Oral Hygiene System Design

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Oral Hygiene System Design

by Jianlin Nie

A Thesis submitted to the Faculty of
the College of Imaging Arts and Sciences for
the Degree of
Master of Fine Arts, Industrial Design
Rochester Institute of Technology

Master of Fine Arts Degree
Industrial Design
School of Design
College of Imaging Arts and Sciences
Rochester Institute of Technology
May 2016
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Acknowledgements

I would like to thank my thesis advisor Professor Gary Molinari, who taught me about design, built my character, and pushed me out of my comfort zone so that I can become the best version of myself. The door to Mr. Molinari’s office was always open whenever I had a question about my research or design.

I would like to thank my thesis advisor Stan Rickel, who always gave me precious learning experiences and extraordinary support. Also, I would like to express my sincere gratitude to Mr. Rickel for always being approachable, helping me walk through all the setbacks during my design process.

I would like to thank my thesis advisor Dan Harel, for always being accurate and precise, which become the power to push me forward constantly.

I would like to thank my thesis advisor Bruce Leonard, for his valuable advice on ideation, design rationales and aesthetics.

I would like to give my deepest gratitude to my parents, my friends and my classmates. Without your sincere and valuable help, I would not be able to finish my thesis project.

I would like to thank my specialists Hao Zeng and Andrew Hobbs. Without their professional knowledge and explanation in patience, I couldn’t finish the design myself. I appreciate the help of those who were involved in the online survey for this project. Without their passionate participation and input, the validation study would not have been successfully conducted.
Abstract

This thesis is focused on the design of oral hygiene system. According to the research done by the author, poor oral hygiene mainly results from bad oral habits, including not brushing teeth before going to bed, failing to keep using dental floss, never going to dentists, and so on. Based on the findings, the author designed a system of oral hygiene products, an oral health database and platform for home use. As for the market, the initial targeting market is Chinese market. Then it can be promoted for universal use.

These oral hygiene products include a mini camera, smart sensors, a water flosser, a toothbrush, a cell phone holder and a UV sanitizer. The oral health database and the platform have five essential functions including providing basic oral health knowledge; providing methods of self-diagnosis; providing oral health point system; sharing good dental resources; providing communication platform. All functions mentioned above are integrated in a mobile phone application. When people get high points from the point system and get a good evaluation from dentists about their oral health status, they will get lower insurance price from the medical insurance company, where the staff can get access to these data.

Keywords: health, oral hygiene, industrial design.
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Regular oral cleaning is a pleasant and relaxing activity after waking up in the morning and before going to bed at night. It can freshen your breath, remove fatigue and exercise the muscle of mouth. This everyday activity is an essential part of everyone’s daily life. Thus every day, we will need to spend time in washroom, where brushing teeth takes place. The author finds oral hygiene system design interesting because it is a daily activity that concerns health, which deserves more attention. In addition, smell, taste, touch, sight, hearing senses are all involved. Therefore, it is always meaningful to work on better interaction between people and oral hygiene products. The stakeholders include
family members, travel companions, close friends, roommates and so on.

Oral Care is an oral hygiene system consisting of a set of oral hygiene products, an oral health database and platform for everyone. These oral hygiene products include a mini camera, smart sensors, a water flosser, a toothbrush and a UV sanitizer. The oral health database and platform is going to benefit patients, dentists, medical insurance company and dental equipment company.

As for the benefits of this system, first of all, Oral Care can improve oral health by motivating users with the point system. Moreover, it shortens the distance between patients and dentists through the self-diagnosis system as well as oral camera, which also benefits those who live in remote areas. In addition, it will prompt communication between patients, dentists, medical insurance company and dental equipment company. This system will be motivating, educational and inspiring. It will help people establish healthy oral hygiene habits and maintain good oral health at home.
Chapter 1 Background research of oral hygiene

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1. Background Research of Oral Hygiene

1.1 Mouth Anatomy Analysis

The research started with the analysis of mouth anatomy, which is shown in Figure 1 and 2.

![Anatomy of nose, pharynx, mouth and larynx](image)

Figure 1: Anatomy of nose, pharynx, mouth and larynx
Lips: a visible body part at the mouth of humans and many animals. Lips are soft, movable, and serve as the opening for food intake and in the articulation of sound and speech. Human lips are a tactile sensory organ, and can be an erogenous zone when used in kissing and other acts of intimacy. The upper and lower lips are referred to as the "Labium superius oris" and "Labium inferius oris". The juncture where the lips meet the surrounding skin of the mouth area is the vermilion border, and the typically reddish area within the borders is called the vermilion zone. The vermilion border of the upper lip is known as the cupid's bow. The fleshy protuberance located in the center of the upper lip
is a tubercle known by various terms including the procheilon (also spelled prochilon), the "tuberculum labii superioris", and the "labial tubercle". The vertical groove extending from the procheilon to the nasal septum is called the philtrum. [1]

Tooth: (longitudinal section) any of the hard, bony conical structures of the upper and lower jaws used for chewing. A tooth consists of a crown portion above the gum, a root portion embedded in a socket (alveolus) of the jawbone, and a neck or cervical constricted region between the crown and root. The soft-tissue gingiva covers the neck and root to a variable extent, depending on age and oral hygiene. The major portion of a tooth consists of dentin, which is harder than bone; enamel; and cementum, which is similar to bone. The pulp cavity contains the dental pulp. Each tooth has five surfaces: occlusal, mesial, distal, lingual, and facial or buccal. [2]

