

DESIGNING ERGONOMIC TOOTHBRUSH, TOOTHBRUSH REFILL, AND TOOTHBRUSH CAP

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ABSTRACT

Used toothbrush is one type of waste that is difficult to unravel. Therefore, it is necessary to design a toothbrush refill that can be reused so that the amount of waste generated fewer.

The data collection was done by distributing questionnaires (preliminary, importance, open, QFD) and measured the molars. Furthermore, the next step was designing some alternative designs of toothbrush, toothbrush refill and toothbrush cap. The refill toothbrush design alternatives, were selected using the method of concept scoring which were based on the criteria of customer needs.

The selected alternative was alternative 1 (the method of screwing the neck of the toothbrush).

Keywords: toothbrush, design, ergonomic

1. INTRODUCTION

Currently, rapid industrial development is characterized by the establishment of a wide variety of plants. These plants produce a wide range of products to be consumed by the segment of consumers. Many consumers consume the product, the more the consumers produce waste from consumption of these products. Waste gives negative impact to humans. The negative impact, making people try to reduce industrial waste or waste generated by performing a variety of prevention and control. In the prevention of waste generated by consumers, then we can apply the principles of reduce (reduction), reuse (reuse), whereas in overcoming waste, recycling principle can be used (turnover reused or recycled). One of the waste that is unraveled, is made of plastic. One of the products that are made of plastic material is stalk toothbrush. Based on the above conditions, it is necessary to design a toothbrush that can be reused so that the number of the waste can be reduced. Factors that must be considered in designing of the toothbrush that can be reused is convenience for consumers who use them. Therefore, an ergonomic toothbrush was designed.

This paper was written based on the thesis titled "Designing Toothbrush, Toothbrush

Refill, Shut Toothbrush, Toothpaste Place, Place Toothpaste Refill, and Box Place Toothpaste with Ergonomics Approach" by Andriyani, Novi, and Christina.

In making this report, limitations and assumptions used were as follows:

1. Toothbrush that would be designed was a toothbrush for adult users.
2. The design did not calculate the cost to produce the toothbrush, toothbrush refill and toothbrush cap.
3. The design and dimensions of the model only included toothbrush, toothbrush refill, toothbrush cap.
4. The level of accuracy that was used was 10% and the 95% confidence level.
5. It was assumed that anthropometric data obtained from the book "Konsep Dasar Ergonomi dan Aplikasinya" by Eko Nurmianto according to anthropometric data users toothbrush and toothpaste.
6. Sample data was assumed equal to the population data.

The formulation of the problem in this study were:

1. What were the customer needs of toothbrush from the point of view of ergonomics?
2. How to design an ergonomic toothbrush, toothbrush refill, and toothbrush cap?

2. STUDY LITERATURE

2.1 Quality Function Deployment

According to Cohen, Quality Function Deployment is a method for designing and developing of a structured product, which allows a team of developers to clearly specify all the wants and needs of customers, and then systematically evaluate each product or service's ability to meet the wants and needs.

2.1.1 Parts of the House of Quality

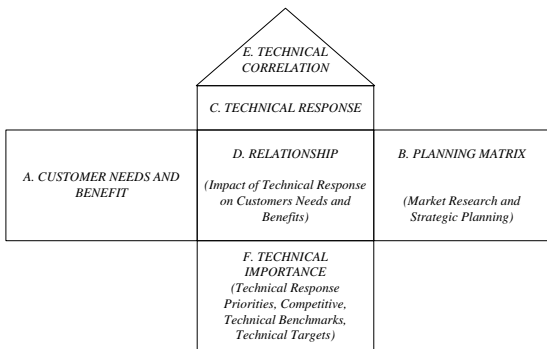


Figure 1. House of Quality

2.1.2 The four-phase QFD model

According Day :

Phase 1: Product Planning

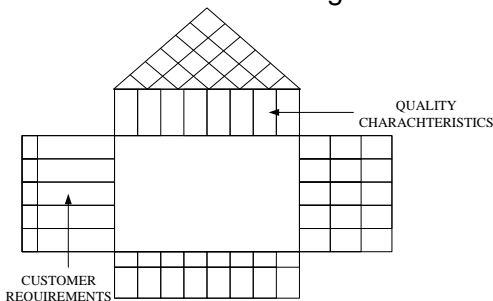


Figure 2 Phase 1 QFD

Phase 1 is the Product Planning where customer requirements (customer requirements) is converted into technical requirements (technical requirements).

