The Research on the Design of a Wearable Artificial Throat for People Suffering from a New Type of Throat Cancer

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Abstract—An artificial larynx is an essential tool for laryngeal cancer patients to vocalise after surgery. With laryngeal cancer patients increasing, the demand for the quantity and quality of artificial larynxes is surging. To improve the convenience of vocalising by patients after surgery and formalise their life, the combination of intelligent phonation technology equipment and design developed both functional and fashionable artificial larynxes for these patients. This paper analysed the overseas and domestic research and concluded the smart wearable artificial larynx's technology, material, and operating principles. Additionally, this research discovered people's demand and design principles for the artificial larynx through the survey. Then, it formulated a relative evaluation system and integrally designed the technology and material that can be applied to the wearable artificial larynx, which was verified by experiment.

Keywords-patients with laryngeal cancer, the artificial larynx, intelligent Wear

1 INTRODUCTION

Laryngeal cancer is a common malignant tumour in clinics, with high disability and fatality rates. Due to the current limited medical technology, most patients lose their language ability for their choice of removing the whole larynx. According to the survey results, 45 per cent of patients are depressed and anxious. Therefore, laryngeal cancer dramatically impacts the patient's body, mind, and life. [1]

To solve the language communication problem of those patients, there are a lot of overseas and domestic research and developments in speech functional rehabilitation auxiliary tools, mainly including the mechanical and electronic larynx. [2] The mechanical larynx produces sounds by air vibrating in the gullet. Although it has a low price and sounds like human voices, its appearance is not good, and manual ventilation is required. Additionally, it is easy for saliva to congeal and germinate bacteria in the mechanical larynx. The electronic larynx makes sounds through the built-in oscillator and can adjust the volume through the power amplifier. It is small and portable but has bad timbres, high prices, batteries that would run out quickly and is not easy to buy. In recent years, the fever and emergence of intelligent wearable devices opened new research spots for the artificial larynx. Based on overseas and domestic research, this paper combined the sound device with the wearable design for voice problems laryngeal cancer patients had after surgery, analysing the working principles, technology, and materials of the wearable artificial larynx. Furthermore, to help design and develop the future

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wearable artificial larynx, based on human needs, it was designed and developed to guarantee users' needs to make voice, free their hands, and improve the quality of their life.

2 THE DEVELOPMENT STATUS QUO OF THE ARTIFICIAL LARYNX

With technology and overseas and domestic research advancing, the mechanical larynx cannot cater for people's needs and faded out from the market, as it is not portable, and with patients ageing, the attenuated breath weakens the sounds of the pneumatic artificial larynx. Due to the technology boom of electronic information and biomedicine, data can be collected and processed through human bioelectrical signals. Goldsten designed the myoelectricity electronic larynx with two EMG electrodes on the neck controlling the switch and frequency of the electronic larynx, using neck straps to fix the electronic larynx and free hands. Based on Goldsten, Stepp and Heaton added the regulatory function of myoelectric signals to the base frequency and the electronic larynx controlled by EMC. [3] Zhunei Zhengshu, a Japanese, designed and developed Syrinx wearable voice products looking like bow ties with its nylon tape fixing the vibration unit and the generator. This product takes advantage of bone conduction vibration and AI vibration parts to produce sounds and use AI to make complex vibration modes, allowing users to customise the sounds and neck straps.

The research on the artificial larynx is late in China, divided into three main aspects. The first aspect of research, based on the traditional electronic larynx, upgraded its noise reduction degree and appearance material. The second is about the graphene artificial larynx being researched and developed by Tsinghua University, using the porous feature of graphene materials to launch voices through thermoacoustic effect and receiving sounds by its piezoresistive effect to create a wearable voice-making accessory receiving and sending voices. However, its intelligent system, for now, can only be adopted by people with vocal cords. The third one is the artificial respiratory larynx applying the principles of the medical ventilator with the volume of the equipment reduced under the power guaranteed. Users of it put the plastic pipe under their tongues to make sounds and vibrations produced by the breath. [4]

Currently, there are a lot of overseas and domestic voice-making auxiliary products, and those are developed and designed by mainly supervising human biological EMG signals and applying new materials. Although the emergence of wearable artificial larynx products, many problems exist in using the products, as the technological innovation in product development and design is higher than the demands of people, and the use of some materials does not consider how people would feel. Therefore, the researcher hopes to study the wearable artificial larynx that helps patients vocalize after surgery and not only fulfils the communication needs of people but also ensures the comfort of wearing and their pursuits of normal life to contribute to intelligent wearing.

3 DESIGN IDEAS

According to the voice needs of patients after laryngeal cancer surgery, combined with the concept of wearable, combining the existing artificial voice technology and wearing method,

people-oriented, designed a practical and beautiful wearable artificial larynx suitable for this group. Therefore, in addition to the technical level of the product, the material, appearance and use mode of the wearable artificial larynx should be determined through its psychological needs.