Tongue: a muscular organ on the floor of the mouth; it aids in chewing, swallowing, and speech, and is the location of organs of taste. The taste buds are located in the papillae, which are projections on the upper surface of the tongue. The condition of the tongue can sometimes be a guide to the general condition of the body. Glossitis (inflammation of the tongue) can accompany anemia, scarlet fever, nutritional deficiencies, and most general infections. Sometimes it is part of an adverse reaction to medication. One form of glossitis causes a smooth tongue, with a red, glazed appearance. A coated or furry tongue may be present in a variety of illnesses, but does not necessarily indicate illness. A dry
tongue sometimes indicates insufficiency of fluids in the body, or it may result from fever. When the tongue is extremely dry and has a leathery appearance, the cause may be uremia.\textsuperscript{[3]}

Soft palate: the structure composed of mucous membrane, muscular fibers, and mucous glands, suspended from the posterior border of the hard palate forming the roof of the mouth. When the soft palate rises, as in swallowing and in sucking, it separates the nasal cavity and the nasopharynx from the posterior part of the oral cavity and the oral part of the pharynx. The posterior border of the soft palate hangs like a curtain between the mouth and the pharynx. Suspended from it is the conical, pendulous, palatine uvula. Arching laterally from the base of the uvula are the two curved musculomembranous pillars of the fauces. In dentistry, the soft palate serves as the anatomical landmark for construction of a maxillary full denture and establishment of a seal which helps retain the denture in the mouth.\textsuperscript{[4]}

Hard palate: the bony portion of the roof of the mouth, continuous posteriorly with the soft palate and bounded anteriorly and laterally by the alveolar arches and the gums. The hard palate is covered with stratified squamous epithelium and furnished with numerous palatal glands lying between the mucous membrane and the surface of the bone.\textsuperscript{[5]}

Salivary glands: the glands in the mouth that secrete saliva. The major ones are the three pairs known as the parotid, sub maxillary, and sublingual glands (see Plates); there are other smaller salivary glands within the cheeks and tongue. The largest are the parotids, located below and in front of each ear. Saliva secreted by these glands is discharged into the mouth through openings in the cheeks on each side opposite the upper teeth. The submaxillary glands, which is located inside the lower jaw, discharge saliva upward through openings into the floor of the mouth. The sublingual glands, beneath the tongue, also discharge saliva into the floor of the mouth.[6]

Gingiva (gums): it is part of the soft tissue lining of the mouth. They surround the teeth and provide a seal around them. Compared with the soft tissue linings of the lips and cheeks, most of the gingivae are tightly bound to the underlying bone, which helps resist the friction of food passing over them. Thus when healthy, it presents an effective barrier to the barrage of periodontal insults to deeper tissue. Healthy gingiva is usually coral pink, but may contain melanin pigmentation.[7]

Mouth is a window into what’s going on in the rest of the body. It can also serve to help the early detection of many diseases. In fact, according to the Academy of General Dentistry, more than 90 percent of all systemic diseases are accompanied by oral symptoms. Therefore, based on the structure we can predict oral illnesses from some symptoms.
1.2 Definition of Oral Health

From the historical point of view, Dr. David Satcher, the United States 16th Surgeon General, made it known that oral health is far more comprehensive than healthy teeth. He stated that optimal oral health means being free of chronic facial pain conditions, oral or throat cancers, oral lesions, cleft lip or palate, and all other diseases and conditions that may affect the tissues of the head, face, and neck collectively known as the craniofacial complex (USDHHS, 2000). Oral health status is known to be the precursor of one’s general health status. Oral health has the potential to affect one’s general health by causing pain by changing eating habits, speech patterns, and, ultimately, one’s quality of life. Poor oral health can affect other chronic diseases and conditions as well (Petersen, 2003). Oral disease has been thought of as the most common disease of humanity (Hendricson & Cohen, 2001). Oral health has been associated with nutrition, physical growth, speech, self-image, and societal functioning (Mouradian, 2001). Oral health is a functional, structural, aesthetic, physiologic and psychosocial state of well-being and is essential to an individual’s general health and quality of life (ADA House of Delegates, 2014). Nowadays, oral health means much more than healthy teeth. Risk factors for oral diseases include unhealthy diet, tobacco use, harmful alcohol use, and poor oral hygiene. 

[8] [9]
Therefore, taking good care of mouth, teeth and gums is a worthwhile goal itself.
1.3 Basic Knowledge of Oral Hygiene

The American Dental Association (ADA) (2012) says that proper oral hygiene includes: (a) brushing teeth at least twice per day with an ADA approved fluoride toothpaste; (b) replacing toothbrushes every 3 or 4 months; (c) cleaning between teeth on a daily basis with floss or an interdental cleaner; (d) eating a balanced diet, limiting sweets and in-between-meal snacks; and (e) visiting a dental professional on a regular basis for professional cleanings and oral exams\[^{10}\].

However, the process is not all plain sailing. According to United States Department of Health and Human Services, the barriers to oral health include lack of access to care, whether because of limited income or lack of insurance, transportation, or the flexibility to take time off from work to attend to personal or family needs for care. Individuals with disabilities and those with complex health problems may face additional barriers to care. Sometimes, too, the public, policymakers, and providers may consider oral health and the need for care to be less important than other health needs, pointing to the need to raise awareness and improve health literacy. Many unanswered questions remain for scientists, practitioners, educators, policymakers and the public. This report highlights the research challenges as well as pointing to emerging technologies that may facilitate finding solutions. Along with the quest for answers comes the problem of applying what is already known in a society where there are social, political, economic, behavioral, and
environmental barriers to health and well-being\textsuperscript{11}.

As is known to all, perfect oral hygiene helps people prevent tooth decay, bad breath, gum disease and keep their teeth as they get older. Researchers are also discovering that a healthy mouth may help people keep away medical disorders. In contrast, an unhealthy mouth, especially one with gum disease, may increase people the risk of serious health issues such as stroke, heart attack, poorly controlled diabetes and preterm labor.

