A flexible pressure-based gingival loosening detection device

Research report

Author: Wu Zhiyuan Wu Lijie, Zou Ruisong

Organization: Dongjiang Middle School attached to Guangzhou University

Instructors: Wei Maoxi, Zheng Junming, Su Yangcheng

summarize summary

Inspired by the problem of loose teeth, this project aims to design a loose teeth detection device to help users visualize and accurately understand the health of their teeth and prevent the aggravation of periodontal problems. The device realizes accurate detection of loose teeth through flexible piezoelectric sensors, miniature airbags, and lamellar pressure sensor technology. When the user wears the device in the mouth like a braces, the inner flexible piezoelectric sensor is attached to each tooth and the airbag is located on the inner side of the tooth and connected to the sensor.

This project designs a tooth loosening detection device based on flexible piezoelectric sensors with a miniature airbag, aiming to realize real-time monitoring of dental health through thin-sheet pressure sensor technology. The shape of the device is wrapped by resin silicone with piezoelectric sensors affixed to the inner side. The airbag applies controlled pressure to each tooth, and determines the looseness of the tooth through the change of resistance captured by the sensors. The data is processed through the ESP32 *and then transmitted via the network to the main board of the intelligent control center,* ESP32, *where users can visually view the health status of each tooth. The innovation of this system is its combination of static and dynamic detection, providing accurate oral health monitoring, especially suitable for periodontitis patients and user groups who need long-term monitoring.*

Upon activation of the device, the detection module, located inside the mouth, with the miniature airbag inside, begins to inflate, gradually applying pressure from the inside out to each tooth. By applying pressure through the airbag, the sensor is able to detect changes in the pressure values of the teeth under different pressures. There is a significant difference in the feedback data from the sensor between normal healthy teeth and loose teeth. These changes are recorded by the sensor and transmitted over the network to the *user's control center motherboard*, the ESP32, *and converted into an intuitive percentage form that shows the looseness of each tooth.*

Compared to the prior art, the device features an integrated airbag and flexible sensor that provides personalized pressure measurement for each tooth and real-time data transmission to the user's mobile device, making it convenient for the user to monitor dental health at any time.

This work has been explored four times and the

second generation of the device improved: the first

work: the unification of the loose teeth detection

module

Second work: Further integration of detection devices

Third work: Embedded in the Internet of Things and consolidated integration Improved accessibility

Keywords: loose tooth detection, flexible piezoelectric sensors, miniature airbags, pressure sensors, dental health monitoring

table of contents table of contents

1 preamble

With the progress of society and the accelerated aging of the population, long-term poor dental habits and neglect of dietary health have left many people facing oral health problems, and limited access to relevant knowledge through the Internet has led to a high incidence of diseases such as periodontitis. This not only exacerbates the risk of loose teeth and tooth loss, but can also lead to more serious systemic health problems. Although the popularization of the Internet has facilitated the dissemination of health knowledge, the public's attention to oral care and scientific knowledge still needs to be improved.

Figure 1 News cases

Figure 2 News Cases


Bai du 百科 牙齿松动 进入词条

临床分度

牙齿松动可急性引起或慢性缓慢进展，可伴有牙齿疼痛不适，也可不伴有。对人造成的主要影响是咀嚼食物是感觉无力或不适。

由牙齿松动的程度不同，临床上可分为Ⅰ度~Ⅲ度三个分度。

Ⅰ度牙齿松动为颊舌方向（内外方向）的动度在1mm以内，其他方向没有动度；

Ⅱ度牙齿松动有两种情况，一为颊舌方向（内外方向）的动度在1~2mm之间，二为牙齿有颊舌方向（内外方向）及近远中方向（左右方向）两个方向的动度；

Ⅲ度牙齿松动也有两种情况，一为颊舌方向（内外方向）的动度超过2mm，二为牙齿存在颊舌方向（内外方向）、近远中方向（左右方向）和垂直方向（上下方向）三个方向的动度。

从Ⅰ度~Ⅲ度牙齿松动的程度越来越重，对患者的生活也有越来越大的影响，一般情况下牙齿脱落或需拔除的可能性也越大。

Fig. 3 Looseness display

Due to the subtle wobbling of the teeth, we **are unable to** visualize the physical changes in the form of numerical data, because the normal range of normal tooth looseness **in a normal person** is around **1 mm of** wobbling, and patients suffering from tooth looseness are also divided into three grades of wobbling as shown in Fig. 3, and therefore it is valuable to make a device that can visually detect the wobbling of the teeth.

2 Project research process

2.1 Purpose of the project study

The device is capable of detecting the gum health of middle-aged and elderly people in advance by monitoring the normal gap between teeth and gums, helping users to view the health data of all their teeth visually through the control center motherboard ESP32 after each use. This feature not only provides users with clear feedback on their health status, but also effectively prevents the occurrence of periodontitis and other serious oral diseases.

2.2 Project information collection

2.2.1 opinion poll

（1） There were 76 investigators at the Central Plaza in Dongwon;

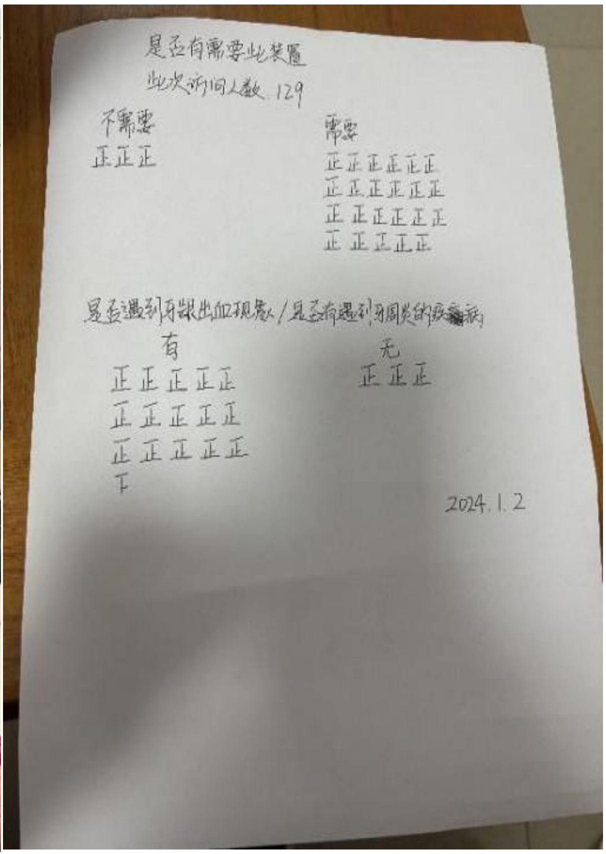
（2） There are 53 residents in the East Side Mansion neighborhood.

	Experiencing bleeding gums	Is there a need for an array of flexible piezoelectric Gingival Gap Detection Device
Dongyuan Central Galleria	41 people have encountered	69 People say they need to; 8 people say they don't need it
East City Residence inhabitants	37 people have encountered	46 people said it was needed; 7 people say they don't need it

Table 1 Demand survey

Figure 4 Field survey

Figure 5 Interview transcripts



It was analyzed and found that most of the residents surveyed had experienced tooth pain, periodontitis, and bleeding gums, so most of the residents thought that they needed this device to ensure their health in order to prevent the occurrence of this disease in advance. During the interviews, 15 people said that they did not need the device, and it was found that the reason for this was that 5 people said that they would probably not experience periodontitis, and 10 students said that it would probably not happen to them.

