Research and Design of A Modern Multifunctional Toothbrush

Yinming Chen[1,a]†, Xintong Ma[2,b]†, Ruiyi Yang[3,c]†, Fangwen Yu[4]*†
[a]Minachen2006@outlook.com; [b]2087917241@qq.com; [c]6596807@qq.com;
*my6927a@student.american.edu

[1]Shanghai Pinghe Bilingual School , Shanghai, China
[2]South China University of Technology, Guangzhou, China
[3]Windermere Preparatory School, Windermere, FL, United States
[4]Windermere Preparatory School, Windermere, FL, United States
†These authors contributed equally

Abstract. Cleaning teeth is one of the daily routines in people's lives, but troubles caused by using too many tools that are more than tedious, are very common. In this study, a new type of intelligent oral cleaner was designed in view of the inconvenience and some deficiencies caused by the tedious oral care process of the existing toothbrushes. The whole tool is combined with toothbrush, toothpaste, and water flosser. A container for toothpaste is set inside the tool, and a button outside the tool can be pushed, enables people to control the amount of toothpaste at will. At the bottom of the tool, there is a water pipe connecting the water pipe with the base which is a container that users can freely add to the water, this component is used for supplying water for the water flosser. For the purpose of environmental protection, the toothbrush head can be changed separately. This design simplifies the process of cleaning oral cavity, reduces the space occupied by the tools used in brushing, whether people are out or at home. Thus, people's daily troubles can be greatly reduced, and our research has achieved the goal of facilitating oral cleaning tools.

Keywords: toothbrush, flosser, intelligence, design, modern

1 Introduction

1.1 Background

Toothbrushes are an important element in people's modern lives. Since ancient times, people have been making tools to take care of their oral health. For example, around 1600 BC, the Chinese were already using chewing sticks to clean their teeth. In modern times, toothbrushes are constantly evolving, with various types developed to meet consumer preferences. There are also more products dedicated to oral hygiene, such as mouthwash, string floss and water flosser. While the greatest concern with toothbrushes remains their ability to remove plaque accumulates and reduce the chance of developing gingival disease, people are beginning to look for more in modern life: comfort, convenience and aesthetics. For many people, the process of oral

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care has become less than ideal due to the many tools included. This research study and design aims to address this problem by simplifying the tedious and inconvenient oral care process.

1.2 Research

Toothbrush designed for convenience is not a new concept. However, existing research and design has been limited to considering innovations in the toothbrush itself, or has stalled on the first step of combining features for convenience. Recent studies showed that one of the most important attributes of toothbrushes that consumers are looking for is its simplicity [1]. Simplicity refers not only to understandable use but also to an uncomplicated brushing process. Most modern toothbrushes have been developed according to this principle. The most current prevalent trend in toothbrush evolution is the emergence of electric toothbrush. The vibratory motion of electric toothbrushes reduces the need of hand movements during brushing, while improving the efficacy in removing plaque and improving gingival health [2, 3]. The popularity gained by electric toothbrushes is a testament to the strong consumer market for convenient toothbrush designs in modern society. Modern toothbrushes also attempt to divide the toothbrush into sections to accommodate use. Some researchers have focused on the design of replaceable toothbrush heads [4, 5]. This feature allows the toothbrush head to be easily changed when worn out, at the same time reducing the amount of waste generated. In addition to innovating on toothbrush itself, researches were conducted in exploring the other tools involved in oral care. For instance, recent designs propose the transformation of traditional toothpaste into toothpaste tablets [6, 7]. By directly chewing the tablet and moistening the toothbrush with water, people can brush their teeth as normal. The process of oral care is greatly simplified. The abandonment of toothpaste packaging materials has also taken into account environmental concerns. Other researchers began to initiating designs that merge the tools utilized in the oral care process. They integrated toothpaste into the toothbrush to create a single-tool experience while brushing [8-10]. The toothpaste with integrated toothpaste streamlines and improves upon the traditionally cumbersome process, providing a simple approach to make this universal set of bathroom tools in one efficient device. Existing research has attempted to address the simplicity issue of oral care to some extent. However, most of their efforts have been devoted to the basic innovation on toothbrush or mere integration of toothbrush and toothpaste, not much considering the other important elements of oral care, such as water flossing, which is increasingly important in cleaning teeth as studies have shown that it is better at reducing gingivitis than manual toothbrushes and string floss [11]. In general, the existing designs are limited in simplifying the complicated process of modern oral care.