1.4 Importance of Oral Hygiene

As the previous research shows, oral hygiene has a significant impact on people physical and mental health. Then how to understand the importance in detail? Does oral hygiene has anything to do with self-image, work efficiency, mouth muscle, personality or psychological health? To dig into the topic, the author started to refer to academic papers.

According to S. Honkala, E. Honkala and N. Al-Sahli, the summary variables of life- and school-satisfaction and self-esteem were all strongly associated with tooth brushing frequency among both boys and girls. Life- and school-satisfaction as well as self-esteem indicators seemed to be strongly related with recommended tooth brushing and weekly with regular flossing\textsuperscript{12}, which proves that there is a positive relationship between oral
hygiene and psychological health. Also, according to Garza Lynn Marie, The risks and benefits of oral health and hygiene, will determine the overall psychological effects on self-esteem. Bad oral health can be detrimental to one’s social life, and can have an impact on the quality of life one lives[^13], which, additionally, proves the same theory.

According to Woelber Johan P and Bienas Helena, their study showed a positive relationship between oral hygiene-related self-efficacy and important indicators of oral health including less gingival bleeding for non-smoking patients, a greater likelihood of appearance of the patient to the dental practice, higher efforts of the patient to receive professional tooth cleaning and larger goals in inter-dental hygiene planning[^14], which provides solid evidence that good oral hygiene can promote work efficiency. Meanwhile, according to Knight Shelton Taneshia, Based on the findings, it appears that the participants reported high levels of self-efficacy and high levels of intention to practice proper oral hygiene. The relationship of self-efficacy and the intent to practice proper oral hygiene was proven to be statistically significant[^15], which also shows the connection.

According to Thomson, W. Murray and Caspi Avshalom, there is a consistent association between negative emotionality and poorer self-reported oral health, whether measured using a sophisticated scale or a single item[^16], which proves the connection between oral hygiene and personality.
Although further proofs and investigations are needed to draw a conclusion, this can point out the direction for future researches.

1.5 Common Oral Diseases

The most common oral diseases are periodontal (gum) disease, dental cavities, oral cancer, trauma, oral infectious diseases and hereditary lesions.

Dental cavities: worldwide, nearly 100% of adults and 60–90% of school children have dental cavities, often leading to pain and discomfort.\[17\]

Figure 4: Dental cavities

Periodontal disease: severe periodontal disease, which may result in tooth loss, is found in 15–20% of middle-aged (35-44 years) adults.\[17\]
Tooth loss: periodontal disease and dental cavities are leading causes of tooth loss.

Complete loss of natural teeth is widespread and mainly affects older people. Globally, about 30% of individuals aged 65–74 have no natural teeth.\[^{17}\]

Oral cancer: the incidence of oral cancer ranges from one to ten cases out of 100 000 people in most areas. The prevalence of oral cancer is higher in older people, in male and among people of low education and low income. Alcohol and tobacco are major causal factors.\[^{17}\]
According to WHO, prevention and treatment include: (a) decreasing sugar intake and maintaining a well-balanced nutritional intake to prevent tooth decay and premature tooth loss; (b) consuming fruit and vegetables that can protect against oral cancer; (c) stopping tobacco use and decreasing alcohol consumption to reduce the risk of oral cancers, periodontal disease and tooth loss; (d) ensuring proper oral hygiene; (e) using protective sports and motor vehicle equipment to reduce the risk of facial injuries.\[17\]

In conclusion, most oral conditions and diseases require professional dental care, but due to limited availability and accessibility, the utility rate of oral health services is remarkably low among the elderly, rural residents and people with low income and poor education. In addition, there is low oral health care coverage in low- and middle-income countries.
Chapter 2 User Understanding

2.1 Common Problems

2.2 Online Survey

2.3 Interviews with Dentists

2.4 Personas
2. User Understanding

2.1 Common Problems

Putting ourselves in the users’ shoes, some common issues were studied based on the problems occurred in real life.

Bad tooth brushing habits: falling asleep without brushing teeth, not enough brushing time, not flossing, brushing too hard, not changing toothbrush or not cleaning regularly enough.

Children dislike brushing their teeth: it can be a challenge because young children can only be attracted by pleasure and fun, without realizing the importance of health and necessity.

Do not clean teeth after meals: foods and drinks, especially those high in carbohydrates and sugar will activate bacterial growth in the mouth that ruin tooth enamel for at least twenty minutes after eating a meal or having a snack. By brushing right after eating, bacteria will be removed before they attack tooth enamel.
Do not floss: flossing is an essential part of taking care of teeth and gums. The American Dental Association recommends that flossing at least once a day to help remove plaque between teeth where the toothbrush can’t reach.

An electric toothbrush is hard to carry around: big in size and needs to be charged.

Public places do not provide cups: ordinary cups are difficult to carry around.

Bristles are not comfortable to use: many people do not know how to choose brush for their teeth. Most dentists agree that the soft bristle toothbrush can suffice the cleaning needs of most people. It gently removes the plaque and debris from the teeth.

Messy washroom: messy, unventilated and humid washroom keeps toothbrushes and cups wet and dirty. Dirt is hidden at the bottom of cups.