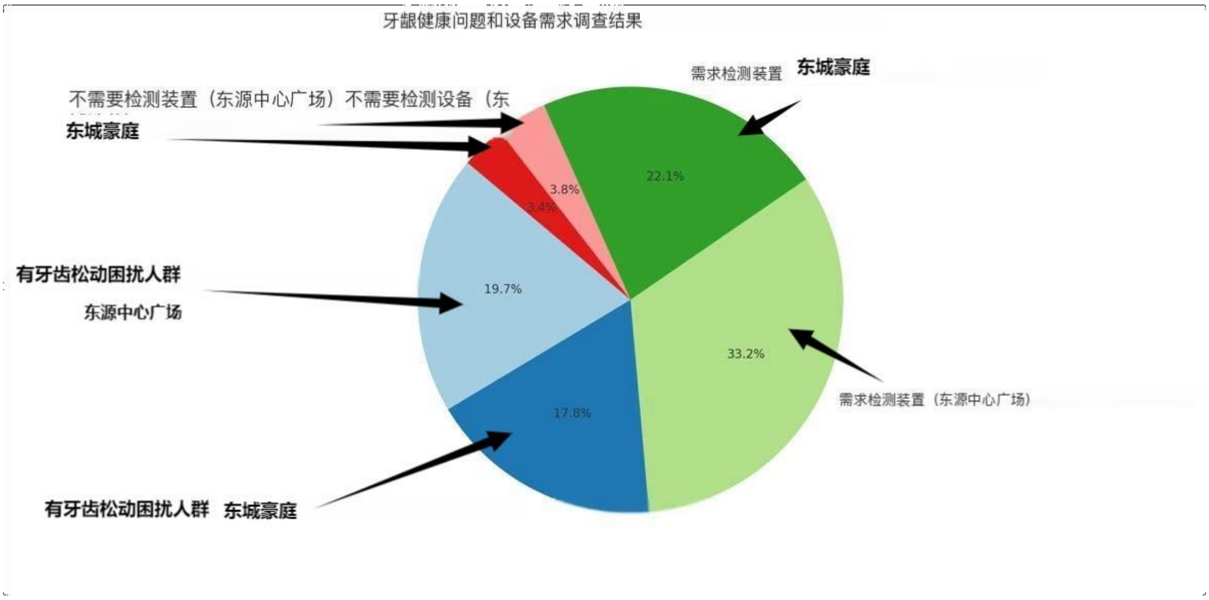


Figure 6 Sectoral diagram of demand

2.2.2 Searching for similar products to discover their defects

The Lura Health saliva monitoring device is shown in Figure 7, and Figure 8 shows the system used by the HKU School of Dentistry team to detect gum inflammation using artificial intelligence to analyze photos of the mouth.

Figure 7 Saliva monitoring device

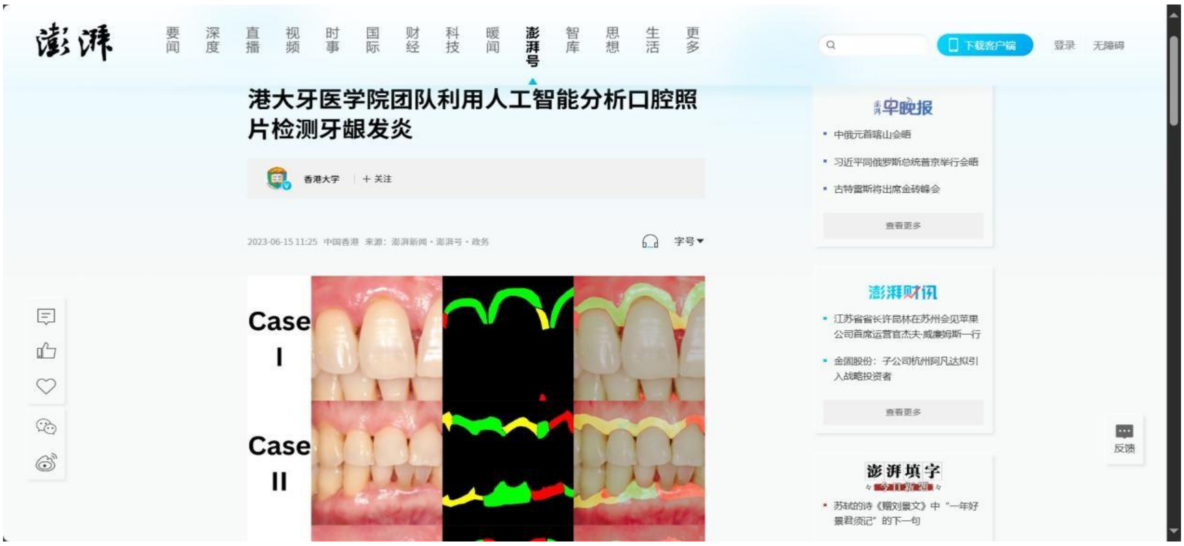


Fig. 8 Photographic inspection of the gums

We are developing a gingival gap detection device based on an array of flexible piezoelectric technology that can accurately assess gingival health with its unique technical advantages and innovative design. By combining flexible piezoelectric sensors and micro air pump technology, the device is able to directly detect tooth looseness and provide real-time physical status feedback, effectively overcoming the limitations of existing market products. Compared to saliva monitoring devices, our method no longer relies on indirect biomarker detection, but achieves higher detection accuracy through pressure application and sensitive sensors, making it applicable to a wider user group; compared to the AI-based gingivitis detection system developed by the University of Hong Kong, our device does not need to rely on image quality and filming skills, and can detect each tooth independently, both dynamically and statically, to It provides more scientific and intuitive diagnostic results. After many experiments and tests, the device optimizes the algorithm to visualize the results as a percentage of health, providing users with a clear and reliable assessment of their gum health.

In summary, the device has reached new heights in terms of accuracy, real-time and applicability, and is particularly suitable for early monitoring of chronic oral diseases such as periodontitis within hospitals, showing strong market competitiveness and commercialization potential.

2.2.3 Comparison of existing related patents and analysis

As shown in Table 2, we compared the four types of detection devices for the type of tooth loosening mentioned in the query report, and our **advantage** lies in the ease of use for the user, the fact that it takes only **10 seconds to detect** the value of the loosening pressure of the tooth, which is visualized as a percentage, and the fact that the quantification of the detection data **is consistent with the amount of inflation of the balloon to maintain the** accuracy.

Patented Product Name	vantage	drawbacks
Dental comprehensive measuring instrument [invention] CN201510460430.6	It is an important reference for the measurement of occlusal force and solves the problems of the prior art.	The sensitivity and accuracy of tooth loosening detection have not been addressed, mainly for the detection of occlusal forces. Explicit optimization.
Tooth looseness detection device [Invention] CN202011611060.9	Before and after looseness of the same tooth can be objectively compared.	The detection principle is more traditional, recording tooth looseness by manual shaking, relying on mechanical structures, which may lead to a lack of accuracy, and cannot be realized. The test data is displayed at the same time.
Oral care device with tooth looseness detection [invention] cn202280077062.5	Detecting tooth looseness by processing signal waveforms, providing tooth looseness A measure of the level or degree of sexuality.	Physical detection of shaking teeth for marking + subsequent manual analysis, presence of Large errors as well as low timeliness.
Tooth loosening degree force feedback interactive device [utility model] CN202320029928.7	Displacement of the teeth is observed by projection and reflection of the laser.	The device is large and inconvenient, and requires subsequent manual analysis, which is important for the stability of the ambient light and the operator. There are higher requirements.
this device	By means of a program that is set up so as to improve accuracy, the airbag inflation volume is kept consistent, and the airbag pressure applied resin is calculated as a numerical percentage of the pressure value of the tooth, the Visual display.	Further device integration is required to reach consumer industrialization levels.