Phase 2 : Design Planning

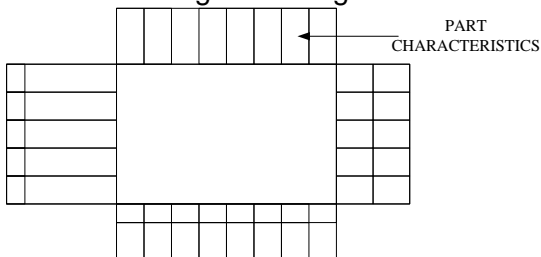


Figure 3. Phase 2 QFD

Phase 2 is where the Technical Design Requirements Planning (Technical Requirements) converted into Part Characteristic (Characteristics Section).

Phase 3 : Process Planning

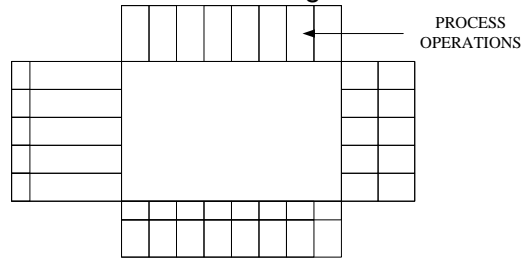


Figure 4. Phase 3 QFD

Phase 3 is where the Planning Process Part Characteristic (Characteristics Section) is converted into a Process Characteristic (Process Characteristics).

Phase 4 : Production Planning

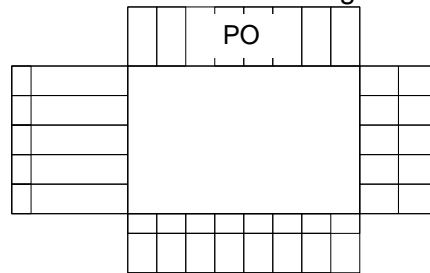


Figure 5. Phase 4 QFD

Stage 4 is where the Production Planning Process Characteristic (Process Characteristics) is converted to Production Requirements (Requirements Production).

2.2 Ergonomics

The term "ergonomics", according Nurmianto, is derived from the Latin, which Ergon (work) and nomos (natural laws) and can be defined as the study of human aspects in the work environment are reviewed in anatomy, physiology, engineering, management, and design or design. Essentially, ergonomics is a branch of science that systematically utilize information about the properties, capabilities, and limitations of humans to design a working system so that people can live and work on the system properly, ie achieve a chill through the job effectively, safe, and comfortable.

2.3 The purpose of Ergonomics

The goal of ergonomics is no 2, ie :

1. To improve the effectiveness and efficiency of the work and activities undertaken, including the improvement of the usability, reduce errors, and increase productivity.
2. To enhance the number and value of the human element, including improving safety, reducing fatigue and tension, improve comfort, increase job satisfaction, and improve quality of life.

2.4 Anthropometry

According to the method of measurement, anthropometry is divided into two parts, namely :

1. Static anthropometry, where the measurements are performed on the human body are in a stationary position.
2. Dynamic anthropometry, which the body dimensions measured in various body positions that are moving, making it more complex and more difficult to measure.

It can be concluded that anthropometric data will determine the shape, size and exact dimensions associated with a product designed and man who will operate or use the product. The results of the design must be able to accommodate the dimensions of the body of the largest populations that use the products designed by them. In general, 90% to 95% of the target population in a group of users of a product must be able to use it properly.

2.5 Concept Scoring

Ulrich said that concept scoring is conducted to determine which is the best product concept among some concept products compared, based on certain selection criteria. Below is a table for purposes of valuation analysis concept.