To sum up, as Figure 8 shows the problems of people’s bad oral hygiene habits are most to blame. Therefore, people need access to more oral hygiene knowledge and feedback of their oral health status.
<table>
<thead>
<tr>
<th>Catalogue</th>
<th>How to solve</th>
<th>Examples</th>
<th>Priority</th>
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<tbody>
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<td>Problems of habits</td>
<td>Access to oral hygiene knowledge</td>
<td>Feedback of oral health</td>
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<td>Problems of products</td>
<td>Provide better user experience</td>
<td>Portable, modular and smart oral hygiene system</td>
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<td>User needs</td>
<td>Create new possibilities</td>
<td>Ultraviolet light sterilizer, smart sensors</td>
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Figure 8: Common problems

2.2 Online Survey

The previous research shows that oral hygiene is closely related to people’s physical health. Then what is the present situation of oral hygiene? Moreover, the author was wondering how to bring the project to a higher level? The project is not only aimed at creating useful products to serve people, but also making the whole oral cleaning process more motivating, educational and inspiring, which can solve the problem in an in-depth and comprehensive way. Therefore, the author conducted an online survey on Survey Monkey about oral hygiene.

The Oral Health Questionnaire took place in the primary stage of the research. The questions in it are concise and to the point, which will provide the author with an overall understanding of the current situation of oral hygiene. The topics covered in the
questionnaire include: sensors in toothbrush, receiving feedback from dentists, reminders from something or someone, more knowledge, provide much more fun, exercise mouth muscle, modular system for future development. Furthermore, it will guide the whole design process during the next stage. All of the questions were confirmed, tested and modified at the beginning of October 2015. The Oral Health Online Survey started on October 15th 2015 and lasted for one month. 100 valid responses were collected. The content is about people’s habits, feelings and evaluations of oral hygiene.

![How often do you see a dentist?](image)

Figure 9 Frequency of going to the dentist
As the formal research shows, annual cleanings and examinations may be adequate for adults without periodontal diseases while people with a higher risk may need to go more often. However, as Figure 9 shows, there are still 48% of the people surveyed that cannot meet the criterion. The reason behind this maybe expensive dental inspection, lack of time, inconvenient transportation and so on, which needs further investigation. In terms of people’s view towards oral cleaning, as Figure 10 shows, 46% of people showed an optimistic attitude, while 38% of people dislike the mouth-cleaning process. It’s not hard to find that there is still space for improvement in term of the user experience of oral cleaning.

Figure 10: Feels of mouth cleaning
Figure 11: Feelings about oral hygiene knowledge

When it comes to knowledge, as Figure 11 shows, most people think more oral knowledge will help them improve their health. On the one hand, a lot of people may lack professional oral health knowledge. On the other hand, most people admire knowledge, which, in other words, is education.
Figure 12: Habits of brushing teeth

Figure 13: Habits of flossing
When it comes to personal habits, lots of people cannot meet the standard of flossing at least once a day and brushing teeth at least twice a day. As Figure 12 and 13 show, the results are not promising, especially, in terms of flossing. Most frequently used excuses are, too tired before going to bed, forgot and didn’t form a good habit. Figure 14 shows most people believe it will help them enjoy the oral cleaning process if more interesting elements are involved.
Figure 15: Meaning of oral hygiene

Figure 16: Meaning of good breath
Figure 17: Feelings of oral cleaning movement

As the Figure 15 and 16 show, people believe good oral hygiene can help them improve their self-image and focus on work. Meanwhile, people are interested in trying a new way to improve their oral health. Therefore, as Figure 17 shows, most people have realized the importance of good oral hygiene and are willing to try even weird exercise.
Lastly, according to Figure 18, people tend to believe smart sensors and feedback from dentists, could improve their oral health, which represents they believe in technology and authority.

In conclusion, education, technology and authority can be the keywords for further development, which needs more investigating in next stage.

2.3 Interviews with Dentists
As Figure 19 shows, after concluding all the work in previous research, the author came up with the first assumption. In the triad of assumptions, patients, dentists and medical insurance company will benefit from each other. An extensive hygiene knowledge database and remote diagnose system will bring them together. At this stage, the project is about a set of oral hygiene products, including but not limited to the toothbrush, floss,
oral rinses, toothpaste and gum, which can potentially make up a system for oral cleaning.

Also, new interactive ways were explored to provide users with better user experience and better health. To test this assumption and some previous ideas, the author did an interview with Andrew Hobbs, who is a dental assistant at Monroe Community College.

Below are the five interview questions:

1. Which methods and tools are you using for dental inspection?
2. Could you make a diagnosis by remote smart sensors and pictures of teeth and mouth?
3. What kind of knowledge do your patients have to know?
4. Are you willing to cooperate with medical insurance companies if they can bring you more patients but you have to write personal oral health evaluations for them?
5. Would it benefit you to have an extensive database of oral health information?

Below are the answers:

1. In our clinic, we use a variety of methods to evaluate our patients. We have them fill out a comprehensive medical history, including past/current conditions and medications. We do an oral-facial screening to detect cancers in the mouth and the face. We use dental tools, like the explorer, to determine the extent and location of plaque and tartar deposits. We utilize periodontal screenings and probing to determine gum health. Various methods are used to screen for decay and potential caries (cavities), including intra-oral, ultra-violet light cameras. Radiographs (x-rays) are very useful in determining the health
of a patient’s bone and teeth. These are just a few, as dental products abound, as you have probably seen on the Internet.

2. Some offices have experimented with remote patient screenings, having a hygienist present with the patient, while consulting with the doctor over the web using cameras and etc. We do not have that experience in our school clinic.

3. We strive to educate our patients, according to their ability/willingness to understand and carry out our recommendations. Our goal is to help them achieve a high standard of self-care at home. It can be accomplished by a number of means tailored to meet the patient’s needs. These interventions may include: Tooth brushing technique, flossing (or other dental aids) instruction, using of oral rinses, dentifrices (toothpastes), fluoride treatments and etc. We want them to understand the relationship between their oral health and their overall well-being. We hope that with each visit, they will make more and more positive changes to their health and self-care.