Table 2 Comparative analysis with similar patents

2.3Research ideas

When the user activates the miniature air pump through the controller, the miniature air pump starts to work and pushes the teeth to move by installing an array of air bladders on the inner side of the teeth that are independent of each tooth and allowing them to apply pressure outward to simulate the external force on the teeth. **The array of flexible piezoelectric pressure sensors installed on the outside of the teeth detects the pressure exerted by the miniature air pump in real time and** transmits **the detected force feedback signal** to the microcontroller through the leads. The microcontroller board will receive the force feedback signal for the microcontroller **to calculate the amount of micro-pressure on the teeth** based on analog voltage calculations, convert it to an intuitive percentage format, and display it on the user's control center motherboard display. Can be installed through the control center microcontroller ESP32 above the LCD display, view each tooth and the gums between the degree of tooth loosening data, to understand the loosening status of each tooth. And take appropriate oral care measures. At the same time, the dentist can utilize this data to improve the accuracy and efficiency of diagnosis.

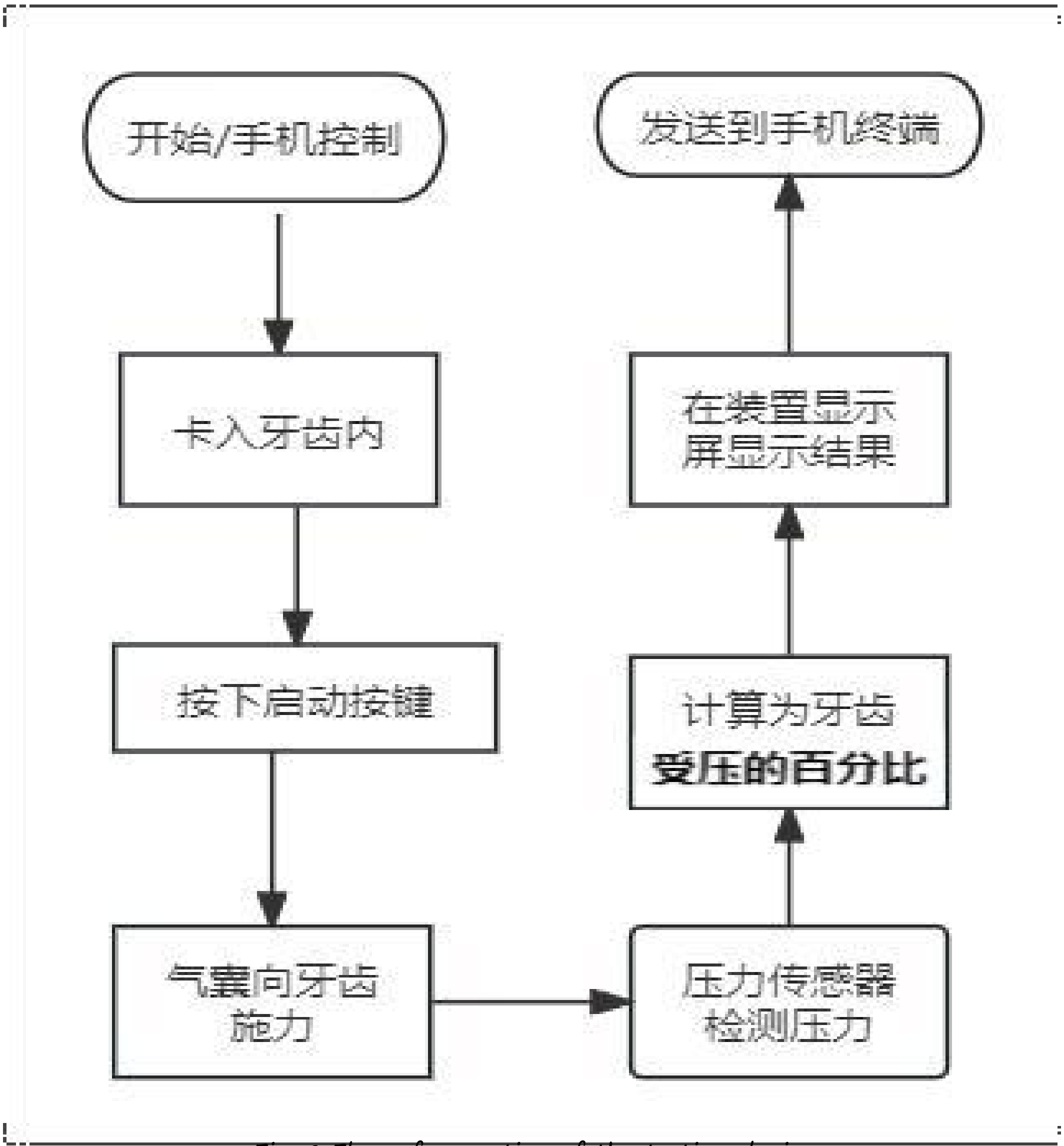


Fig. 9 Flow of operation of the testing device

3 Innovative points and research process

3.1 Project Innovation Points

The innovation of the device is that a gingival gap detection device based on array flexible piezoelectricity comprises a tooth sleeve, a U-shaped groove opened on the tooth sleeve for being stuck on the outside of the tooth, a PCB board set on the side corresponding to the open end of the U-shaped groove in the tooth sleeve, a miniature airbag set on the inside of the tooth sleeve close to the inside of the tooth, a pressure sensor set on the outside of the tooth sleeve close to the outside of the tooth, and a controller set on the tooth sleeve and connected to the PCB board and the pressure sensor. the pressure sensor, and a controller disposed on the braces and connected to the PCB board and the pressure sensor. The controller is connected to the main board of the user control center, ESP32, by means of WIFI.

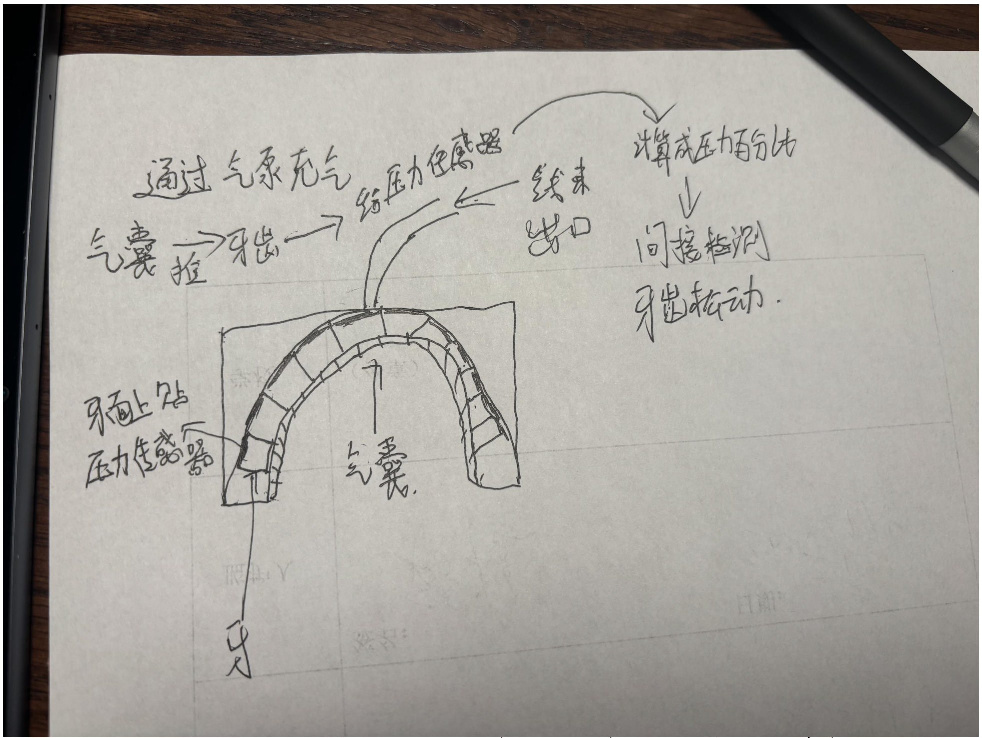


Figure 10 Oral Internal Inspection Module

3.2 Project Patent Application and Project Search

This project has filed a patent application on October 22, 2024, Patent Application No.: 202422552519.2, and conducted a scientific and technological research at the Documentation and Intelligence Center of the Chinese Academy of Sciences, which concluded that the same content has not been reported in the domestic open literature.