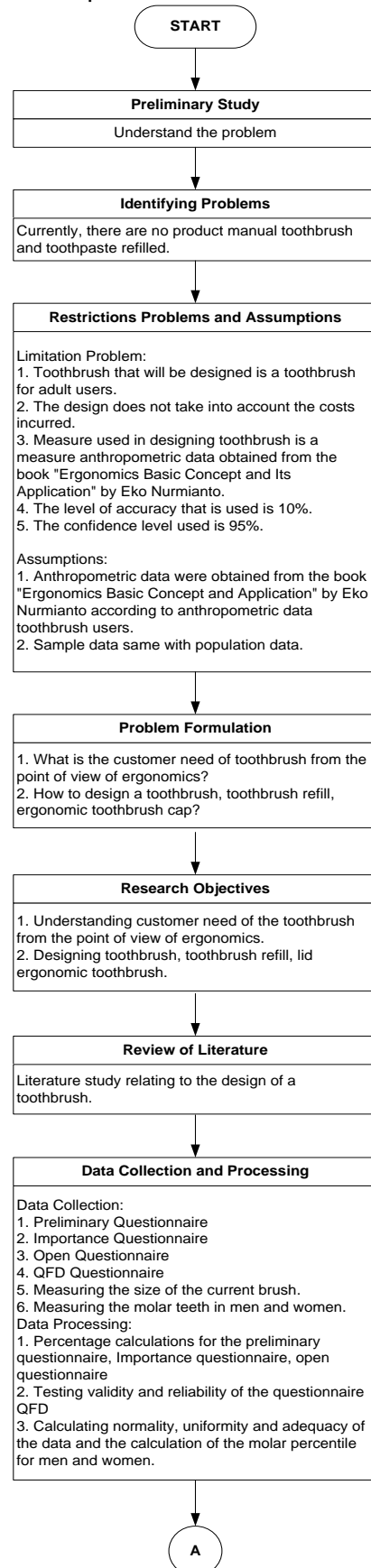
Table 1. Analysis of Concept Scoring

		Compared Product Concept					
		A		...		Z	
weight (w)	selection criteria analysis	Rating (r)	Value (r x w)	Rating (r)	Value (r x w)	Rating (r)	Value (r x w)
	1						
	..						
	n						
Total Value (N)							
Ranking							

Source : Ulrich & Eppinger ()

3. RESEARCH METHODOLOGY

Research steps were as follows :



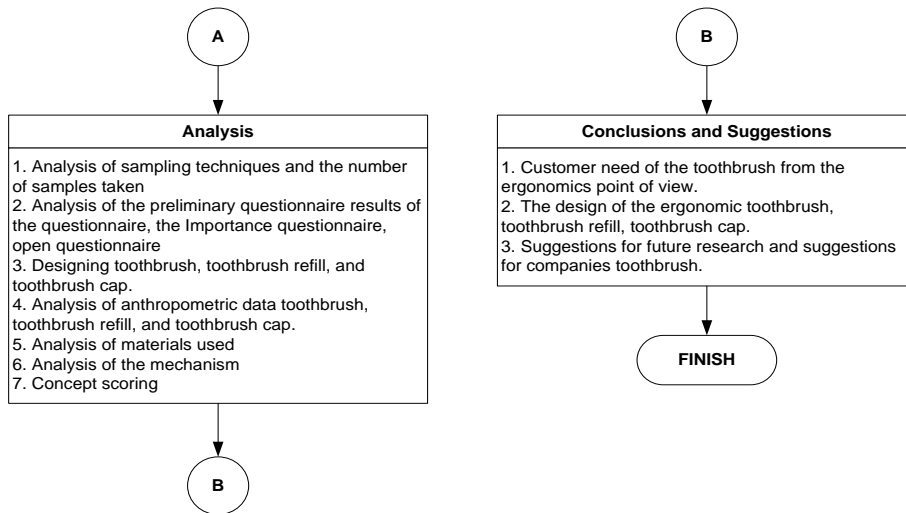


Figure 6. Research Methodology

4. ANALYSIS AND DESIGN

After having validity and reliability tests, QFD questionnaire made design planning and product planning.