4. I don’t have a lot of knowledge of the relationship between health insurance companies and the office. I would suggest talking to a clinician in practice, or to a dentist who manages their practice.
5. Yes, I believe it would. Having a database of dental knowledge that was readily available to use in office would help a lot in helping us educate our patients as well as make good clinical decisions.

According to Andrew’s answers, a large database of oral health knowledge would help a lot. However, he is not sure about the remote diagnose system part, which requires further research in the next stage. Afterward, the author made another interview with Hao Zeng, who is a doctor of dental surgery at Wuhan University. Mr. Hao is quite optimistic about both the remote diagnosis system and oral hygiene knowledge database. He believes communication between patients and dentists is significant so that a platform can be added to the database. Also, he suggested that dental equipment company has the motivation to invest a large sum of money to get information feedback to guide their product development. Moreover, talking about the form of the database and platform, both Mr. Hao and the author thought a cellphone application would be the best way because of its convenience, popularity and maturity. In addition, He thought that a point system like those that record sports statistics would help while medical insurance company can access these data and provide lower insurance price to healthy people. Therefore, as Figure 20 shows, the tetrad of assumptions camp up.
2.4 Personas

As Figure 21, 22 and 23 show, concluding all the information acquired in the user understanding stage. The author created three personas as the target users for future design.
Figure 21: Persona of Jianguo Chen

Jianguo Chen, 45
Primary School Math Teacher

Personality

Extrovert
Introvert
Sensing
Intuition
Thinking
Feeling
Judging
Perceiving

Technology

IT and Internet
Software
Mobile Apps
Social Networks

Lifestyle
- Jianguo is right-handed.
- He speaks aloud and enjoys talking.
- He is a well-respected and passionate person.
- He has a style of making everything under control.

Interests
- He likes jogging.
- Banana is his favorite fruit.
- Grey is his favorite color.
- He dislikes too much pressure from work.
- He likes geometry shape and traditional patterns.

Oral Hygiene Habits
- He brush teeth twice a day.
- He doesn’t floss.
- He went to dentist less than once a year.
- He likes to try new things like electric toothbrush but when he find it noise and hard to carry around, then he goes back to the traditional toothbrush.

Goals
- His life goal is making his students achieve academic progress and success, giving students good impact and earning reputation.
- His goal of oral health is keeping good oral hygiene habit, getting rid of plaque as well as bad breath and having white teeth.
**Figure 22: Persona of Xiaoyu Xie**

**Personality**
- Extrovert
- Introvert
- Sensing
- Intuition
- Thinking
- Feeling
- Judging
- Perceiving

**Technology**
- IT and Internet
- Software
- Mobile Apps
- Social Networks

**Lifestyle**
- Xiaoyu is right-handed.
- She is a quiet, careful and kind person.
- She enjoys slow-paced life.
- Sometimes she stays up late to finish her work.

**Interests**
- She loves drawing.
- Strawberry is her favorite fruit.
- Pink is her favorite color.
- She dislikes impolite people.
- She likes organic shape and patterns.

**Oral Hygiene Habits**
- She brushes teeth twice a day.
- She keeps flossing for health but she felt bored.
- She went to dentist less than once a year.
- She may fall sleep without brushing teeth but then she will brush one more time the other day.
- She is in good oral health status.

**Goals**
- Her life goal is marrying a handsome and talented man who can accompany her traveling around the world.
- Her goal of oral health is to keep good oral hygiene habit, having white teeth.
Lifestyle
-Dali is right-handed.
-He is an outgoing and active person.
-He enjoys slow-paced life.

Interests
-He loves eating delicious food.
-Sometimes he stay up late to finish his work.
-Watermelon is her favorite fruit.
-Blue is his favorite color.
-He dislikes arguing with others.
-He likes simple shape and patterns.

Oral Hygiene Habits
-He brush teeth twice a day.
-He always forget to floss while he knows it is important.
-He went to dentist less than once a year.
-He may fall asleep without brushing teeth, especially after working at late night.

Goals
-His life goal is making more money to afford a comfortable house for his family.
-His goal of oral health is to keep good oral hygiene habit, having white teeth and keeping away from all kinds of oral diseases.

Figure 23: Persona of Dali Wang
Chapter 3 Further Research about Potential Ideas

3.1 The Potentiality of Remote Diagnose in Future  
3.2 Technology Related to Oral Cleaning Products  
3.3 The Environment Analysis of Bathroom
3. Further Research about Potential Ideas

3.1 The Future Potential of Remote Diagnose

Taking previous research into consideration, the author still needs proof to support that remote dental diagnosis is promising in the future. On the Internet there are lots of supportive voices. According to Anshuman Das, “Remote diagnosis for rural patients will become a true possibility through telemedicine centers. Screening in rural areas will help hospitals identify patients at early stages, effectively increasing and evaluating the influx of symptomatic patients, thereby establishing India’s first widespread early detection system for oral cancers[18].” Additionally, the tele-diagnosis by digital photographic technology, presented as identifying potential dental problems and is a resource to be exploited. Therefore, it seems remote diagnose system is valuable, feasible and promising, especially to children in rural areas, through public opinions.

However, the author still needs substantial evidences from the experiments. For example, what do people in academic circle think? According to Amável Rui and Cruz-Correia Ricardo, results suggest that remote diagnosis of children dental problems based on non-invasive photographs constitute a valid resource when we pretend to exclude referred children to a dentist for treatment of dental problems, but further studies should be carried out to increase the validity of this proceeding to referring children for the same treatment[19]. Also according to Patterson S and Botchway C, in under-serviced or remote
areas, the tele-diagnosis system may allow for accurate identification of oral conditions and act as a means of consultation at a distance between specialists, general dental practitioners, dental hygienists and individual patients\textsuperscript{[20]}. 

To sum up, in this stage, the author assumed remote diagnose is a useful and promising technology to be put in the system.

