepts, and in regard to each customer need, you rate each concept on a 1-5 scale which serves as a multiplier for the percentage of the specific customer need. The sums are added up to create a reference value which gives you a perspective on how the concepts match up. The reference design, in our case the Oral-B Pulsar, has a 3 on all customer needs, meaning that 1-2 are features worse than the reference, and 4-5 are better.

Table 6: Concept Scoring

Selection Criteria	Weighting	Concepts									
		A		B		C		D		E	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Easy to use	20%	3	0.6	3	0.6	4	0.8	3	0.6	3	0.6
Brush reaches all areas	20%	2	0.4	4	0.8	2	0.4	3	0.6	3	0.6
Brush can clean user's tongue	5%	2	0.1	2	0.1	4	0.2	2	0.1	4	0.2
Product is durable	10%	4	0.4	3	0.3	3	0.3	5	0.5	3	0.3
Product is long lasting	15%	4	0.6	4	0.6	4	0.6	5	0.75	3	0.45
Brush head assists in cleaning	20%	4	0.8	4	0.8	4	0.8	5	1.0	4	0.8
Product is portable	10%	2	0.2	3	0.3	2	0.2	1	0.1	3	0.3
Total Score		3.1		3.5		3.3		3.65		3.25	
Rank		5		2		3		1		4	
Continue?		Drop		Combine		Combine		Use		Drop	

After completing the grading, we ended up with one main design and some that we wanted to combine. To determine whether we could combine them or not, we created a morph chart which shows the main functional features, to determine if it would allow us to combine the designs we wanted to combine.

Figure 1: The Morphological Chart



We found ways to make the different parts interact in each of the respective manors, resulting in the chart above, which clearly shows that there would be no issues using either application method with any of the energy sources used in the concept generation.

5.0 Final Design

5.1 Design Drawings and Parts List

Figure 2:

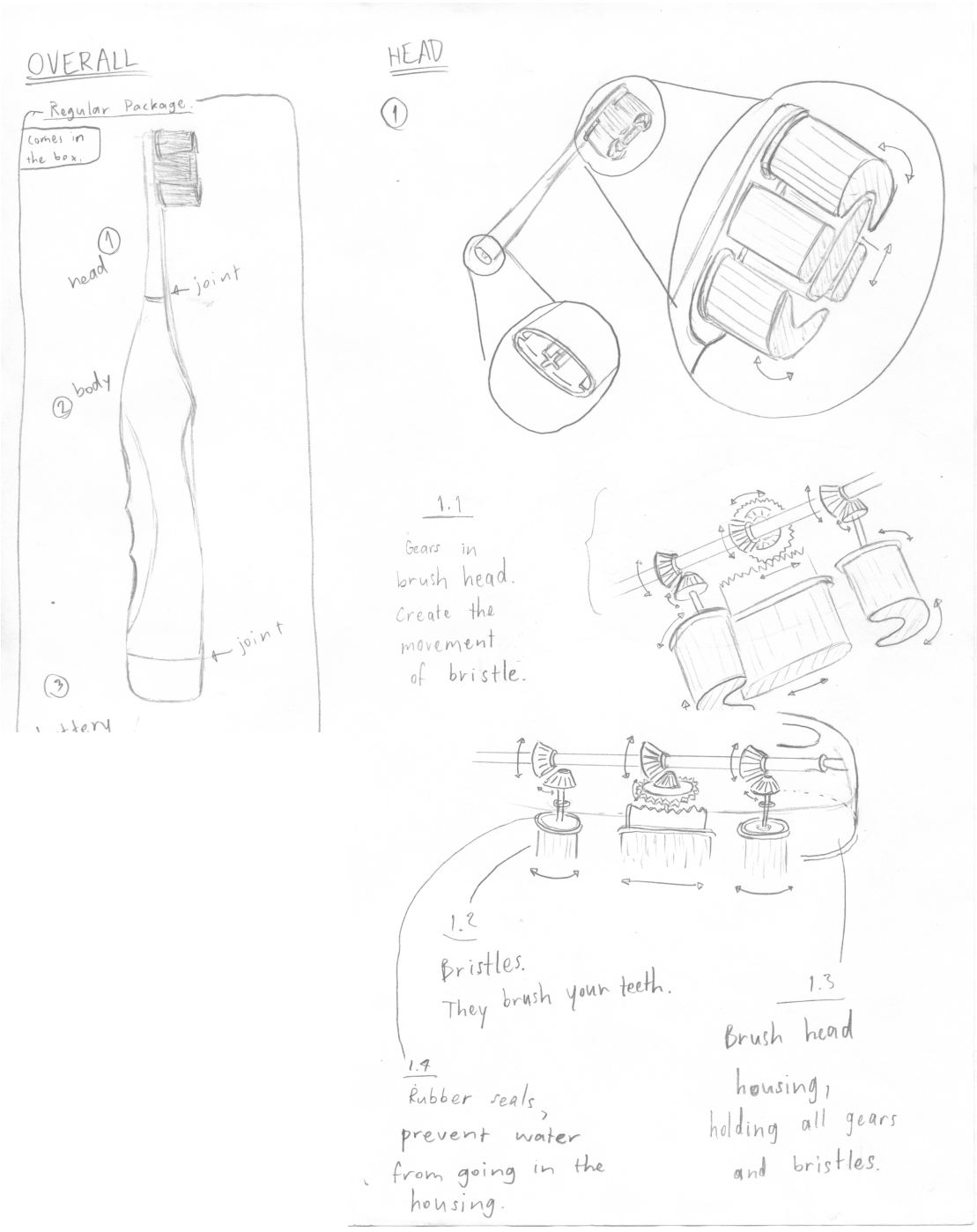


Figure 3:

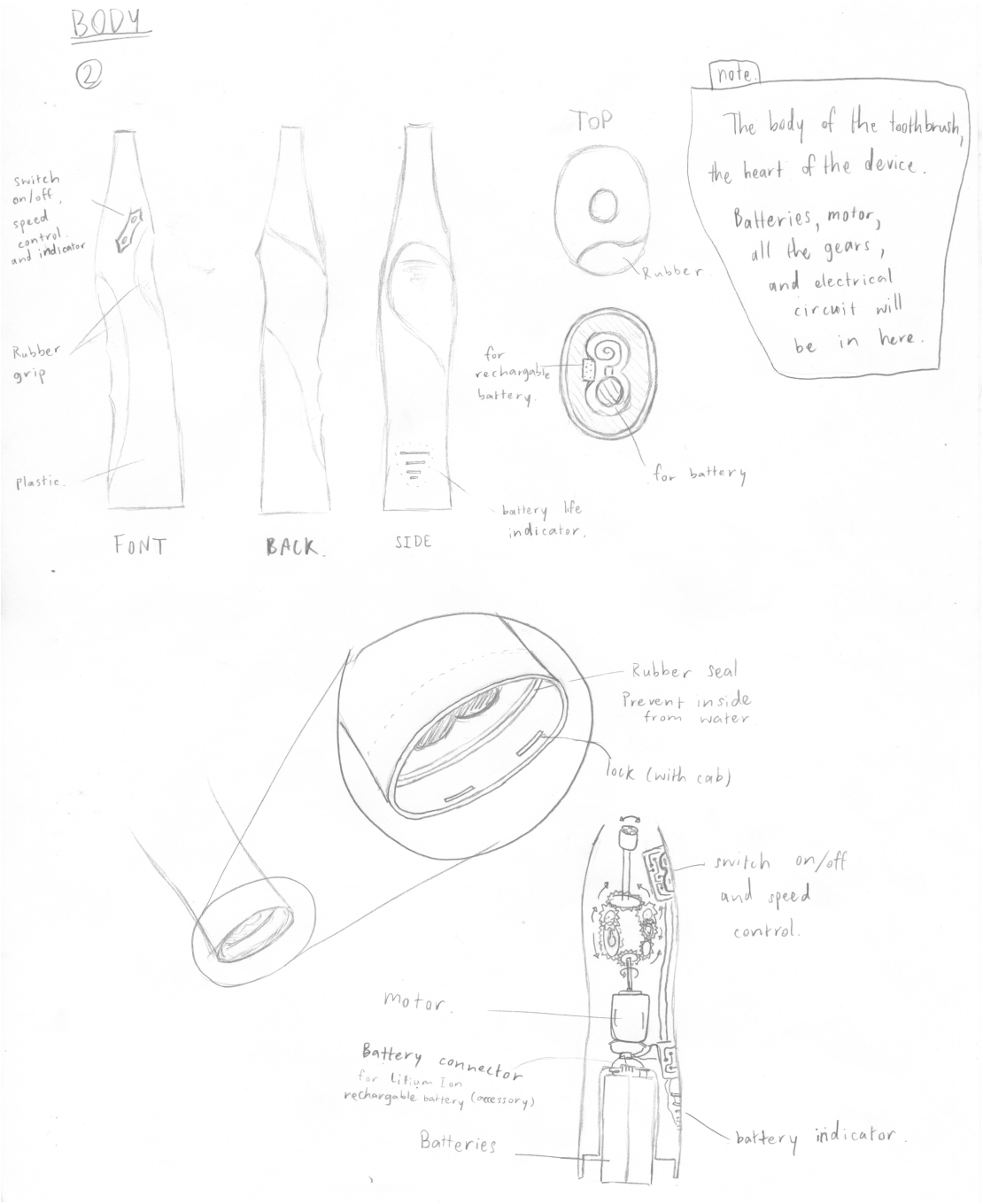

BODY
②
switch on/off, speed control and indicator
Rubber grip
Plastic.
FONT
BACK.
SIDE
battery life indicator.
TOP
Rubber
for rechargable battery.
for battery
note.
The body of the toothbrush, the heart of the device.
Batteries, motor, all the gears, and electrical circuit will be in here.