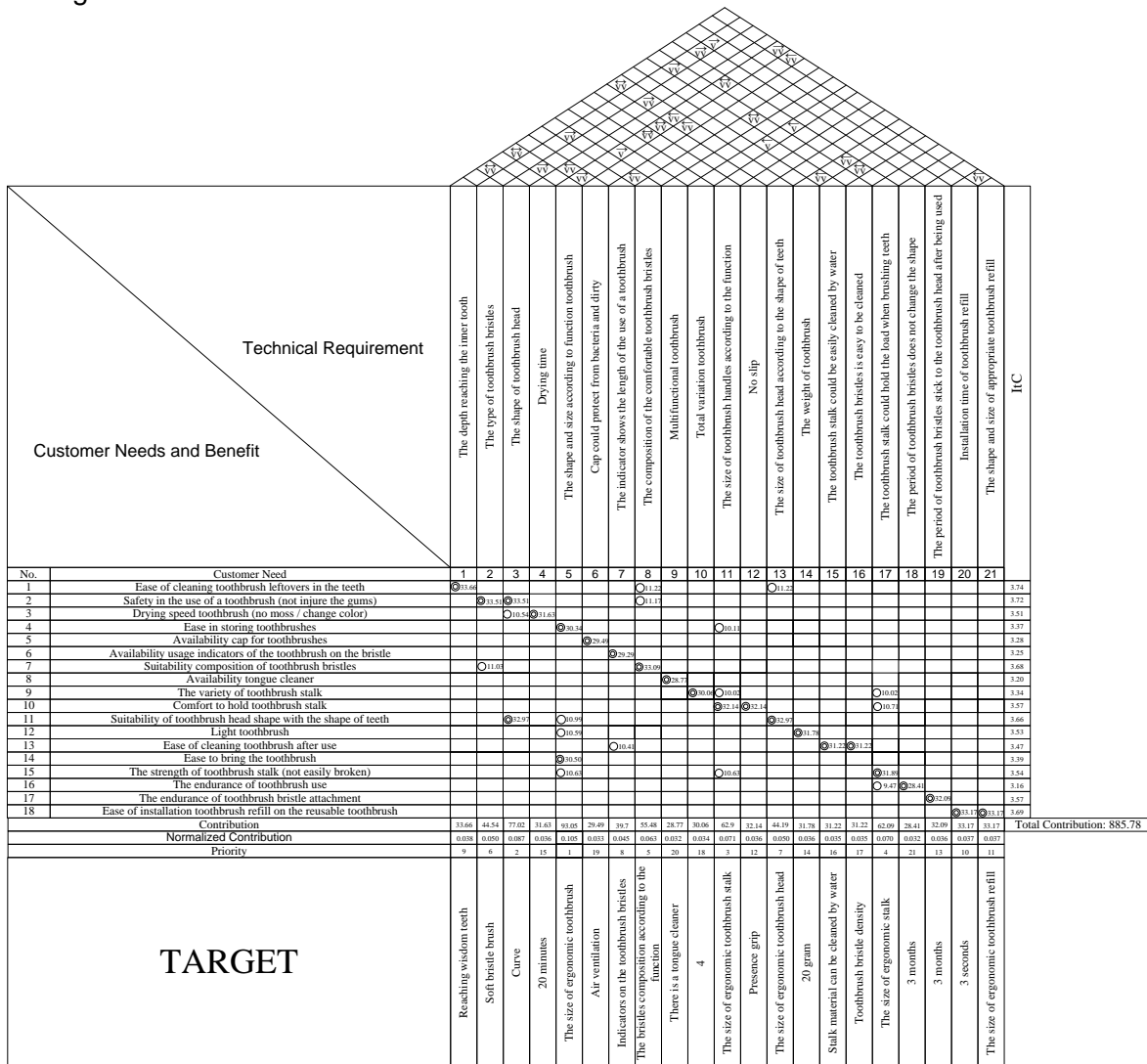


Figure 7. Toothbrush Product Planning

Technical Requirement		Critical Part Requirement																																		Contribution															
		The composition of the toothbrush bristles	The length of toothbrush head	The width of the tip toothbrush head	The width of the intermediate toothbrush head	The width of the toothbrush neck	The material of toothbrush stalk	The length of toothbrush stalk	The width of toothbrush stalk	The thickness of toothbrush stalk	The length of the grip	The length of toothbrush neck	The width of toothbrush neck	The height of the neck - head toothbrush	The thickness of toothbrush head	The thickness of toothbrush head	The length of toothbrush bristles	Method of doing the toothbrush cap	The length of toothbrush cap	The width of toothbrush cap	The thickness of toothbrush cap	The length of toothbrush cap opener	The width of toothbrush cap opener	The length of the toothbrush stalk holder	The width of toothbrush stalk holder	Color indicator diameter of use	The method of indicator of use	The duration of indicator when change color	Placement of rubber element	The shape of toothbrush stalk	The grip shape	The grip material	The number of toothbrush bristles in one layer	The material of toothbrush bristles	Materials filament arrangement		The sample insulation method	The length of the toothbrush head fill	The width of the toothbrush head fill	The thickness of toothbrush head fill	The length of toothbrush bristle in fill										
No.	Customer Need	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40										
1	The depth reaching the inner tooth																																																		
2	The type of toothbrush bristles																																																		
3	The shape of toothbrush head																																																		
4	Hygienic time																																																		
5	The shape and size according to function toothbrush																																																		
6	Can avoid spread from bacteria and fungi																																																		
7	The indicator shows the level of the use of a toothbrush																																																		
8	The composition of the Comfortable toothbrush bristles																																																		
9	Multi-functional toothbrush																																																		
10	Easy variation toothbrush																																																		
11	The size of toothbrush handle according to the function																																																		
12	No slip																																																		
13	The size of toothbrush handle according to the shape of teeth																																																		
14	The weight of toothbrush																																																		
15	The toothbrush stalk easily cleaned by water																																																		