3.2 Technology Related to Oral Cleaning Products

Sonic electric toothbrush: the motion and vibration of the brush have to be quick enough to produce a sound that is within the audible range of the human ear (20 Hz to 20,000 Hz). Sonic brushes typically produce 24,000-48,000 movements per minute. Sonic brushes rely on a sweeping motion to clean the teeth\textsuperscript{[21]}.

Ultrasonic electric toothbrush: an ultrasonic toothbrush is one that using a very high frequency of vibration referred to as ultrasound to remove bacteria and plaque from the teeth. The brush has to emit a wave of 20,000Hz per minute, considerably more than the sonic technology\textsuperscript{[21]}. 
Ionic toothbrush: the ionic toothbrush produces negative ions, which travel along the toothbrush rod into the mouth, where the saliva mixes these negative ions to acids produced by bacteria, which cause plaque. When the negative ions reach the plaque, they draw positive hydrogen ions out of the plaque, which will damage its molecular structure and dissolve it away.[22]

Blizzident: a 3D-printed toothbrush, looks like a mouth guard lined with 600 bristles. People bite down into the 3D replication of the mouth and grind the teeth on the bristles, which cleans all of the teeth simultaneously.[23]

Water flosser: a water flosser is an oral hygiene appliance designed for dental care at home. A typical water flosser includes: motor with pump, water reservoir, special water flosser tips. The motor and pump emit a stream of pressurized, pulsating water to flow from the water tank through the tip and into the mouth. The targeted stream of water removes plaque, food particles and bacteria in an effective, comfortable and easy way.[24]

Air floss: the air floss is a new device to remove plaque biofilm between the teeth. It uses a rapid burst of air and water droplets to disrupt the biofilm between the teeth.[25]
Dental intraoral camera: it is designed to allow dentists to capture and display digital images from inside a patient’s mouth. A problem like a fractured tooth can be spotted and hard to ignore since it is magnified on a TV screen or computer monitor. Most dental intraoral cameras are highly portable and easily connect to a network wirelessly. Most are commonly equipped with LEDs so that digital cameras can capture images without the need for external lighting\(^{[26]}\).

UV light dental cleaner: it uses germicidal UV light to clean and sanitize orthodontic devices, dentures, athletic mouth guards, and teeth whitening trays\(^{[27]}\).

Considering that air floss, ionic toothbrush and blizzident are not mature enough in terms of technology and application, the author decided not to use them in the oral care design. The author chose electric toothbrush and water flosser to put into the hardware of the oral care system. Moreover, a mini oral camera is necessary for the remote system while a UV light cleaner is also needed for cleaning all the parts. However, how to choose between sonic and ultrasonic toothbrush, and why are they better than a manual one are waiting to be discussed. Below is an article to discuss.

According to Thomas P. Connelly, a practicing dentist, “I will say that the evidence does suggest that a sonic toothbrush will indeed clean areas that a conventional brush cannot.
This is because the extreme vibration creates a substantial amount of energy and motion, powering mouth fluids (saliva, water, toothpaste) into the areas between teeth and below the gum line. The result is these areas are given an amount of attention that otherwise would not happen with a standard (or electric) toothbrush. So in that sense, a sonic brush is definitely superior to a standard brush. In addition, studies have shown that people brush longer with a sonic toothbrush. All else being equal, brushing longer is usually a good thing, so score another point for sonic toothbrushes. Lastly, many sonic toothbrush users report that their teeth “feel” better with a sonic toothbrush. That’s worth considering.

However, that doesn’t mean they are truly “better.” As is said earlier, it depends on you and your oral hygiene routine. If your daily routine includes using a standard toothbrush for two minutes, and also floss, you are getting everything (and more) than a sonic toothbrush can give. Flossing scrapes/cleans the areas where a normal toothbrush cannot reach, and it does so better than any sonic toothbrush can (please don’t think a sonic toothbrush is a substitute for flossing, despite whatever advertisement claims.) Also, some people use a water flosser (like a Water Pik®) — again, this goes beyond what a sonic toothbrush can do.

So in the end, it really depends on you. If you don’t floss (and I’m a realist — I know most people don’t), a sonic toothbrush will certainly serve you better than a regular toothbrush, and is probably worth looking into. But if you do brush diligently and floss
regularly (and/or use a water flosser), a sonic toothbrush probably isn’t totally necessary — you are likely covering all the bases with your current oral hygiene routine (and congratulations on doing well in this area.)

But if you REALLY want to be sure, a sonic toothbrush AND flossing AND water flossing is an unbeatable combination. At least until technology gives us laser-powered nuclear fusion space-age super toothbrushes[28].”

In conclusion, considering all the elements above, the combination of a sonic brush, a water flosser and a mini oral camera will be useful and effective as the hardware part of the system.

3.3 The Environment Analysis of Bathroom

According to Wikipedia, “A bathroom is a room for personal hygiene activities, generally containing at minimum a toilet and sink. A bathroom may also contain a mirror, a bathtub or a shower, and possibly also a bidet. In North America and some other regions, it characteristically contains at least a toilet and a sink; hence in North American English the word “bathroom” is commonly used to mean any room containing a toilet, even a public toilet (although in the United States this is more commonly called a restroom). In other countries, including the UK, Australia, France, Eastern Europe and Japan, homes may have a separate toilettroom. In Iran almost all homes have two
distinct rooms for the bathroom and the toilet room. Bathrooms often have one or more
towel bars or towel rings for hanging towels. Some bathrooms contain a medicine cabinet
for personal hygiene products and medicines and drawers or shelves for storing towels
and other items.