1.3 Overview

The aim of this research study is to design and develop a modern toothbrush that incorporates both the products of toothpaste and water flosser, thereby streamlining a modern person's process of oral care. The design is addressing the consumer concerns about simplicity, and it needs to have a mechanism that is ease of use, ease of refill and clean, hygienic, and durable.

The rest of the paper is organized as follows: Section II shows an overview of the current market of oral care. It then presents a detailed analysis of the product design. The product is a toothbrush containing an integrated toothpaste and integrated water flosser. The upper part of the toothbrush is detachable from the lower part, allowing filling with toothpaste and cleaning. The

toothbrush is equipped with a separate base that is connected to a water reservoir. When inserted in the base, the toothbrush functions as a water flosser. The toothbrush head contains two apertures, one for toothpaste and one for water. After presenting the design ideas, the results, essential testing and evaluation of usefulness to consumers are discussed in Section III. Lastly, a conclusion with future concerns is shown in Section IV.

2 Method

2.1 Market Analysis

As far as the specific needs and sub-categories of oral care are concerned, refreshing breath, whitening, and yellowing have become the most concerned effects of oral care for consumers. Electric toothbrush and toothpaste are the core categories with a relatively high consumption scale, while more advanced oral care products such as water floss and mouthwash show a high consumption growth rate and become the trend category of the industry. In terms of consumer groups, women, Generation Z and urban people occupy a large market share, of which 70% are female customers. If the consumer groups are subdivided according to age, city level and purchasing power, luxury beauty and backbone markets with higher purchasing power account for more than 40% and 30% respectively, becoming the core consumption power of the oral care market, while the young market aged 18-25 has become the driving force of the industry with a growth rate of more than 40%. Different people's pursuit of efficacy is also different. Luxury market and backbone market are faced with problems such as oral ulcer and gingival atrophy, and prefer professional advanced oral care products such as water floss. The young market pays more attention to whitening, yellowing, sterilization, breath freshening and other effects, and the products prefer electric toothbrushes, tooth stickers, mouthwashes and so on. The epidemic situation of COVID-19 promotes the growth of electric toothbrush market. Meanwhile, with the spread of Covid-19 pandemic, people began to pay more attention to their own health and hygiene. Consumer demand for personal care and hygiene products has increased. In terms of product types, the global sales of toothbrushes are USD 35,184.3 million dollars, including USD 31,420.8 million for electric toothbrushes and USD 4,524.2 million for manual toothbrushes. The sales volume of toothpaste is USD 12,921.3 million, of which toothpaste is USD 8,895.5 million, gel is USD 2,657.8 million, powder is USD 1,140.9 million and polishing agent is USD 444.9 million. Mouthwash is currently worth $329.1 million, including $159.8 million with drugs and $176 million without drugs. Different types of dental floss are worth $2.75 billion. According to the calculated by Statista based on the U.S. Census data and Simmons National Consumer Survey (NHCS), 72.42 million Americans used electric-rechargeable power toothbrushes in 2020. And 46.17 million of Americans used battery operated toothbrushes. Obviously, although there are more users of manual toothbrushes, electric toothbrushes occupy most of the market share. And in the future, this trend will gradually increase.