4 Project Research Creation and Implementation Process

4.1 Prepared Materials

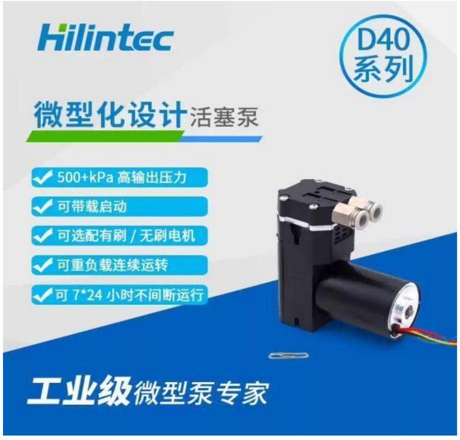


Figure 11 V-Bushings Fig. 12 Pressure Transducer Fig. 13 Miniaturized design piston pump

Figure 14 Airbag Figure 15 ESP32 Main Board Figure 16 LCD Display

4.2 Information gathering and innovation analysis

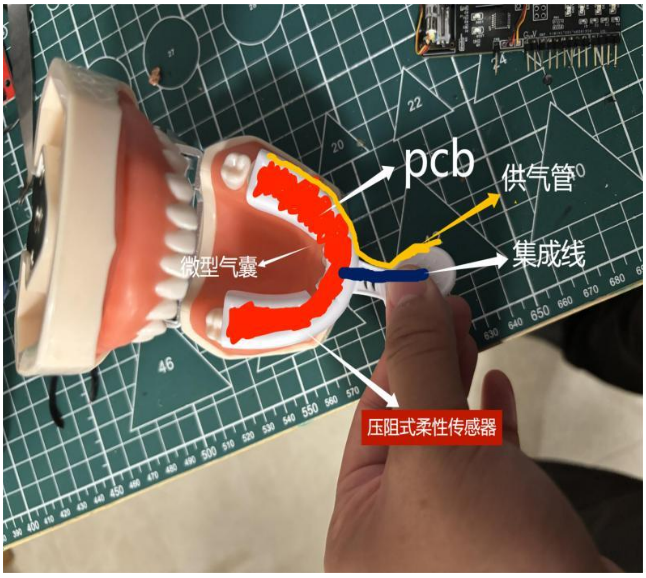
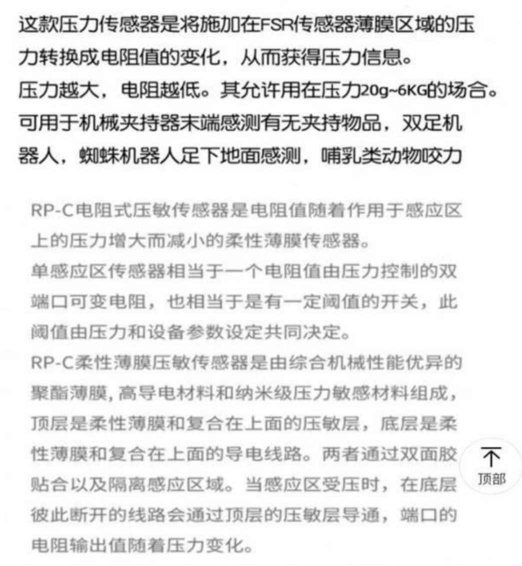


Figure 17 Physical Design Ideas



这款压力传感器是将施加在FSR传感器薄膜区域的压力转换成电阻值的变化，从而获得压力信息。
压力越大，电阻越低。其允许用在压力20g~6KG的场合。
可用于机械夹持器末端感测有无夹持物品，双足机器人，蜘蛛机器人足下地面感测，哺乳类动物咬力

RP-C电阻式压敏传感器是电阻值随着作用于感应区上的压力增大而减小的柔性薄膜传感器。
单感应区传感器相当于一个电阻值由压力控制的双端口可变电阻，也相当于是有一定阈值的开关，此阈值由压力和设备参数设定共同决定。
RP-C柔性薄膜压敏传感器是由综合机械性能优异的聚酯薄膜，高导电材料和纳米级压力敏感材料组成，顶层是柔性薄膜和复合在上面的压敏层，底层是柔性薄膜和复合在上面的导电线路。两者通过双面胶贴合以及隔离感应区域。当感应区受压时，在底层彼此断开的线路会通过顶层的压敏层导通，端口的电阻输出值随着压力变化。

顶部

Figure 18 Sensor principle

We utilize the principle of FSR pressure sensor, the piezoelectric sheet is placed on top of the fabricated *shell, through the design of the oral cavity to measure each tooth independent of the miniature airbag vibration, when the beginning of the detection, the air pump to the airbag inflation, the airbag began to expand to the teeth from the oral cavity outward slightly out of the FSR pressure sensors mounted on the outside of the teeth attached to the surface of the piezoelectric sheet to conduct the pressure, and then send FSR data back to the computer for calculation to determine the expansion force exerted on each tooth, when a certain period of time, to analyze the returned pressure value, we will remove the screws to simulate the tooth mold expansion force.* The FSR *data is sent back to the computer to calculate the expansion force applied to each tooth, when the airbag is inflated for a certain period of time, the returned pressure value is analyzed, we remove the screws of the dental mold to simulate the loosening of the tooth, and find that the returned pressure value of the loosened tooth is larger, and the inverse value is smaller, and finally the dental health data is displayed on the LCD on the main board, so that the user can visualize the health level of the teeth and gums. and gum health. We utilize the sensor principle in Figure* 18, ***the higher the pressure, the lower the resistance***.

Figure 19-20 *Overall view of three generations of works*

4.3 *Program flow and its algorithm description*

Start: *The process starts here and different branching paths are triggered by two keys.*

Start button activation: *enters the left branch and executes the main program: pressure detection and data processing operations.*

Raw data view button activation: *access to the right branch, mainly used to read and display the voltage analog data before and after airbag inflation*