The design of a bathroom must account for the use of both hot and cold water, in
significant quantities, for cleaning the human body. The water is also used for moving
solid and liquid human waste to a sewer or septic tank. Water may be splashed on the
walls and floor, and hot humid air may cause condensation on cold surfaces. From a
decorating point of view the bathroom presents a challenge. Ceiling, wall and floor
materials and coverings should be impervious to water and readily and easily cleaned.
The use of ceramic or glass, as well as smooth plastic materials, is common in bathrooms
for their ease of cleaning. Surfaces like that are often cold to the touch, however, and so
water-resistant bath mats or even bathroom carpets may be used on the floor to make the
room more comfortable. Alternatively, the floor may be heated, possibly by strategically
placing resistive electric mats under floor tile or radiant hot water tubing close to the
underside of the floor surface.

Electrical appliances, such as lights, heaters, and heated towel rails, generally need to be
installed as fixtures, with permanent connections rather than plugs and sockets. This
minimizes the risk of electric shock. Ground-fault circuit interruptor electrical sockets can reduce the risk of electric shock, and are required for bathroom socket installation by electrical and building codes in the United States and Canada. In some countries, such as the United Kingdom, only special sockets suitable for electric shavers, and electric toothbrushes are permitted in bathrooms, and are labeled as such. UK Building Regulations also define what type of electrical fixtures, such as light fittings (i.e. how water-/splash-proof) may be installed in the areas (zones) around and above baths and showers. Contrary to some information provided with bathroom light fittings, sinks and basins do not affect bathroom zones, as a bathroom is solely defined as a room containing a bath or shower, by wiring regulations. It is still, nevertheless good practice to avoid installing unsuitable fixtures close to sinks, as damage from water splashes may occur.

Bathroom lighting should be uniform, bright and must minimize glare. For all the activities like shaving, showering, grooming etc. one must ensure equitable lighting across the entire bathroom space. The mirror area should definitely have at least two sources of light at least one foot apart to eliminate any shadows on the face. Skin tones and hair color are highlighted with a tinge of yellow light. Ceiling and wall lights must be safe for use in a bathroom (electrical parts need to be splash proof) and therefore must carry appropriate certification such as IP44. Bathroom chandeliers for example should always be rated IP44. “
Also, as Figure 24 shows, the bathroom is a humid but cozy place. To make the oral care system integrated into the bathroom, the design language of the oral care system should be of the same style.
Chapter 4 Design Process

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4. Design Process

4.1 Ideation

Figure 25: Mind map 1

Figure 26: Mind map 2
The author’s design process started with mind maps. Firstly, as Figure 25 shows, the author began with the word oral hygiene and tried to come up with as many words as possible related to oral health in categories like stakeholders, current situation, history and future. Then, as Figure 26 shows, the second step is to categorize all of the words into another new category. Lastly, as the Figure 27 shows, different questions were generated from the new mind map such as:

1. Is there a relationship between oral hygiene and better self-image?
2. Can we make oral hygiene easier?
3. How can we make a nice and fancy oral hygiene package system for travelers?
4. Can we improve our work efficiency with good oral hygiene?
5. How can we get more information about our health through oral hygiene activities?
6. Is flossing an important habit?

7. What is the relationship between oral hygiene and personality?

8. How can we play with germ in our mouth?

Afterward, with these questions and guidelines from previous researches the author started sketching some potential deliverable products.

![Figure 28: Sketches](image)

As precious researches show, the bathroom is a humid but cozy place. To make the oral care system integrated into the bathroom, the design language of the oral care system should be of the same style. So as for the appearance of the products, it can be round, smooth, gentle, mild and elegant. On the other hand, mouth, as a theme of the whole design can be related as well. Next, considering the function, as the former research shows, the system should have an electric toothbrush, a water flosser, a mini oral camera.
and a UV light cleaner. The handle part of the product should be modular to meet the need of multi-function. In addition, in order to connect the database, send out pictures for remote diagnose and recording daily oral cleaning information there should be a cell phone holder. Therefore, after negotiating with thesis committee members, the author chose the concepts that showed in Figure 29, 30 and 31 as primary concepts for further development.

Figure 29: Sketch 1
Figure 30: Sketch 2

Figure 31: Sketch 3
4.2 Final Concepts

As is shown in Figure 32, the hardware consists of a cellphone holder, a mini oral camera, smart sensors, a water flosser, an electric toothbrush and a UV sanitizer box. As Figure 33, 34, 35 and 36 show, it has four basic working modes including toothbrush mode, oral camera mode, water floss mode and changing tips mode, all of which, when working together can help people keep good oral hygiene as tools.
Figure 33: Toothbrush mode

Figure 34: Oral camera mode
Figure 35: Water flosser mode

Figure 36: Changing tips mode
As Figure 37 shows, the oral hygiene database and platform have five basic functions. Such as, providing basic oral health knowledge, providing methods of self-diagnosis, providing oral health point system, sharing good dental resources and providing instructions of choosing dentists and dental equipment, providing communication platform for users, dentists, medical insurance company and dental equipment company. All of these functions are combined in a cell phone application as Figure 38 shows.
Figure 38: Cellphone application interface

1. Provide basic oral health knowledge

Figure 39: Knowledge
As Figure 39 shows, regarding knowledge part, dental equipment company provides investment to the medical insurance company to help construct the database in exchange of medical research results and feedback, which can help their product development.

Within the oral health knowledge system, patients get instructions for daily oral cleaning and pre or post surgery oral health suggestions. Dentists help to answer questions online.