16	The toothbrush bristles easy to be cleaned																																																		
17	The toothbrush stalk could hold the load when brushing teeth																																																		
18	The period of toothbrush bristles does not change the shape																																																		
19	The period of toothbrush stick to toothbrush head after being used																																																		
20	Insulation time of toothbrush refill																																																		
21	The shape and size appropriate toothbrush refill																																																		
Normalized Contribution		13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33	13.33				
Priority		12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
TARGET		Core Bristles	21 mm	11.4 mm	13.8 mm	Nylon	19 mm	24 mm	24 mm	24 mm	24 mm	5 mm	5 mm	5 degree	5 mm	5 mm	10 mm	Pushing from the side	29 mm	17 mm	18.5 mm	11.2 mm	64 mm	7 mm	Blue	Color changing	1.2 month	At the back of the toothbrush	Round	Stainless with hard core	Rubber	Plastic + rubber	4	Brass	Brush	Turning, sliding, pressing	24 mm	11.4 mm	4.5 mm	10 mm	10 mm	10 mm	10 mm	10 mm	10 mm	10 mm	10 mm	10 mm	10 mm	10 mm	10 mm

Figure 8. Toothbrush Design Planning

In designing toothbrush, it was required anthropometric data as follows:

- Toothbrush Alternatives 1, 2 and 3

Table 2. Toothbrush Size Alternatives 1, 2 and 3

Product dimension	Anthropometric Data					Allowance		Ergonomic size (mm)
	Type	Percentile	Sex	Calculation (mm)	Size (mm)	Type	Size (mm)	
The length of toothbrush stalk	LTT+PIJ	95%	Men	88+51	139	-	0	139
The width of toothbrush stalk	Kell DG- PIJ	5%	Women	$((3.14*43)-42)/3.14$	29.6	Latitude	5	24
The thickness of toothbrush stalk	Kell DG- PIJ	5%	Women	$((3.14*43)-42)/3.14$	29.6	Latitude	5	24
The length of the grip	1/2 PIJ	95%	Men	0.5*51	25.5	-	0	25.5
The length of toothbrush neck	(survey of existing products)	-	-	-	45	-	0	45
The width of toothbrush neck	(survey of existing products)	-	-	-	5	-	0	5
The slope of the neck - head toothbrush	(survey of existing products)	-	-	-	5 degree	-	0	5 degree
The thickness of toothbrush neck	(survey of existing products)	-	-	-	5	-	0	5
The length of toothbrush head	-	-	-	-	25	-	0	25
The thickness of toothbrush head	(survey of existing products)	-	-	-	4.5	-	0	4.5
The length of toothbrush bristles	(survey of existing products)	-	-	-	10	-	0	10
The width of the tip toothbrush head	The width of the tip of the tooth	5%	Women	7.4	7.4	Thick materials	4	11.4
The width of the central part toothbrush head (alt 1 & 3)	dental widest	5%	Women	9.8	9.8	Thick materials	4	13.8
Elbow length (alt 3)	2 * Width Elbow	-	-	2*1	2	-	0	2
Elbow width (alt 3)	Thick Materials (survey existing products)	-	-	1	1	-	0	1

Note :
 Circumference DG=3.14*DG
 LTT: Handwidths (Metacarpal)
 PIJ: Long thumb
 DG: Diameter handheld