2.2 Design

Most of the existing products are used during travel or at home. Most of the concern about the oral cleaning tools is their large volume, the mad feeling when accidentally squeezing too much toothpaste that causes wasting, the inconvenience because of the number of the oral cleaning

tools which people need to bring with them, and being unwilling when thinking of it's time to change a new brush but cannot bear to. In this context, we hope to design a toothbrush that can be used both during travel and living. No matter what environment the product is used in, the toothbrush needs to optimize the steps of squeezing toothpaste and covering it. When it is used somewhere, it can provide the function of both dental floss and toothbrush. If users want to take it out, they can conveniently put the toothbrush and toothpaste in the bag together, and users have no need to rush to find the dental floss when it is needed. Therefore, combining the concepts of convenience, art and modernity, we propose the following design. The conceptual drawing is shown in figure 1. It can simplify the process of oral cleaning, letting users enjoy this process and add more intelligence to people's lives.

In this design, toothbrush, toothpaste, and water flosser are integrated. The tool is simple in appearance, with a concave-convex structure in the middle which is suitable for people to hold. We divided the whole tool into two parts. Bottom is the container of toothpaste. It is connected with the toothbrush in the upper half and is extruded from the valve port at the lower part of the brush through a pipe. When not in use, the valve port is close, which can prevent air from entering and prevent the inside of the toothpaste from hardening.

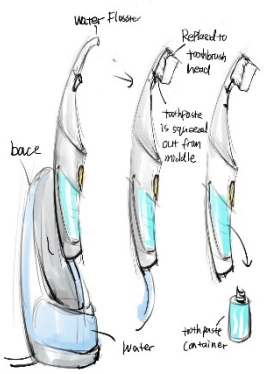

Fig. 1. Conceptual toothbrush design

When the toothpaste is used up, the container can be taken out. Users can squeeze the toothpaste into the container and put it back into the tool. This design can reduce the use of toothpaste packaging materials to some extent. The container of this toothpaste is about half the capacity of regular toothpaste, ensuring users' monthly usage and avoiding feeling heavy when holding the tool. A needle-like structure is at the middle of the toothbrush, used for pushing the toothpaste inside the container. Users can control the amount of toothpaste at will so that the toothpaste can be squeezed evenly and neatly on the brush head, and the toothpaste can be prevented from unnecessary waste. There is no doubt that the details of people’s lives will become more comfortable. At the top, the brush head can be replaced. In this way, when the toothbrush becomes deformed or reaches its hygiene period, people can replace the old brush head with a new one instead of using a brand-new toothbrush. The environmental purpose is obvious and people do not need to be confused and reluctant when having to get a new toothbrush. The underside of the toothbrush is connected to the base of the tool through a hose, which is also a water

reservoir. Its overall capacity is just enough for oral cavity cleaning, so that people can fully enjoy the cleaning process instead of spending time on add water when doing the cleaning. After adding water, the toothbrush can be taken out of the base and only a telescopic tube is attached, which is long enough for people to move the toothbrush freely. The water flosser appears when the brush head is removed. One can use it like a regular water flosser with a nozzle at the top that sprays water quickly to clean the teeth. Just place the brush head back while finishing the irrigation of the teeth, plugging the toothbrush onto the base. When one wants to clean this tool, one only needs to take out the toothpaste container and the brush head and then clean the internal channels, since all the internal structures are connected.

Fig. 2. Structure Demonstration

2.3 Mechanical Structure

There are two heads of the tool that can be used interchangeably. One is the toothbrush head that can squeeze out toothpaste from the center, and the other is the water flosser for further cleaning of teeth. Two channels are mounted inside the toothbrush. One is a water pipe that runs the water from the reservoir base to the flosser head. Through the channel, a tiny water line can be ejected at a high speed to remove debris from the mouth, and at the same time, give the users a gentle sensation. The other one leads to the center of the removable brush head, and the lower part is connected to the toothpaste container. The capacity of the toothpaste container is about half a stick of toothpaste, and it needs to be reloaded after use up. The bottom of the toothpaste is a needle-like structure, which is fixed outside the container of toothpaste being mounted on the toothbrush. The user pushes up the middle button to squeeze the toothpaste out of the toothbrush head. When not in use, the toothbrush can be placed on the base. The base can contain the water needed for per time oral cleaning. When the tool is used as a water flosser, water flows from the base of the water reservoir to the top of the brush through the connected pipe. Water goes from the container to the top through the connected pipe. Structure demonstrations are shown in figure 2.