![Figure 40: Self-diagnosis method](image)

As Figure 40 shows, speaking of the self-diagnosis system, patients get step-by-step self-diagnosis instructions and provide primary oral health status collected by the oral camera and smart sensors in return. Dentists deal with primary oral health status from patients.
As Figure 41 shows, when it comes to the point system, patients provide the primary oral health status collected by the oral camera and smart sensors while getting evaluation and feedback about their oral health. The higher the points are from the point system, the lower the insurance premium will be from the medical insurance company, which is able to access these data at the cloud, if they are in perfect oral health status. Dentists write personal oral health evaluation.
As Figure 42 shows, while patients provide feedback on choosing dentists and equipment, dental equipment company can get chances of putting an advertisement. At the same time dentists can also get professional training.
As Figure 43 shows, patients, dentists and dental equipment companies get precious opportunities of exchanging ideas with each other.

Taking all the facts into consideration, as Figure 44 shows, the square shape assumption is formed.
4.3 Final Outcomes

The author 3D printed the appearance model and made the testing cell phone application.
4.4 Scenarios

Figure 46: A traditional way of conducting a tooth implanting surgery
As Figure 32 and 33 show, in the past, a patient needs to go to the dentists several times before and after the surgery to finish primary examination and post-surgery examination, which costs a lot of time and energy both for the patient and the dentists. However, with the introduction of the oral hygiene system, the patient can finish the primary examination and post-surgery examination at home by the self-diagnosis system. It will save plenty of energy and time both for patients and dentists. In an assumed case, if a patient living in rural China gets a severe oral cancer, there are only a few who might be able to cure him while the best one lives in Chicago. So through the remote diagnose system, his chance of survival would significantly improve.

4.5 Design Statement

Oral Care is an oral hygiene system, consisting of a set of oral hygiene products and an oral health database and platform for all people. These oral hygiene products include a
mini camera, smart sensors, a water flosser, a toothbrush and a UV Sanitizer. The oral health database and platform is going to benefit patients, dentists, medical insurance company and dental equipment company. This system will be motivating, educational and inspiring. It will also help people establish healthy oral hygiene habits and good oral health at home.
Conclusion

My intent was to design a system that will have the chance to help people get better oral health and provide better interactive experience. Moreover, to be a motivating, inspiring and educational system. The outcomes and findings of the whole thesis process met the initial aim, thanks to the step-by-step, thorough and comprehensive research.

Oral Care is related to oral hygiene system design. The author designed a system of oral hygiene products and an oral health database and platform for home use. As for the target market, it has been proved that the potential user can be all kinds of people. Oral Care has four basic working modes: E-toothbrush mode, water flosser mode, oral camera mode and changing with cleaning mode. These are the key technologies.

These oral hygiene products include a mini camera, smart sensors, a water flosser, a toothbrush, a cellphone holder and a UV Sanitizer. The oral health database and the platform has five basic functions including: providing basic oral health knowledge; providing methods of self-diagnosis; providing oral health point system; sharing good dental resources; and providing communication platform. All functions mentioned above are integrated in a mobile phone application.

When people get high points from the point system and get a good evaluation from
dentists about their oral health status, they will get lower insurance premium from the medical insurance company, which is able to access these data at the cloud.

As for the benefits of this system, obviously, people will have better oral health. Oral Care will motivate them to finish oral cleaning through the point system. Also it shortens the distance between patients and dentists through the self-diagnosis system as well as oral camera, especially for those living in the remote areas. In addition, it will promote communication between patients, dentists, medical insurance company and dental equipment company.

However, due to the limitation of time and resources, there are still lots of aspects which require future improvements. For example, the tetrad of assumptions between patients, dentists, dental equipment company and medical insurance company is in its primary stage. It needs further enhancement concerning economics and logics. Also, the handle of part of the products needs more ergonomics study. In addition, the products and cellphone application needs future tests. Last but not least, there is still room for improvement in terms of fun and practice value of the system. For example, for children there can be a game application maybe related to germs in the mouth to encourage them to finish oral cleaning and bring them fun. Moreover, for couples there can be something promoting sharing and communicating.
Bibliography


## Appendices

### Online survey questionnaire

* 1. How often do you see a dentist?
  - Once a week or more
  - Once a month
  - Every two to three months
  - Two or three times a year
  - Once a year
  - Every two to three years or less

* 2. How do you feel about the process of cleaning your mouth?
  - Vaginal
  - Comfortable
  - Interesting
  - Daily
  - Tiring
  - Other

* 3. Do you believe you can improve your oral health if you get more knowledge of oral health?
  - Definitely
  - Quite likely
  - Probable
  - Maybe or not
  - Probable
  - Maybe or not
  - No

* 4. How often do you brush your teeth with patience and care?
  - Three times a day or more
  - Twice a day
  - Once a day

* 5. How often do you floss your teeth with patience and care?
  - Twice a day or more
  - Once a day
  - Every two to three days
  - Every four to six days
  - Once a week or less

* 6. Do you think you are going to enjoy the process if it is much more fun?
  - Definitely
  - Quite likely
  - Probable
  - Maybe or not
  - No

* 7. Do you believe fresh breath and white teeth makes you more confident and attractive?
  - Definitely
  - Quite likely
  - Probable

* 8. Are you willing to do weird movement to exercise your mouth muscle to improve oral hygiene?
  - Definitely
  - Quite likely
  - Probable
  - Maybe or not
  - No

* 9. Do you believe oral health could be improved by: a) including sensors in toothbrush b) receiving feedback from dentists c) receiving reminders to clean teeth from something or someone? (You can choose more than one answer)
  - 
  - b
  - c

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Interview questions

1. Which methods and tools are you using for dental inspection?

2. Could you make a diagnosis by remote smart sensors and pictures of teeth and mouth?

3. What kind of knowledge do your patients have to know?

4. Are you willing to cooperate with medical insurance companies if they can bring you more patients but you have to write personal oral health evaluations for them?

5. Would it benefit you to have a large database of oral health information?
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