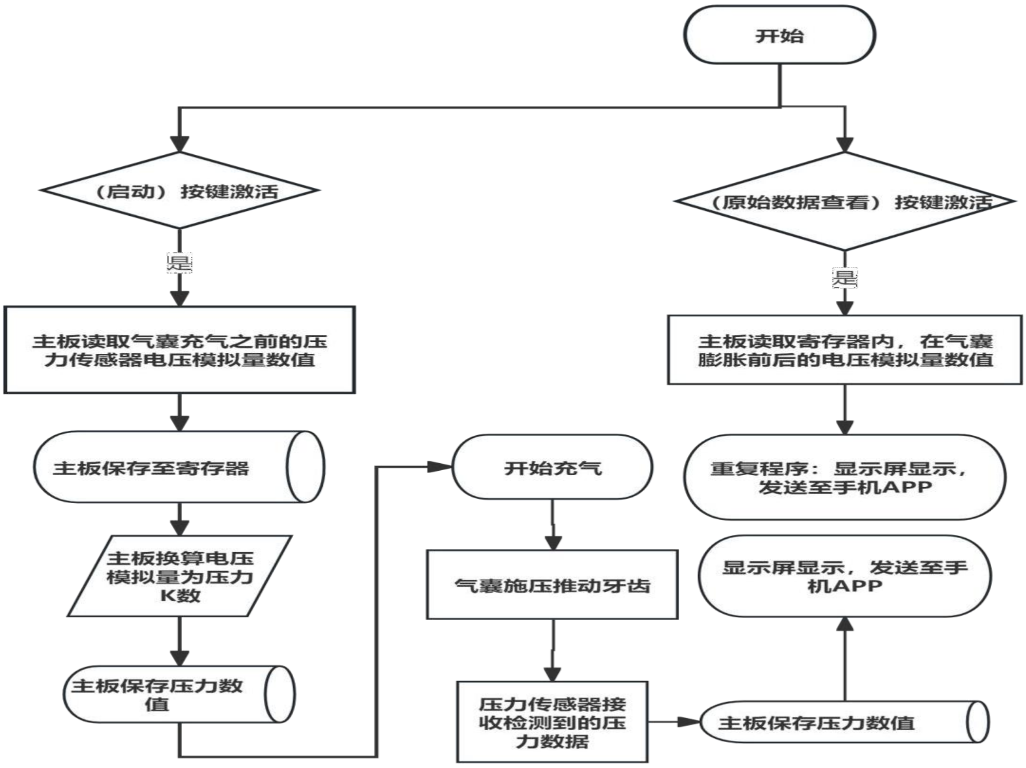


Figure 21 Project flow chart

1. Left branch (flow after start button activation)

Read pressure data: The main board reads the analog data of the pressure sensor voltage before the airbag is inflated.

Save Data: Stores the read data in a register. **Data conversion:** The main board converts the voltage analog data to pressure K numbers.

Save again: stores the converted pressure value in the main board.

Start inflation: the air pump is activated to

inflate the airbag.

Tooth pressure application: The airbag applies an external force to push the tooth to move.

Detecting Pressure: The pressure sensor receives the applied pressure data and transmits it to the main board.

Display and transmission: Pressure data is shown on the display and sent to the cell phone APP for users to view and analyze. **Data storage:** The main board records the values detected by the pressure sensor.

2. Right branch (raw data to see the flow after key activation)

Read data: The main board reads the voltage analog data recorded in the registers before and after airbag inflation.

Display and transmission: Display the data on the screen and send it to the cell phone APP at the same time, which is convenient for users to view the original data information.

Through the above process, the force on the teeth can be comprehensively examined and analyzed to provide intuitive data.

1. 公式和转换关系

FSR传感器的基本原理是：

$$\text{Resistance} = \frac{V_{supply} \cdot R_{pull-up}}{V_{out}} - R_{pull-up}$$

假设你已经在电路中使用了一个10kΩ的上拉电阻（`R_pull-up`），则根据压敏电阻的特性曲线和经验公式，我们可以从模拟值推算出压力。

2. 模拟值到压力的转换

你可以通过以下近似公式（经验值）转换得到 `force`（单位：牛顿 N），其中 $fsrValue$ 为模拟值（0-1023）：

$$\text{Force}(N) \approx \text{constant} \times \frac{fsrValue}{1023}$$

3. 牛顿到公斤力转换

1牛顿约等于0.10197公斤力（kg）。因此：

$$\text{Mass (kg)} = \text{Force (N)} \times 0.10197$$

Fig. 22 Operational method (formula for conversion of voltage analog to pressure value)

型号：10*40MM@2kg	
压力/kg	电阻/kΩ
0.2	11.20
0.4	6.07
0.6	4.31
0.8	3.43
1	2.97
1.2	2.67
1.4	2.48
1.6	2.30
1.8	2.19
2	2.08

Table 3 Sensor Pressure vs.

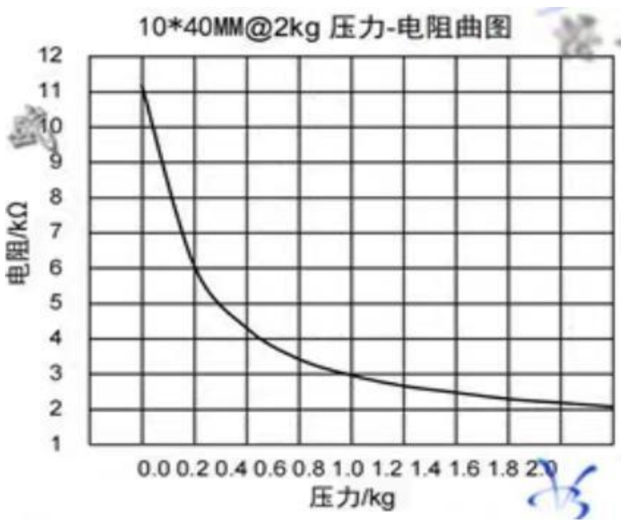


Table 4 Sensor Pressure vs.

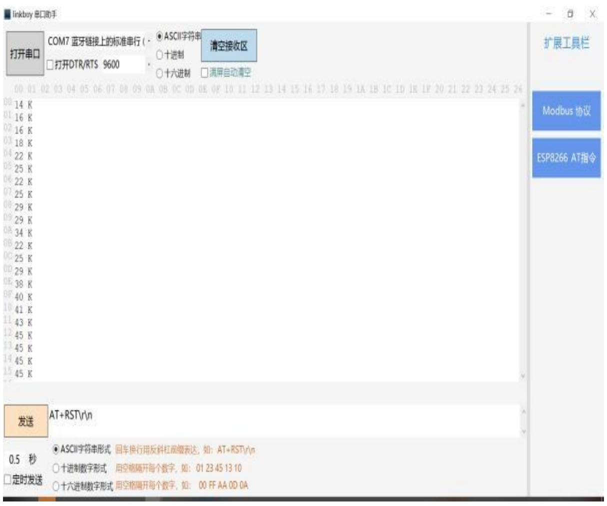
As shown in Table 3, we are using a specific pressure sensor for 2KG maximum Table 4 shows the relationship between pressure and resistance as supplied by the vendor. We used a dental grinder. The two cases are divided into two separate 10 times when the specification test, as shown in the figure

23 All tooth screws were tightened and then the teeth were tested by squeezing them from the inside out using the program's testing device.

Observe the change of voltage analog through the serial port of the host computer, and then calculate the resistance, and Table 3 Table 4 of the pressure and electricity

For reference, we calculate the average value by averaging the 10 detected resistances when the teeth are ~In the tight state the resistance is between 9.45 9.78, i.e. the pressure value varies between 14 and 41 grams.

By setting the power supply to the air pump to exactly 10 seconds, we recorded during this time the force value that was fed back after the tooth was ejected by the force generated by the expansion of the airbag.