Rubber seal
Prevent inside from water
lock (with cab)
switch on/off and speed control.
motor.
Battery connector
for Lithium Ion rechargable battery (accessory)
Batteries
battery indicator.

Figure 4:

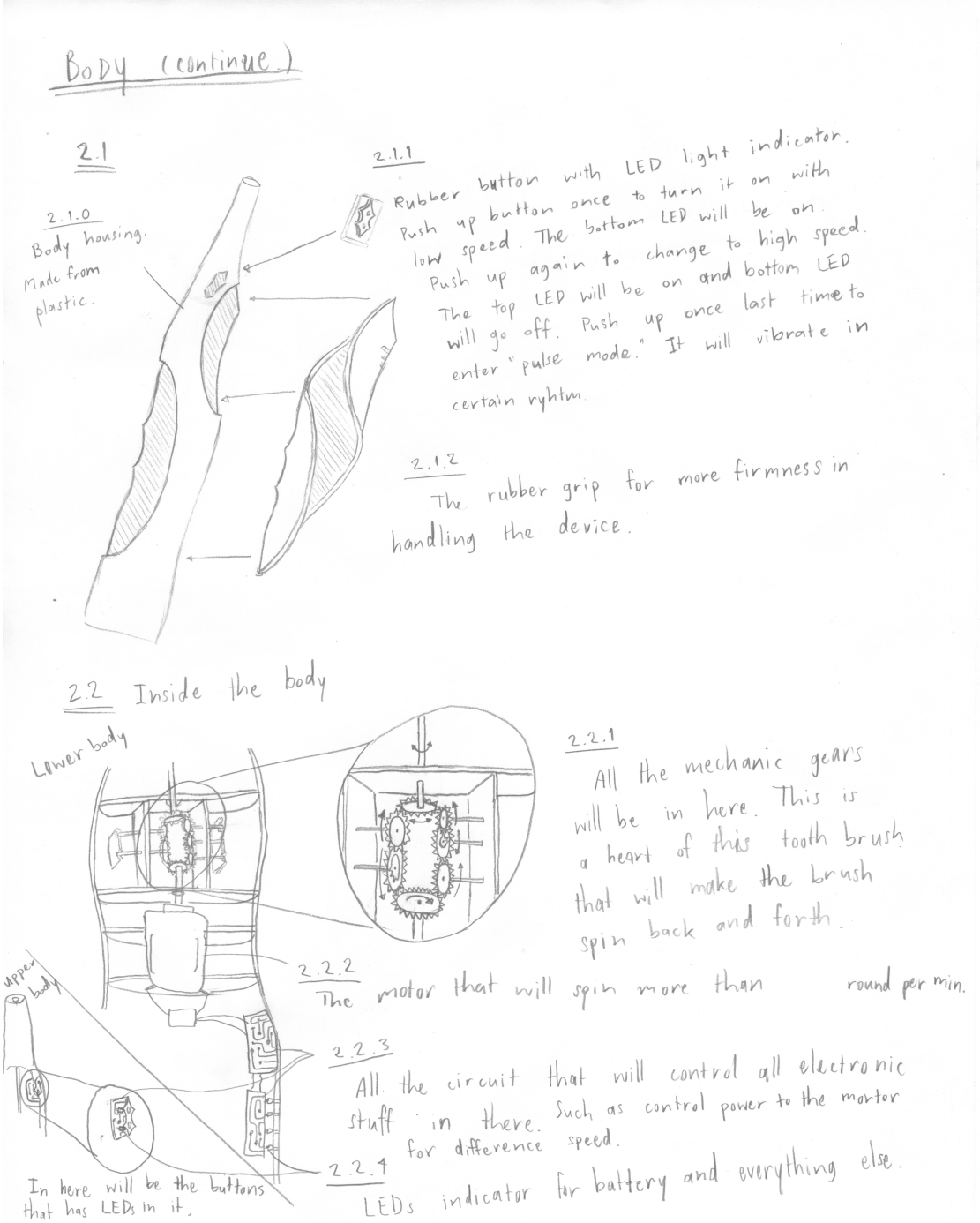
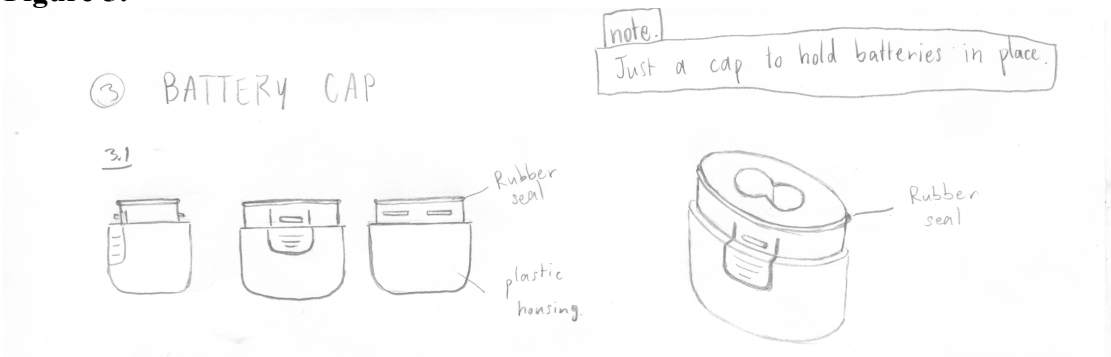