3 Results

3.1 The Toothbrush Design

The final design of the toothbrush features an integrated toothpaste dispenser with a washable toothpaste container stored inside the body of the toothbrush. The toothbrush head has a toothpaste aperture, as well as an aperture for the water flosser. When needed, water flows from bottom water reservoir through an internal pipe to the aperture on the toothbrush. The toothbrush also features a replaceable toothbrush head that can be changed according to the user's habits.

3.2 Customer Survey

A customer survey was conducted on the design explained in the previous section. A total of 20 participants between the ages of 16 and 49 were recruited. The majority of participants were students and working professionals. To reduce gender bias and increase generalizability, participants consisted of 10 females and 10 males. The survey was divided into three sections: 1) customer habits during oral care, 2) comparison between toothbrushes of different designs, and 3) overall customer feedback on this product design.

The objective of the first section of the survey was to identify the habits of customers during routine oral care. Participants were given five multiple choice questions, listed below:

1. Number of times brushing per day
2. Duration of oral care process
3. The time period for replacing toothbrush/toothbrush head
4. The other supplementary tools used during oral care process

5. Type of toothbrush currently used

These questions were designed to analyze the habits of the general population during oral care in order to reconfirm the need for this design as explained in the previous sections. The participants' responses are presented in Table 1.

The majority of participants brush their teeth twice a day, which is the official recommended number of brushing times [12]. 80% of the respondents brush their teeth twice a day, 15% brush their teeth once a day, and 10% of the respondents reported brushing their teeth three times a day. This confirms that the toothbrush is an important element of modern life. In terms of time spent on the oral care process, 65% of respondents reported spending 5 to 15 minutes, while 35% said they spent less than 5 minutes. None of the respondents reported spending more than 15 minutes. This trend in results may be due to the fact that respondents are predominantly in students ages and tend to spend less time on non-academic related matters. It is worth noting that the relatively short oral care process may indicate weaker and incomplete oral care, such as not using all the necessary tools. This raises the importance of the design discussed in this paper, which incorporates core important elements of oral care in one product to improve efficiency and save time for a fast-paced population while completing the oral care process in a comprehensive manner.

Table 1. Habits About Oral Care

Questions	**Responses (%)**
Number of times brushing per day	
1	15
2	80
>2	10
Duration of oral care process	
Less than 5 min	35
5-15min	65
>15min	0
Time period for replacing toothbrush	
Once a month	30
Once 3 months	65
Once 6 months	10
Other supplementary tools used during oral care process	
Toothpaste	100
String floss	35
Water flosser	45
Mouthwash	60
Tongue cleaner	0
Type of toothbrush currently used	
Manual toothbrush	50
Electric toothbrush	50

65% of respondents indicated that they replace their toothbrush or toothbrush head every three months, which is largely expected. The design of the new toothbrush in this paper needs to

ensure the durability of the replaceable toothbrush heads to last approximately three months or longer. When participants were asked about other tools used in the oral care process, 100% reported they use a toothbrush and 45% said they use water flosser. None of them use tongue cleaner. Despite the high use of mouthwash at 60%, its medical nature makes it unsuitable for inclusion in a toothbrush. Based on these data, the proposed new toothbrush design would satisfy most of the customers' needs. A surprising result was that the same percentage of respondents used manual or electric toothbrushes.

The second part of the survey was to determine customers' evaluation of the features in the three toothbrush designs. Design 1 refers to the design proposed in this paper; Design 2 refers to the basic type of electric toothbrush on the market; and Design 3 refers to the traditional manual toothbrush. Seven core attributes that consumers are concerned about when purchasing toothbrushes were first identified: (1) ease of use; (2) efficiency; (3) utility; (4) economic value; (5) durability; (6) modernity; and (7) environmental friendliness. All seven criteria were given specific percentage weights, which were determined by consensus. Participants were asked to rate these attributes on a scale of 1 to 5, with 1 representing “very poor” and 5 representing “excellent”. The average ratings were recorded, and each multiplied with the weights, which were then added together to obtain a total score.