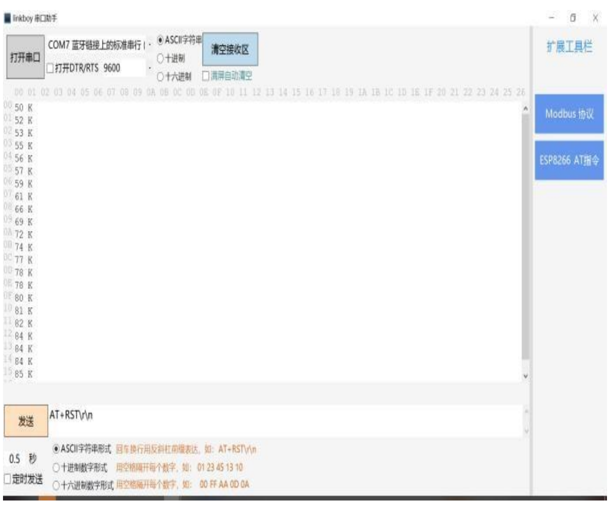


Fig. 23 Stable teeth data Fig. 24 Loose tooth data

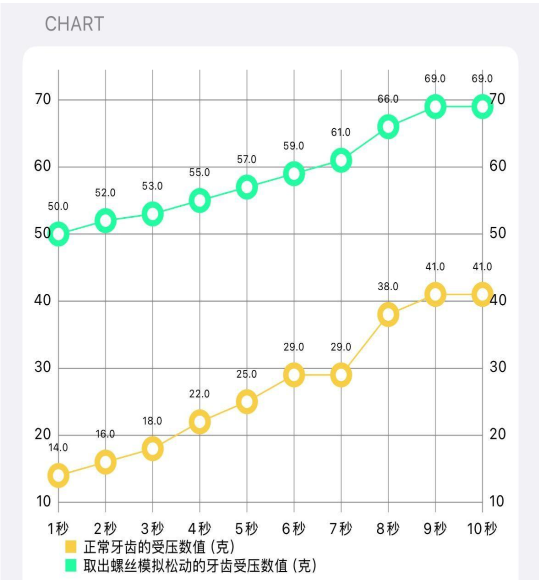
As in the experiment of Fig. 24, when the fixation screws were removed from one of the teeth on the dentine to simulate the teeth when suffering from periodontitis

Loose teeth. The results show that, as shown in the figure, the force feedback values returned by the serial port are generally in the range of 50 grams to 85 grams when the loose teeth of the screws are removed, converted using the calculation method as described in the previous paragraph, while the force feedback values without removing the screws are generally in the range of 50 grams to 85 grams.

For fixed teeth, the feedback force values usually range from 10 grams to 45 grams. Through 10 repetitions of the experiment, we analyzed and calculated the change in feedback force for healthy and loose teeth, and converted it into a percentage of dental health, which was visualized on the LCD screen in the control center.

Data summary: Average value of pressure in 10 seconds for healthy teeth: 27.5 K, average value of pressure in 10 seconds for loose teeth: 59.1 K.

In order to make it easier to show the intuitive force situation, we for the pressure sensor only do the acquisition of voltage analog arithmetic processing, through the first data before the detection into the teeth, and then inflated, so that the teeth were stressed after the voltage analog value, the greater the pressure, the smaller the resistance voltage analog value is also larger.



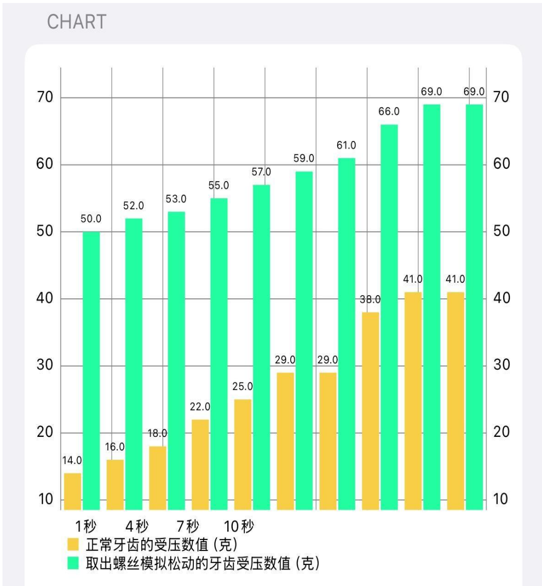


Table 5 Pressure data line comparison (in K) Table 6 Comparison of Pressure Data

As shown in Tables 5 and 6, the experimental results further clarify the force feedback characteristics of the teeth in different states. When the screws on the tooth membrane were not removed, the tooth was in a **fixed state**, and **the grams of** thrust force **feedback were small** at this time, and showed a gradual increasing trend. After 10 seconds of power supply, the feedback force reaches a stable value, indicating that 10 seconds is exactly the time when the tooth thrust force reaches the limit value, corresponding to the green curve; while when the membrane fixation screws are removed and the tooth is in the **simulated loosened state**, the onset of the force feedback curve is significantly

higher than that of the healthy tooth *within 10 seconds, but also tends to stabilize after 10 seconds. Tables 5 and 6 clearly show the significant difference in force feedback characteristics between healthy and loose teeth, providing reliable data for assessing dental health.*

4.4 *Product Improvement and Iteration*

First Generation Work: *Harmonization of Tooth Loosening Detection Modules*

As we want to quickly practice, found that you can use the teeth now common on the market pressure mold of the teeth on top of the modification, respectively, on the inside of the installation of a row of airbags spaced out a layer of teeth and then installed a flexible pressure sensor, it was only produced to achieve the detection of four teeth teeth for the degree of looseness of the teeth of the detection function.

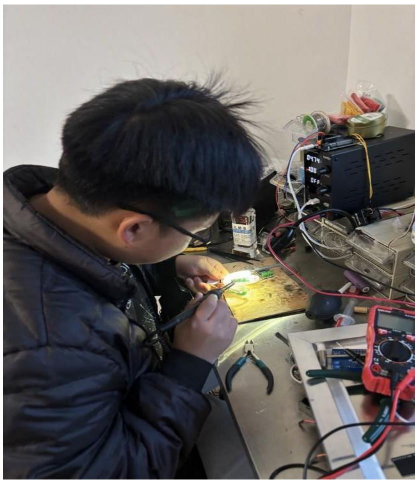


Fig. 25 Building the Braces Module

Fig. 26 Test calculation results

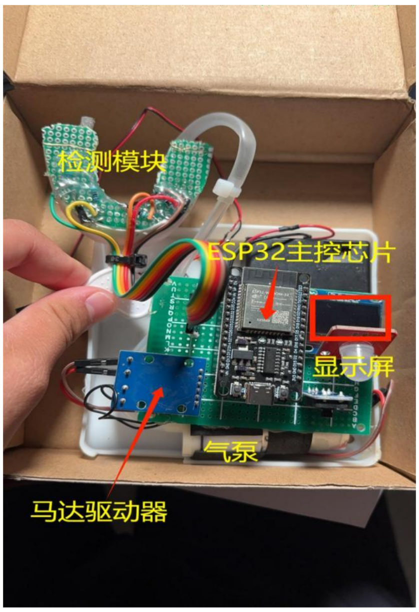


Fig. 27 First generation model inside the tooth

Fig. 28 Installation of the detection module

Second generation: further integration of detection devices

We started learning about dentistry on the internet, trying to divide long strips of airbags into small, individual pieces.

The air bladder, which applies pressure to each tooth individually, is used for PCB painting to minimize detection errors caused by excessive wiring.

Improved usability as well as lightness reduces wiring interference for each individual sensor and finally pokes the air hose into the air inlet of the array airbag.