Figure 5:



5.2 Bill of materials

Table 4: Bill of Materials

Part Number	Part Name	Qty	Function	Mass	Material	Dimensions (inches)
1.1	Gears (in brush head)	7	Make movement of bristles	2g	metal	0.2-0.5 round 0.1-0.2 thick
1.2	Bristle	3	Bush your teeth	3g	nylon	0.5 tall 0.3-0.5 wide
1.3	Head Housing	1	Hold bristle and gears	4g	plastic	2.25 long 0.4-0.5 wide
2.1.0	Body housing	1	Hold all the internal stuff	10g	plastic	4.5 long 1-1.3 round
2.1.1	Control button	1	Control speeds	1g	Rubber, plastic	0.25x0.6
2.1.2	Handle grip	1	For your hand to hold	5g	rubber	1.5-4 x 1.5
2.2.1	Driven gears	7	Make transition and make it move back and forth	4g	metal	0.1-0.3
2.2.2	Motor	1	Making movement	13g	Metal, plastic	0.5x1
2.2.3	Circuits	3	Control electric stuff	2g	Metal, copper, laminate	0.5-1.0 x 0.25-0.5
2.2.4	LEDs indicator	6	Indicate the status of everything	1g	Plastic, metal	0.1x0.1
3.1	Battery cap	1	Hold the batteries	5g	plastic	1.0 x 1.0-1.3 round
3.2	Rechargeable Lithium-ion battery (optional)	1	The power source of toothbrush	30g	Plastic, metal, lithium	1.5 x 1.0-1.3 round
4	Docking station (optional)	1	Dock the toothbrush, and recharge it	15g	Plastic, metal	2x3