In this paper, a new wearable artificial larynx designed by sensing and monitoring technology is mainly used to analyze and process the vibration data of the mouth and larynx. Combining sensing technology and large database with protective materials, the artificial larynx is presented in the form of wearing, freeing the hands of users, so as to achieve the purpose of users' normal communication and life style. It is convenient to use, comfortable to wear, and ergonomic, so that the product is truly people-oriented. (as shown in Figure 1)

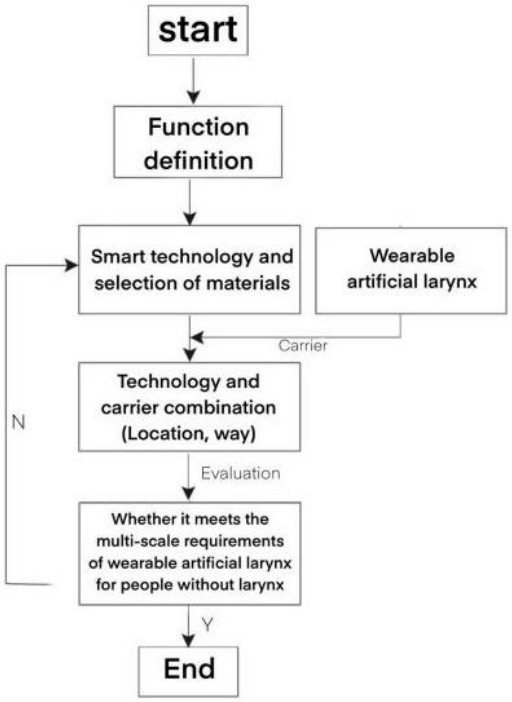

Figure 1. Flow chart of wearable artificial larynx design

4 DESIGN PRINCIPLE

4.1 Questionnaire survey

Respondents: To understand people’s demands for function, design, and psychological needs of the wearable artificial larynx, this research in Dalian surveyed 15 patients who removed their larynx by surgery. Those respondents are above 40 years old and now communicate with others by using the electronic larynx, the shape of their mouth or gesture language. Each person has tried to use one or more sounds making methods. Among them, ten used pneumatic artificial larynx and electronic larynx, 2 used electronic larynx, and three only used pneumatic

artificial larynx.

Analysing the results of surveys: According to the investigation on patients using the artificial larynx after surgery, this paper analysed and concluded its current problems, the psychology of the user and its design requirements. The results showed that 73.33% thought the sound effect was mediocre. People considering its sound is good took up 20%, while 6.67% of those believe it is terrible (as shown in figure 2). Their feeling about using it: 66.67% of users considered the artificial larynx not convenient, and 60% thought its sound was hard to understand (as shown in figure 3). Its appearance design: 46.67% believe the product is ugly, 40% believe the design is generic, and only 13.33% are satisfied with the current appearance design. (As shown in figure 4) according to the survey, almost 100% of respondents expected the sounds of products to be clear enough to guarantee normal conversations. Secondly, they hope it is comfortable to wear and easy to operate with. (As shown in figure 5) The design requirements for the wearable artificial larynx: 80% of respondents are looking for unobtrusive, convenient, and small products that are easy to wear, while 60% like simple designs and 13.33% prefer products with a sense of fashion and technology (as shown in Figure 6). Other announcements for the larynx: more than 90% of respondents pay attention to laryngeal hygiene and protection, and 53.33% focus on keeping the throat warm. (As shown in figure 7).