Figure 29 Fabrication of Oral Dental Test Module

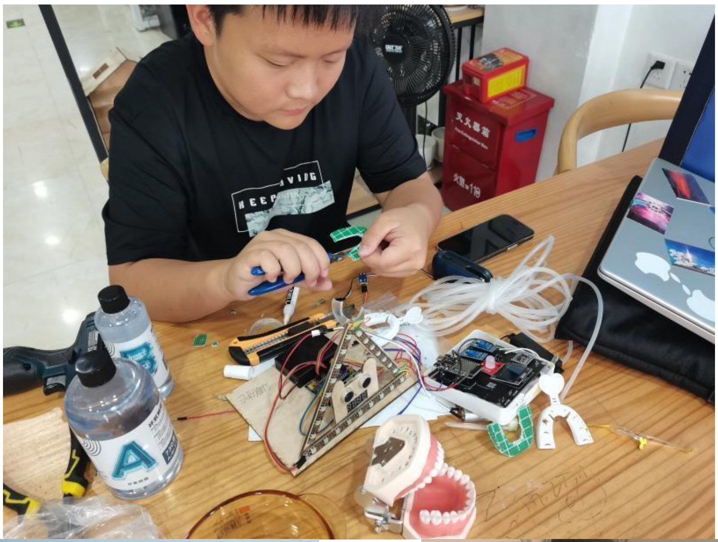


Fig. 30 Fabrication of the array airbag

Figure 31 Repeated testing

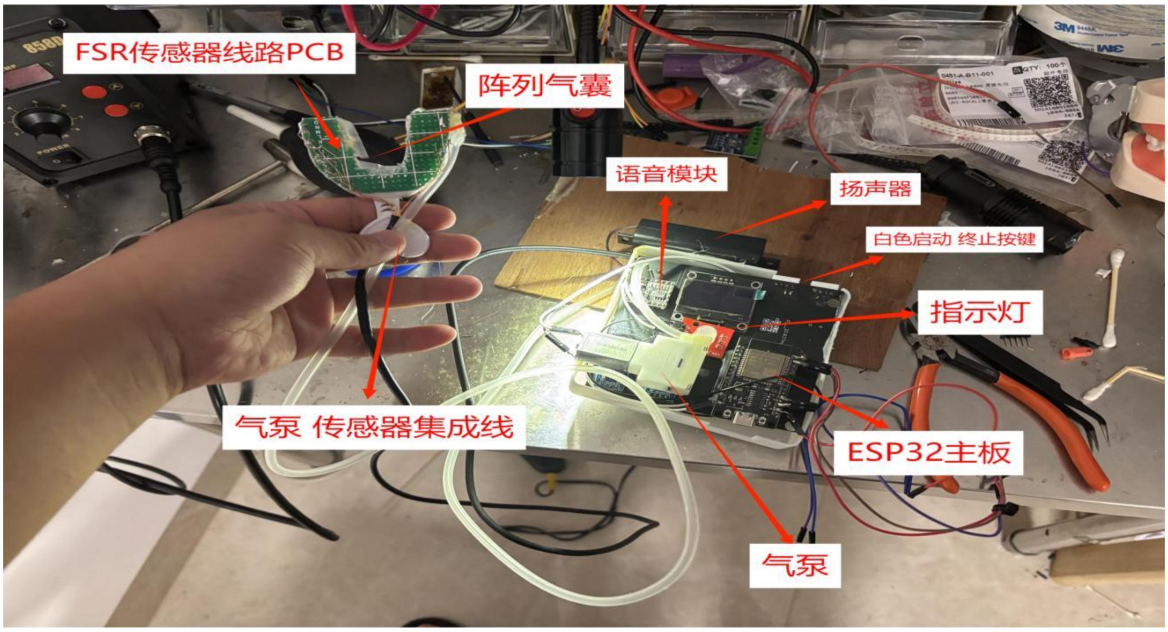


Fig. 32 Layout of second generation works

As shown in Figure 32, all the layout of the second generation works after the improvement of the display instructions, the user only needs to activate the device by pressing the upper right corner of the white start button, after the completion of the detection will be the results of the data will be displayed on the LCD display as well as voice and indicator feedback, this time, the design idea is modularization, will be the motherboard chip processing as well as oral and dental detection is split into two modules, but it will lead to the volume of the overly large It is not convenient to use.

Third-generation work: embedded in the Internet of Things and consolidated integration Improved accessibility

Figure 33 Drawing the PCB

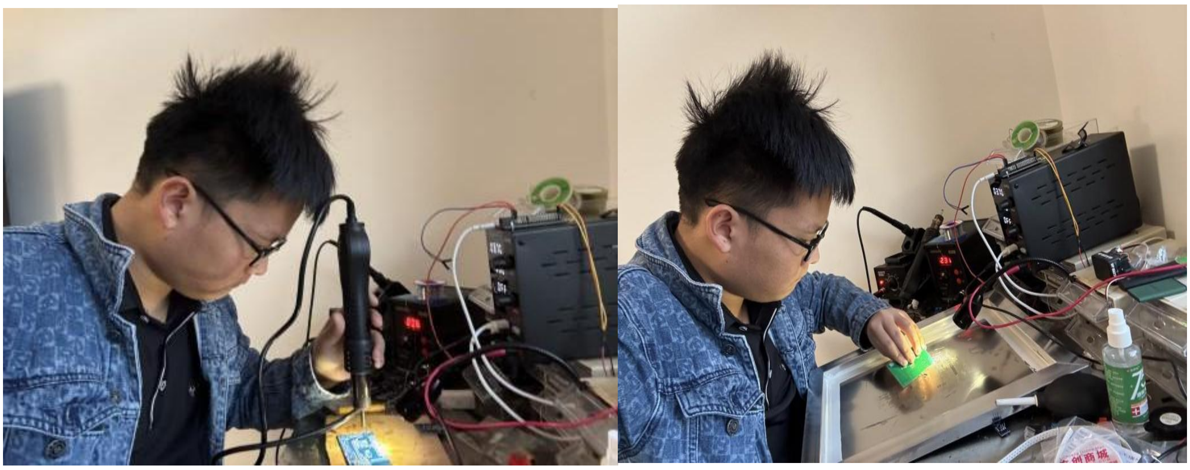


Figure 34-35 The author is building a circuit board and soldering it.

The third generation of works in consideration of further integration, as well as the degree of durability and detection of humane, respectively, replaced the detection area into a laser cutting machine cut out of the form of wooden pieces of braces model, the rest of the circuitry part of the PCB board integration, as well as to join the Internet of Things function, the user can be clicked on the screen through the cell phone to start the detection device as well as to record the detection of the data, and to further increase the degree of reality.

Figure 36 Third generation front view

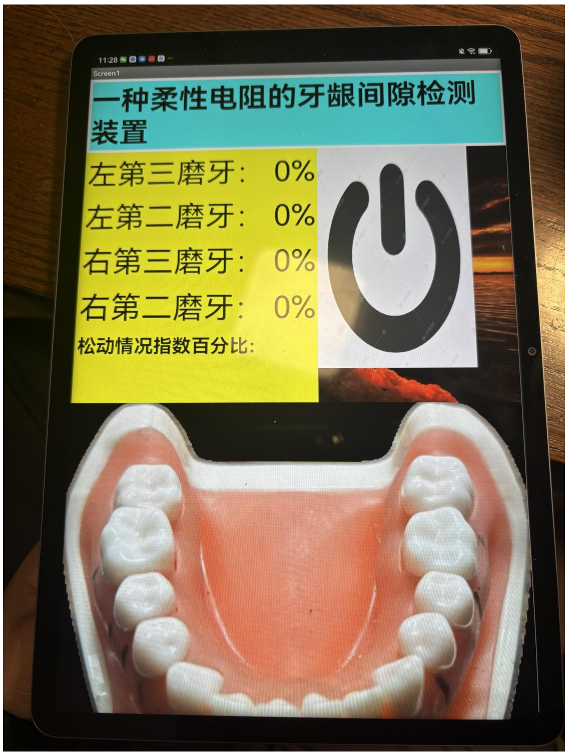
Figure 37 Back view of Generation III

As shown in the figure, we combined the detection part as well as the microcontroller and the display part into an integrated detection device, as shown in the figure, due to the fact that the size of the existing braces model is too small for the insertion of the airbag as well as the

Sensors, so we use wood for laser customization, we use a laser engraver to change the drawings and cut out the teeth

of the outer contour shape to replace the braces model used in

the first two generations. **IoT Features:**



We based on as shown in Figure 39 is the international definition method defined dental name, to the user as the first perspective to define the left and right sides, percentage algorithm: through the pressure sensor second sensor feedback in the voltage analog data minus the initialization of the voltage analog data, and after the value is divided by the pressure sensor voltage analog sum of the pressure sensor within 10 seconds, it can be converted to an average value, as shown in Figure 38.