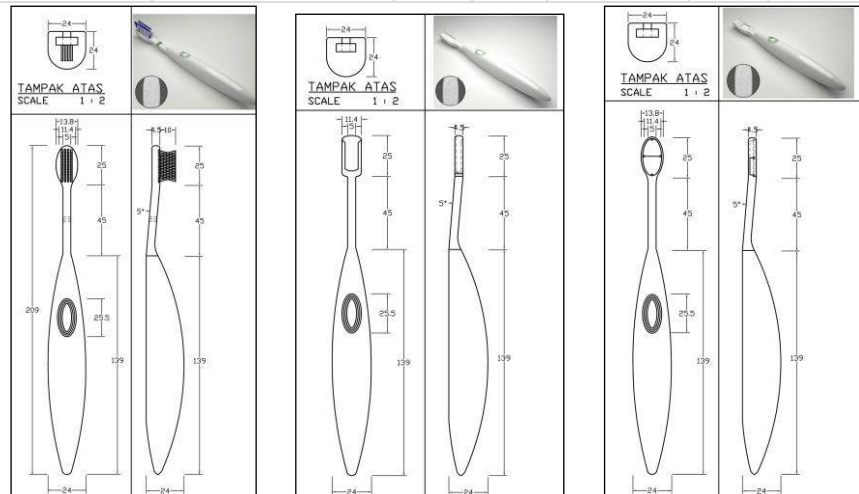


Figure 9. Toothbrush Alternatives 1, 2 and 3

In designing toothbrush refill, required anthropometric data as follows:

Table 3. Refill Toothbrush Size Alternative 1,2,3

Product dimension	Anthropometric Data					Allowance		Ergonomic size (mm)
	Type	Perce ntile	Sex	Calculation (mm)	Size (mm)	Type	Size (mm)	
The length of toothbrush bristles	(survey of existing products)	-	-	-	10	-	0	10
The length of Toothrush Head (alt 1)	-	-	-	-	25	-	0	25
The length of Toothbrush Head (alt 2 & 3)	-	-	-	-	25	The thickness material	2	23
The width of the tip of the toothbrush head	Tooth tip width	5%	Wo men	7,4	7,4	The thickness material	2	9,4
The width of the central part of the toothbrush head	Dental widest	5%	Men	9,8	9,8	The thickness material	2	11,8
The thickness of Toothbrush Head (alt 1)	(survey of existing products)	-	-	-	4,5	-	0	4,5
The thickness of Toothbrush Head (alt 2 & 3)	(survey of existing products)	-	-	-	4,5	The thickness material	1	3,5
The length of toothbrush neck	(survey of existing products)	-	-	1/2*45	22,5	-	0	22,5
The width of the toothbrush neck	(survey of existing products)	-	-	-	5	-	0	5
The slope of the toothbrush neck head	(survey of existing products)	-	-	-	5 degree	-	0	5 degree
The thickness of toothbrush neck	(survey of existing products)	-	-	-	5	-	0	5
Elbow length (alt 3)	Thick material (surveys of existing products)	-	-	1	1	-	0	1
Elbow width (alt 3)	2 * width elbow	-	-	2*1	2	-	0	2

In designing a toothbrush cap, it was required anthropometric data as follows:

Table 4. Cap Toothbrush Size Alternatives 1, 2 and 3

Product dimension	Anthropometric Data					Allowance		Ergono mic size
	Type	Percentil e	Sex	Calculation (mm)	Size (mm)	Type	Size (mm)	
The length of toothbrush cap	The length of Toothbrush Head	-	-	-	25	For drying + thick places	4	29
The thickness of toothbrush cap	The thickness toothbrush head + the length toothbrush bristles (survey existing products)	-	-	4.5+10	14.5	For drying + thick places	4	18.5
The length of toothbrush cap opener	1/2 IPJ	95%	Men	(1/2)*23	11.50	-	0	11.5
The width of toothbrush cap opener	1/8 PIJ	95%	Men	1/8 *51	6.38	-	0	6.4
The length of toothbrush stalk's hole	The thickness of toothbrush neck (survey existing products)	-	-	-	5	Discharge of water	2	7
The width of toothbrush stalk's hole	The width of Toothbrush neck (survey existing products)	-	-	-	5	Discharge of water	2	7
The width of toothbrush cap (alt 1 & 3)	The width of toothbrush head	-	-	-	13.8	For drying + thick places	4	17.8
The width of toothbrush cap (alt 2)	The width of toothbrush head	-	-	-	11.4	For drying + thick places	4	15.4
Note :								
IPJ: Thumb width								

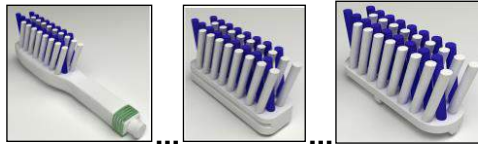


Figure 10. Refill Toothbrush

Refill toothbrush was made of nylon material, the attachment of the filaments using brass, head toothbrush alternatives 1 and 3 were made of plastic, while the second alternative was made of rubber. Is a rubber grip material, the neck and the stalk of a plastic toothbrush.