6.0 Conclusion

The project began with a goal of designing an electric toothbrush that persuades more customers to switch to an electric toothbrush by meeting the demands of our customers. Through external surveys and research, the group accumulated a list of customer needs and effective features found on the most innovative electric toothbrushes available on the market. After assessing the initial concepts, a final design with an assortment of unique features. The primary feature is the head's three sets of brushes, with the upper and lower layers oscillating back and forth in a circular motion, while the central layer oscillates vertically. This allows the brush head to cover the entire tooth when used at a 45 angle. The brush also has a battery cap that contains the batteries during removal of the cap, to prevent dropping and potentially losing the batteries. Furthermore, the brush rotates at 10000RPM, a speed that will ensure that food particles are dislodged from the gaps between the teeth. This speed is superior to all brushes other than ultrasonic brushes; however, ultrasonic toothbrushes cost over a USD $100, which is beyond the reach of the average customer. Therefore the final design provides superior effectiveness at a low cost. The included features help the toothbrush address all the customer needs, due to its simplicity, length, replaceable heads and batteries, and brush head dimensions. Therefore, the project appears to be a success, as the group was able to achieve its goal and design a toothbrush that should represent the ideal electric toothbrush for all children and adult users.

References:

"MANUAL TOOTHBRUSH VERSUS ELECTRIC TOOTHBRUSH." Web log post.*Cosmic Smile*. N.p., 30 Nov. 2011. Web. 18 Oct. 2013. <http://www.cosmicsmile.com/blog/archives/23-Manual-Toothbrush-versus-Electric-Toothbrush.html>.

Moore, Shelley. "Who Invented the Electric Toothbrush?" *EHow*. N.p., n.d. Web. 19 Oct. 2013. <http://www.ehow.com/about_4598206_who-invented-electric-toothbrush.html>.

Pacific, Research Consulting. "3 Head Attachment Electric Toothbrush." *Cosmetics & Toiletries & Household Products Marketing News in Japan* 26.1 (2004): 1. *ProQuest.* Web. 22 Oct. 2013.

Pacific, Research Consulting. "Double Head Electric Toothbrush." *Cosmetics & Toiletries & Household Products Marketing News in Japan* 25.2 (2003): 1. *ProQuest.* Web. 22 Oct. 2013.

Pacific, Research Consulting. "Double Movement Head Electric Toothbrush." *Cosmetics & Toiletries & Household Products Marketing News in Japan* 25.7 (2003): 1. *ProQuest.* Web. 22 Oct. 2013.

Pacific, Research Consulting. "Stylishly Compact Ultrasonic Electric Toothbrush." *Cosmetics & Toiletries & Household Products Marketing News in Japan* 26.10 (2004): 1. *ProQuest.* Web. 22 Oct. 2013.

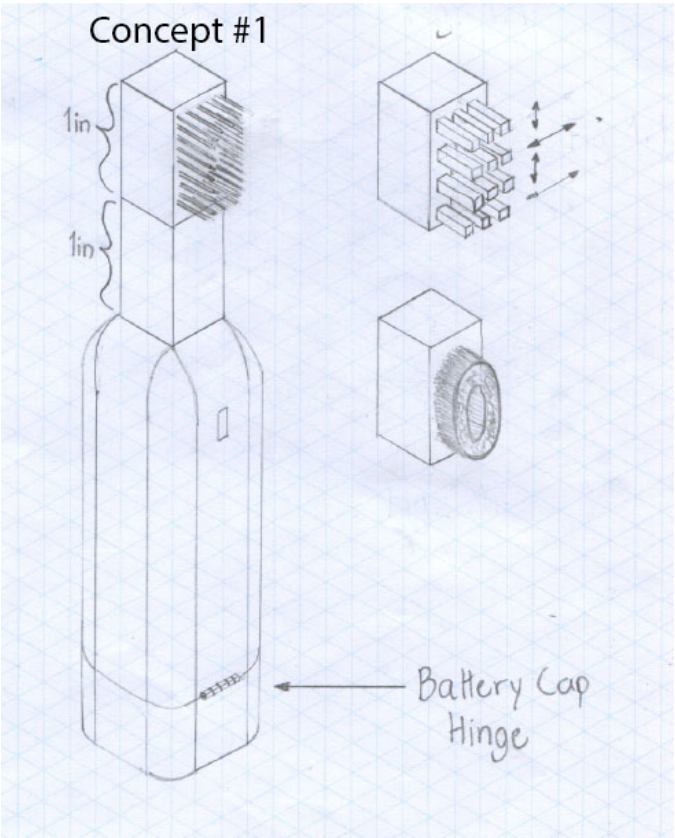
Pacific, Research Consulting. "Triple Brushing Mode Electric Toothbrush." *Cosmetics & Toiletries & Household Products Marketing News in Japan* 26.12 (2004): 1. *ProQuest.* Web. 23 Oct. 2013.