By cutting customized plank shapes and installing air tubes as well as pressure sensors inside, the advantages over the second generation work are better all-round wrapping of the teeth without relying on the existing braces models in the market, as well as being more integrated, with the two parts merged into one and the inclusion of IoT functionality, which feeds back the final test results to the cell phone, making it available for the user to view at any time.

5 Conclusion of the study and future outlook

5.1 Findings

The device utilizes a state-of-the-art FSR lamella piezoelectric load cell in combination with a miniature airbag corresponding to each tooth made from a packed air column. When the user applies pressure to the miniature air bladder by activating the air pump through the controller, the air bladder begins to operate, pushing the tooth to move by applying outward pressure to mimic the external force applied to the tooth.

An array of flexible piezoelectric pressure sensors mounted on the outside of the teeth detects the pressure exerted by the miniature airbag in real time and transmits the detected force feedback signal via leads to a PCB board, which initially processes the feedback signal and transmits the data to the controller. The controller further processes and analyzes the signal, converting the loosening value into a visual percentage and displaying it on an LCD screen controlled by the ESP32 motherboard on the outside of the braces.

The LCD screen presents data on the health of the 4 teeth corresponding to the jaw, and the looseness of each tooth is demonstrated by standing feedback. The system collects data on the voltage changes resulting from these feedback signals, utilizing the characteristic of higher voltage with higher resistance with higher pressure. The analog voltage output is converted into a percentage health result.

Users can clearly view the data on the degree of tooth looseness between each tooth and the gums through the display screen and cell phone APP to understand the condition of tooth looseness, take timely oral care measures, and prevent the occurrence of oral diseases in advance. At the same time, the dentist can also use these data as the basis for auxiliary diagnosis, effectively improving the accuracy and efficiency of diagnosis.

5.2 outlook

Add a button for each tooth on the App so that the user can select the tooth they want to test to activate the pressure sensor for that tooth, making the testing device more personalized and targeted. At the same time, we need to further optimize the appearance and hygiene issues, we will soon make a device similar to the lung capacity test users before the detection of tooth loosening situation to ask for a rubber mold to fix the shape of their teeth before placing the device for testing and more quantitative, but also improve the accuracy of the test.

harvest obtain experience experience

This year's R&D and learning journey has been an unforgettable experience for me. In countless days and nights, I explored technical solutions, wrote programs, wrote papers and faced one challenge after another alone. Now that I see the success of my work, my heart is full of emotions. This is the first time I experienced such a difficult exploration process. Although I sometimes felt pressurized, I always persevered and finally achieved a proud result.

During the process of R&D, I have thought about the choice of technical solutions over and over again, and I have also felt frustrated because of the technical bottlenecks I encountered. Facing the double pressure of academic and R&D tasks, although I had thought of giving up, every progress became my motivation to keep going. I deeply realized that continuous attempts and efforts are the key to overcome difficulties.

Looking back on the whole process, I have not only made progress in technology, but more importantly, I have improved my self-management, independent thinking and problem-solving skills. The Science and Technology Innovation Competition provided a stage for me to show myself and let my creativity fly. On this stage, I found my goal and worked hard for it, and completed a piece of work that I am proud of. This creation is not only a test of my personal ability, but also a valuable growth experience.

Looking ahead, I will continue to maintain my passion for science and technology innovation and incorporate this spirit of hard work into my future studies and life. What I have created this time is not only a successful work, but also a personal growth and transformation for me. In the future, I will continue to try and carry forward the spirit of practice to meet more challenges and opportunities.

Acknowledgement thank

The experience of this competition has made me cherish it and made me realize the importance of teamwork and perseverance.

This journey has not only allowed me to expand my horizons, but has also challenged me to find greater motivation to move forward.

First of all, I would like to express my most sincere gratitude to my parents who have given me endless support and encouragement. It is your selfless love and warmth that has become the most solid backing on the road of my growth. Whether in the face of difficulties in the encouragement, or in the achievement of the company, you have always been my soul harbor and source of strength. Every care and payment is deeply engraved in my heart, and has become the inexhaustible power for me to move forward.

In addition, I would like to thank my classmates. In this journey of exploration, your companionship has made me feel warm, and your encouragement has filled me with confidence. We discussed and worked together, faced the challenges and shared the rewards together. It is because of your support and cooperation that I can feel the true team spirit and the preciousness of friendship in this experience. At the same time, I would like to express my deep gratitude to my school. The school has provided us with a superior learning environment and much

The diversified resource support enables me to find my way in exploring my interests and abilities. The nurturing and motivation here has strengthened my belief in pursuing my dreams and made me more confident to face every challenge in the future.

The road ahead may be full of unknowns, but I believe that with the belief of gratitude and hard work, I will be able to continue to transcend myself and chase higher goals. I will use this experience as a new starting point, continue to study hard, try bravely, and write a more wonderful chapter for my life.

Thank you again to my parents, classmates, and school! It is your support and companionship that gives me the courage and motivation to go forward!

References

1. " Recent Advances in Flexible Sensors and Their Applications "
Authors: Bouchaib Zazoum, Khalid Mujassam Batu, Mohammad Al-Azhar A Khan Publisher: MDPI

Publication date: June 20, 2022
Description:This review explores recent developments in flexible sensors, focusing on applications in health monitoring and robotics. It provides insights into the materials, sensing mechanisms, and fabrication methods that are critical for enhancing the sensitivity and flexibility of wearable sensors for human health monitoring, including dental applications.

2. " Flexible Piezoelectric Materials and Strain Sensors for Wearable Electronics and Artificial Intelligence Applications "Published by Chemical Sciences, Royal Society of Chemistry

Publication date: recent
DESCRIPTION: This paper reviews piezoelectric polymer materials such as polyvinylidene fluoride (PVDF) and hydrogels, which have excellent biocompatibility and flexibility, making them suitable for wearable health monitoring sensors. It covers fabrication techniques and enhancements of piezoelectric properties relevant to dental applications where sensitivity and real-time monitoring are critical.

3. An overview of salivary health monitoring systems: technologies, biomarkers and applications by Lula Health Research Team

Published by: MDPI

Published: June 15, 2022
DESCRIPTION: This paper systematically reviews the current state of development of saliva-based health monitoring systems, in particular technologies for monitoring key biomarkers in saliva. The study compares existing assays and discusses the potential and challenges of such devices for long-term health monitoring.

4. Advances in Oral Health Testing: Spotchem ST System by Arkray Research Group

Published by Springer

Release date: March 12, 2021
DESCRIPTION: This paper discusses the application and clinical performance of Arkray's Spotchem ST system in detecting salivary health indicators, analyzes the system's applicability in a dental healthcare setting, and evaluates its rapid analysis capabilities and saliva monitoring technology.

5. *Artificial intelligence in dentistry: detecting gum disease through image analysis*
Artificial Intelligence and Dental
Research Team, The University of Hong
Kong Published by Elsevier

Published: May 8, 2023

DESCRIPTION: This paper reviews the development of artificial intelligence-based systems for detecting gingival disease, particularly gingivitis. The paper describes the limitations of the system in terms of image quality and user operational requirements, and analyzes the accuracy and future prospects of AI systems in practical applications.