The difference of the three design alternatives was on the method of the installation of the toothbrush. The first alternative had the method of screwing the neck of the toothbrush. The second alternative was the toothbrush with the rails located at the head of the toothbrush. The third alternative had the method of pressing the base of the bristles to the toothbrush head.



Figure 11. Toothbrush Cap

Toothbrush cap was made of plastic material, and opened by the flick of a finger.

The best alternative was chosen based on the assessment concept (concept scoring) with a toothbrush concept evaluation criteria derived from the questionnaire revelation QFD and weights obtained from the sorting value ITC (Important to Customer). Here is a concept scoring of toothbrush:

Table 5. Toothbrush Concept Scoring

i	Selection criteria analysis	Priority weight	Rating					Score
			Alt 1	Score	Alt 2	Score	Alt 3	
1	Ease of cleaning toothbrush leftovers in the teeth	1	2	2	2	2	2	2

Table 5. Toothbrush Concept Scoring

i	Selection criteria analysis	Priority weight	Rating					Score
			Alt 1	Score	Alt 2	Score	Alt 3	
2	Safety in the use of a toothbrush (not injure the gums)	2	2	4	2	4	2	4
3	Ease of installation toothbrush refill on the reusable toothbrush	3	1	3	2	6	3	9
4	Suitability composition of toothbrush bristles	4	2	8	2	8	2	8
5	Suitability of the toothbrush head shape with the shape of teeth	5	1,5	7,5	3	15	1,5	7,5
6	Comfort to hold toothbrush stalk	6	2	12	2	12	2	12
7	The endurance of toothbrush bristle attachment	7	2	14	2	14	2	14
8	Light toothbrush	8	2	16	2	16	2	16
9	The strength of toothbrush stalk (not easily broken)	9	2	18	2	18	2	18
10	Drying speed toothbrush (no moss / change color)	10	1,5	15	3	30	1,5	15
11	Ease of cleaning toothbrush after use	11	2	22	2	22	2	22
12	Ease to bring the toothbrush	12	2	24	2	24	2	24
13	Ease in storing toothbrushes	13	2	26	2	26	2	26
14	The variety of toothbrush stalk	14	2	28	2	28	2	28
15	Availability cap for toothbrush	15	2	30	2	30	2	30
16	Availability usage indicators of the toothbrush on the bristles	16	2	32	2	32	2	32
17	Availability tongue cleaner	17	2	34	2	34	2	34
18	The endurance of toothbrush use	18	2	36	2	36	2	36
Total			331,5		357		337,5	
Ranking			1		3		2	

Alternative 1 was the most well compared with other alternative products.

Value analysis of this toothbrush refill product was based on 4 categories. Based on use value, this product had more than one purpose, that was in addition to cleaning teeth, could also be used to clean the tongue. Product design that was chosen was also easy to use, had ergonomic design, and also had simple replacement mechanism. Based on esteem value, the product design had a pretty good aesthetic value due to the exclusive look with bright colors. Based on the criteria of exchange value, product design had a high exchange rate, because we could refill the toothbrush bristles. However, there were currently no similar products circulated in the market, so there is no standard size. In this paper, it is not considered about the cost value.

5. CONCLUSION AND SUGGESTION

5.1 Conclusion

1. The customer needs for toothbrush-related aspects of ergonomics are the variables in the QFD.
2. The design of the toothbrush, toothbrush refill, toothbrush cap that was chosen was alternative 1. The mechanism of toothbrush alternative 1 was by screwing the neck of the toothbrush.

5.2 Suggestion

- In a subsequent study, it is suggested to measure anthropometric data for the dimension of the toothbrush which are the length of the toothbrush neck, width of the toothbrush neck, thickness of the toothbrush neck, length of the toothbrush head, slope of the toothbrush neck-head, thickness of the toothbrush head, length of the toothbrush bristles and thickness of material.

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