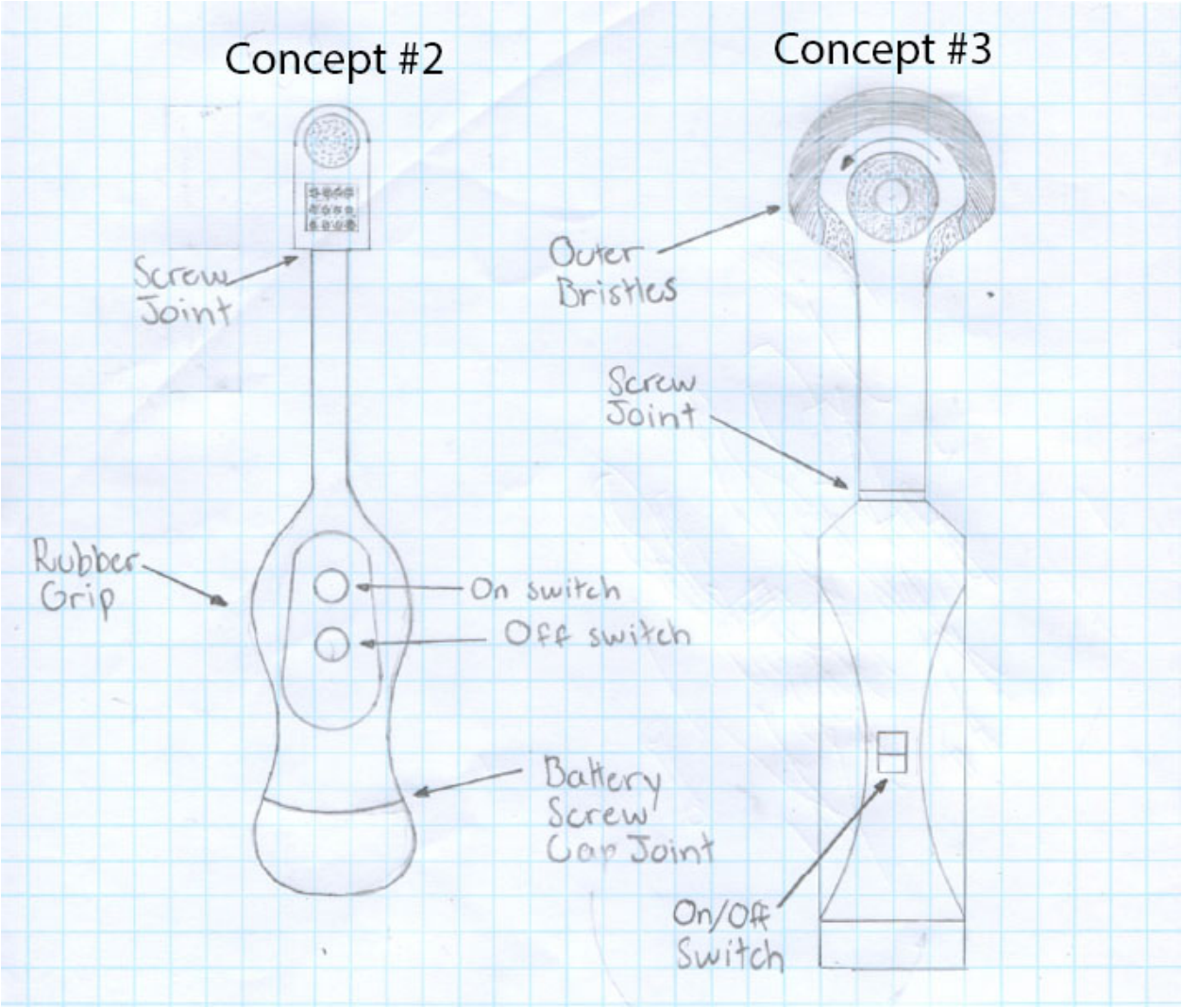
Appendix

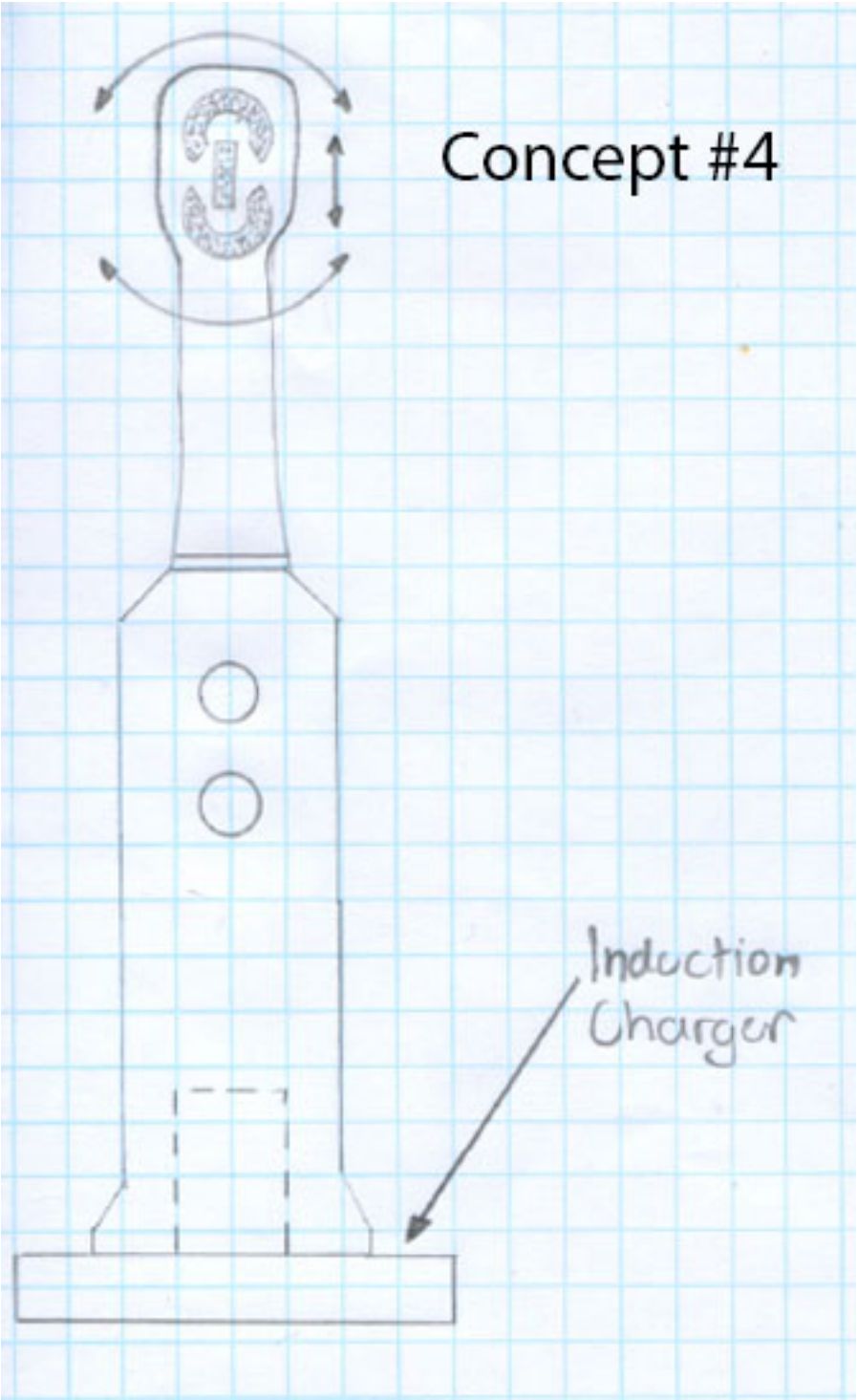
A: Custom Survey Questions

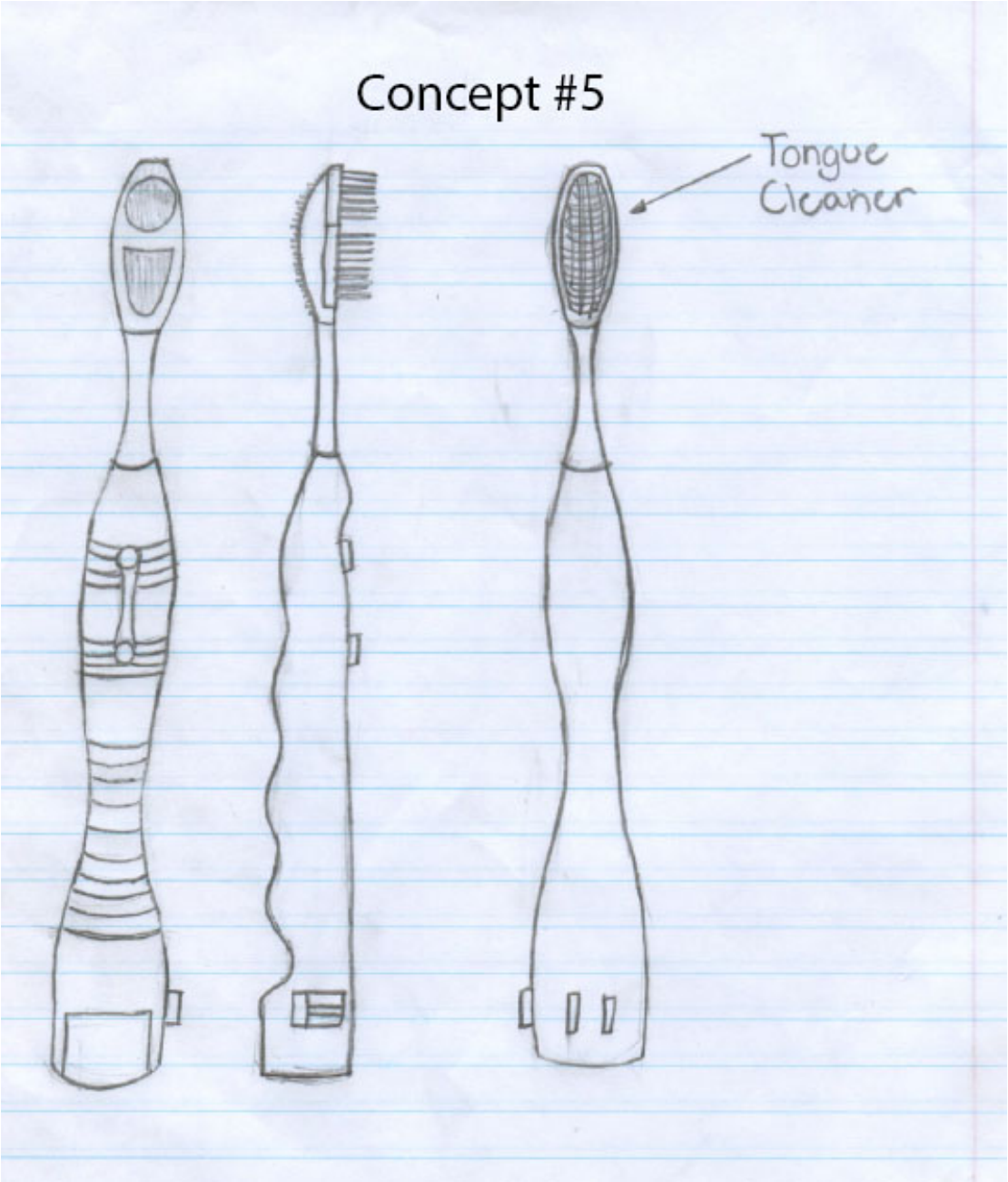
1. **Which of the following factors do you take into account when choosing your electric toothbrush?**
    a) Environmentally friendly (materials and production process)
    b) Design (Colors/Non-functional features)
    c) Durability
    d) Ease of cleaning
    e) Price of accessories (replacement brushes etc.)
    f) Rounds per minute
    g) Ability to clean the surface of the tongue
    h) Grip
    i) Quiet
    j) Gets to hard-to-reach places
2. **Are there any functions that you miss with your current toothbrush, electric or not?**
3. **What is your favorite function with your current toothbrush, electric or not?**

B: Concept Designs




Concept #2
Concept #3
Screw Joint
Rubber Grip
On switch
Off switch
Battery Screw Cap Joint
Outer Bristles
Screw Joint
On/Off Switch


Concept #4
Induction
Charger


Concept #5
Tongue Cleaner