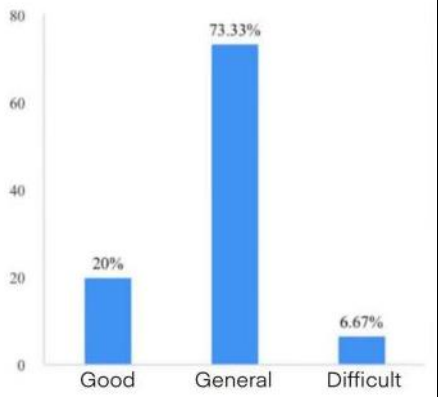

Figure 2. Artificial laryngeal sound effect

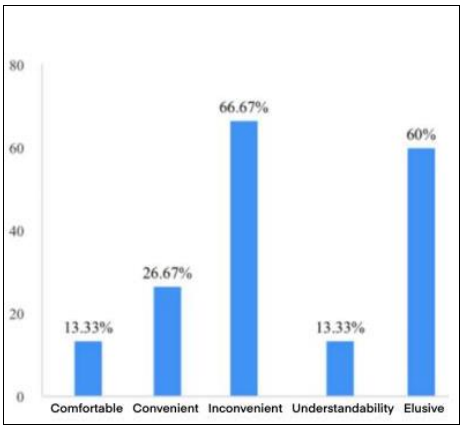

Figure 3. Feeling of using artificial larynx

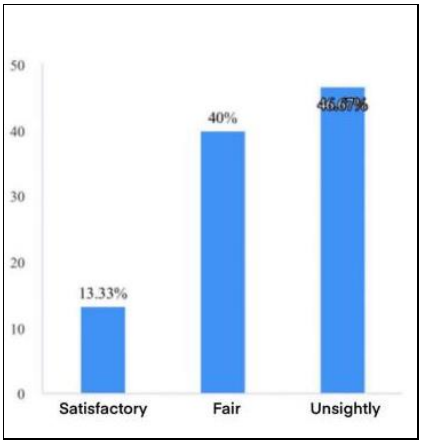

Figure 4. Artificial laryngeal appearance data

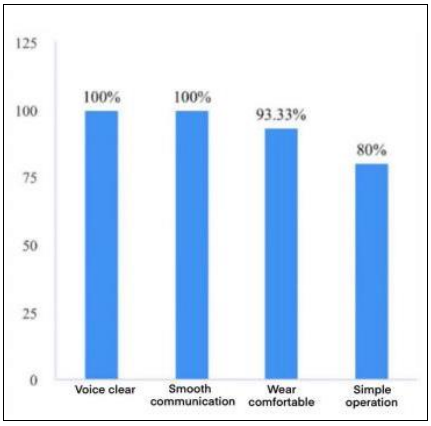

Figure 5. Functional data of wearable artificial larynx

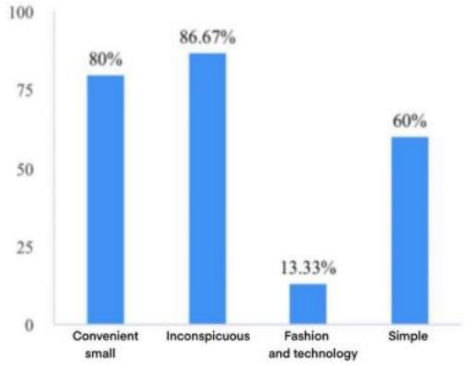

Figure 6. Wearable artificial larynx appearance data

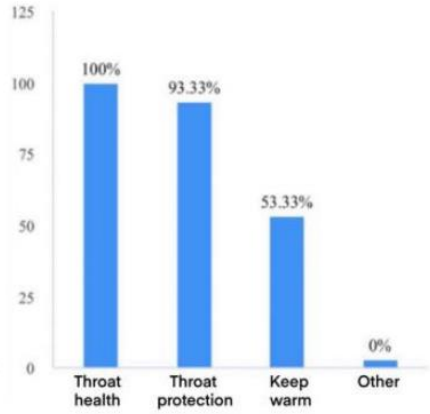

Figure 7. Laryngeal Health Considerations Data

The survey results show respondents had a high demand for language function recovery, and the sound effect and the use pattern of the artificial larynx are essential factors for them. According to data and communications with them, these people have low self-esteem due to the loss of their language functions, so the wearable artificial larynx should be as beautiful and small as possible to reduce the feeling of the presence of vocal AIDS.

4.2 The working principles of the artificial larynx

The voice of ordinary people is completed by the laryngeal cavity muscle and the syllable-forming organ. However, since laryngeal cancer patients lost their larynx and laryngeal cavity muscles after surgery, a database chip was put inside the sounder of the wearable artificial larynx to save many pitch data and acoustic audio in the database. Two sensors were placed at the larynx to capture changes in oral cavity volume and receive laryngeal sounds that vibrate through the larynx. Then those sensors simultaneously transferred data into the database that later integrated and analysed those data into the

language. At last, the wearable artificial larynx formed voices for communication through the speaker in the larynx and controlled the volume of sounds by amplitude based on the monitoring. (As shown in figure 8)

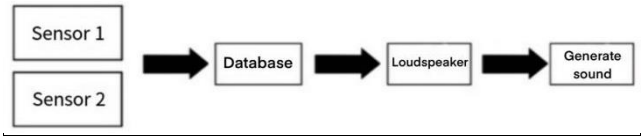

Figure 8. Working principle of wearable artificial throat

5 THE DESIGN SCHEME OF THE WEARABLE ARTIFICIAL LARYNX

5.1 The design of intelligent modes

1）The database chips： Combining the sound storage technology and wearable design, the data chips were stored with vowels, letter sounds and the user's sounds. The information is recycled through the database for output. When the sensors sense the information was loaded into the database, the database will integrate and analyse the stored and received information to form acoustic information. (As shown in figure 9)

2）The Graphene sensor: As the mesh graphene strain sensor is very light with high sensitivity and physical stability, it can facilitate collecting and recognising different degrees of stretching and human signals and detect weak human motions. [5] Thus, those sensors are applied to the side place of the wearable artificial larynx to receive amplitude produced by vocal movements of the lateral laryngeal muscles and monitor the phonetic syllables. As it is super light, it will not cause any burden on the shoulders.