Table 2. Comparison Between Three Toothbrushes

Attributes	**Weight**	**Design 1**		**Design 2**		**Design 3**	
		Average rating	***Weighted score***	***Average rating***	***Weighted score***	***Average rating***	***Weighted score***
Ease of use	20%	3.974	0.794	4.05	0.810	3.58	0.716
Efficiency	20%	4.248	0.845	3.95	0.770	3.16	0.632
Utility	15%	4.058	0.608	4.00	0.600	3.05	0.458
Economic value	15%	3.341	0.501	3.61	0.542	3.84	0.576
Durability	15%	3.635	0.545	3.58	0.537	3.50	0.525
Modernity	10%	4.455	0.445	4.08	0.408	2.95	0.295
Environmental friendliness	5%	4.211	0.211	3.95	0.198	3.11	0.156
Total Score		3.952		3.865		3.358	

Shown in Table 2, design 1 (the new toothbrush design discussed in this paper) scored particularly high on the attributes "efficiency" and "modernity", with average ratings of 4.24 and 4.45, respectively. This confirms that the design achieves its intention in simplifying the process of oral care for modern people. The lowest average rating for Design 1 was for the attribute of economic value. Its average rating of 3.34 is 7.4% lower than that of Design 2 and 13% lower than that of Design 3. This reveals a general concern about the pricing of this product in the

potential market. With the exception of the attributes "ease of use" and "economic value," the average ratings for Design 1 all exceeds the ratings for Design 2 and Design 3. In addition, Design 1 has a total score of 3.952, which is greater than those for both Design 2 and Design 3. This demonstrates that the product is preferable in customers' perspective and is considered a successful design.

In the last section of the survey four questions were prepared to observe whether the demands of the participants were satisfactory met or not. These questions are as follows:

1. Do you like our new toothbrush design?

2. What do you like the most?

3. What do you like the least?

4. What are your biggest concerns about buying this product?

The feedback indicated that the majority of respondents responded positively and found the design to be creative and useful. Only 6% of respondents reported neutral or negative feedbacks. The answers to the second question indicated that most respondents like the idea of combining three common functions (65%) and some appreciated the replaceable toothbrush heads (10%). The answers to the fourth question indicated that the biggest concern was the price of the product, with many respondents concerned that it would be very expensive. A minority of respondents questioned the practicality of the proposed design.

From this survey, it was noted that the proposed design meets the concerns of most people regarding the oral care process and is preferred over other toothbrushes currently on the market. However, further research should be conducted in the future regarding the price of the product and the actual manufacturing of the product.

4 Conclusion

The paper mainly states the new invention of toothbrushes by combining convenience-oriented devices (toothbrush and toothpaste) with hygiene-oriented sector (flosses) according to the findings of a wide series of market research and literature review. To realize this new design, five essential concepts are employed: First, the container of toothpaste in the body of the toothbrush. Second, is the control of toothpaste amount. Third, the moisture maintaining function for toothpaste. Fourth, the changeable and replaceable toothbrush heads. Finally, the settings of water flosser. Thus, the new toothbrush is more convenient, economic-friendly, and healthy than the traditional toothbrush. Compared to other modern designs, the design discussed herein contains more detailed features of the tools involved in the oral care process. This multi-function design would provide an enjoyable experience for its potential consumers and, presumably, a huge potential commercial value for enterprises. In conclusion, the new toothbrush outperforms the other designs of toothbrushes in the market because of its clean, convenient, and environmental-friendly quality. In the future, according to the current demand of people, we will continue our research on the pricing and materials of this product, as we need products with the right cost performance and high quality. Through the emergence of this new multifunctional toothbrush,

it will bring more convenience and more experience in using toothbrushes, toothpaste and other tools involved, and brushing teeth will no longer require tedious steps to complete.

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