3）The motion capture sensor: An adjustable motion capture sensor in the oral cavity monitors and captures its movements, volume, and mouth shape changes. Due to different pronunciations of letters, when people are speaking, the internal volume and shape of their mouths will change. [6] Based on the data acquired by monitoring, the specific syllables spoken by users were analysed and passed into the database for sound processing and then converted into concrete sounds. (As shown in figure 10)

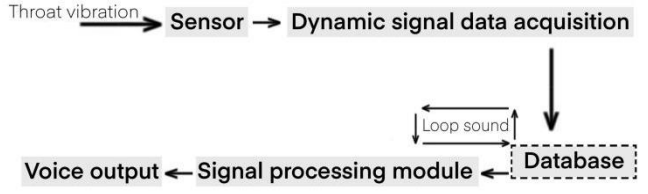

Figure 9. Database working diagram

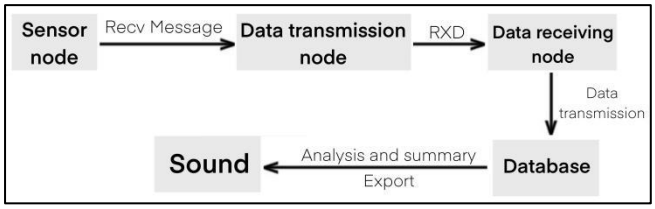

Figure 10. Sensor workflow diagram

5.2 The wearable design

1）The style designs: To satisfy users' needs to speak and free their hands, this paper designed a wearable artificial larynx product for the neck (as shown in figure 11). The closer sensors are put to the throat, the more accurate the data is. To capture more precise changes in the oral cavity, the motion sensing units are adjustable for users to adjust according to their conditions. To guarantee its essential functions, hygiene, and that it will not obstruct normal breathing and is easy to pop on and off, the materials are comfortable, antibacterial, and elastic, the speaker is set in the throat, and there are hollows around it to make sure the user can breathe normally. According to users' psychological needs, the product's presence should be as feeless as possible. Therefore, when the product is expanded, it looks like a thin strap with its two ends connected to the neck and a USB charging port fixed at the back end of it to solve the difficulty of buying batteries. (As shown in figure 12)

2）The Graphene sensor: Laryngeal cancer patients are usually old and pay attention to laryngeal health and safety after surgery, so the wormwood nanofiber composite was chosen. That material with elasticity, strength, high barrier, and antibacterial properties is easy to bend and wear, protecting the health of the user's throat. [7] Besides considering hygiene and health, patients value the comfort of wearing the product. That material has high air permeability and moisture-reducing capacity. In summer and autumn, the patient may feel uncomfortable due to the vapour in the throat. Therefore, using that material can reduce uncomfortable feelings caused by moisture and ensure the daily comfort of users using the product.

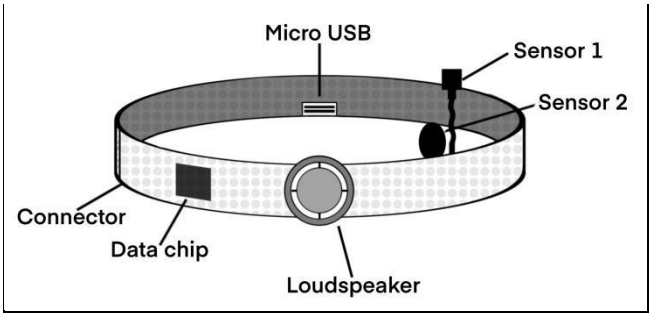

Figure11. Wearable artificial larynx structure

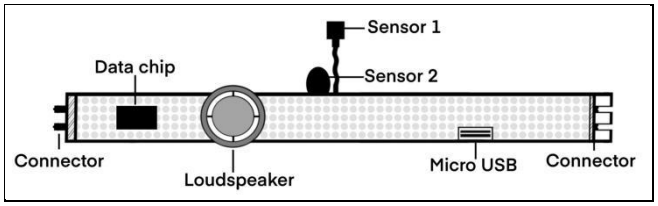

Figure 12. Wearable artificial laryngeal plane unfolds

6 CONCLUSION

This paper analysed the current technology and problems of the artificial larynx, surveying its users. According to survey results, this paper concluded problems of the artificial larynx and user needs for the function and appearance of the artificial larynx. From the people-oriented perspective, it proposed the combination of sensing technology and wearable design, focusing on the research of sensing technology application, product styling design and material selection application. Additionally, to offer a reference for future research on the artificial larynx, it expanded the application method of the artificial larynx and got the relevant design results.

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