A MEDICAL INTELLIGENT REHABILITATION SYSTEM FOR HALLUX VALGUS DISEASE

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Introduction. In October 2016, the Chinese Central Government and the State Council released the "Healthy China 2030" planning document, which proposed five strategic tasks including promoting healthy living, optimizing health services, improving health security, building healthy environments, and developing healthy industries. The 18th National Congress of the Communist Party of China further enshrined the implementation of the Healthy China strategy as a fundamental policy for national development, placing people's health as a "key indicator of national prosperity and national strength" and requiring "totality and comprehensive care for the people," indicating that the construction of Healthy China has entered the full-scale implementation stage[1]. China faces an unprecedented challenge in chronic diseases. Eighty percent of annual 10.3 million death tolls are caused by chronic non-communicable diseases. While the prevalence of these diseases is on the rise, awareness, treatment, and control rates are strikingly low[2]. The foot is often referred to as the "second heart" of the body, as the entire weight of the human body is carried by the pelvic and lower limb joints, with the foot serving as the primary support. Modern biomechanics indicate that the health of the foot has far-reaching effects on various aspects of the body. Foot diseases often lead to complications such as ankle，knee-joint，hip, and spine deformities, as well as abnormal development of the lower limbs and spine in children, emphasizing the importance of maintaining foot health[3]. Foot disease has become a common epidemic among modern people. According to a "5-year epidemic survey on foot diseases" conducted by the Chinese Society of Dermatopathology and Immunology, every two people in China have foot diseases, and the rate is as high as 3/4 among adults. Common foot diseases include calluses, flat feet, ulcers, hallux valgus, and hammertoe. Foot disease is not only increasing in prevalence in China, but also globally. According to the latest statistics from the United States Center for Disease Control, almost half of Americans are affected by foot disease. In the United Kingdom, over 2 million people seek

treatment each year for foot problems. However, due to low awareness and lack of importance attributed to foot diseases, the condition has become worse, highlighting the need for greater attention to foot health[4].

Hallux valgus (**Fig.1**) is one of the most common foot diseases and is also one of the most easily ignored foot diseases in the early stages. Its main clinical manifestations include an external rotation of the hallux, a partial dislocation of the first metatarsophalangeal joint to the outer side, metopic calcification of the first metatarsus, and protrusion of the sesamoid to the outer side[5], the main cause of hallux valgus is a dislocation of the joint at the base of the hallux, which causes the hallux to bend outward and cause the head of the hallux to protrude outward.

Fig.1 Hallux valgus.

The prevalence of hallux valgus is as high as 20% to 50%, with a male-to-female ratio of 1:9 to 15. In women aged 18 to 65, the prevalence is 23%, while it is 35% in women over 65. The prevalence of hallux valgus in children is 2% to 36%[6], these symptoms typically occur due to the too-narrow width of the shoe upper, which fails to provide enough space for the foot to expand. High heels can also be a predisposition for hallux valgus, as wearing pointy-toed shoes compresses the feet and affects the muscles that attach to the big toe, causing it to move towards the other toes, leading to hallux valgus[7].

The severity of hallux valgus can only be accurately judged on the basis of the angle of the orthopantomogram. Patients are unable to judge the condition and its recovery by themselves with the naked eye, which requires several follow-up visits to the hospital during rehabilitation.

The normal range of the hallux valgus angle (HVA) is 10°~15° and the 1-2 intermetatarsal angel (IMA) is 3°~8°. The diagnosis of hallux valgus is made when the HVA is >15° or when there is an IMA >9°%. The clinical classification is based on HVA: (1) mild hallux valgus: 15<HVA≤19°; (2) moderate hallux valgus: 20°≤HVA≤40°; (3) severe hallux valgus: HVA>40°[8].

During the recovery process, for patients who have purchased hallux valgus braces without consulting a hospital, it is impossible to know if their wearing

is appropriate and effective. Establishing a patient-specific database to explore the recovery status after wearing hallux valgus braces, and proposing different recovery plans for different stages, has significant importance for the treatment of hallux valgus and serves as a foundation for further research in this field.

Current Research Status of The Project. Doctors can diagnose hallux valgus symptoms with experience alone, but this is only an empirical diagnosis. Only the angle measured on an X-ray positive position is a precise diagnosis. Patients lack the experience of doctors and cannot diagnose their own condition during the therapeutic treatment process, which often requires multiple referrals for follow-up observation. With the advancement of technology, the application and management of Internet technology in the medical field have shown a trend of growth in recent years.

One important component of intelligent healthcare is intelligent health management, which focuses on patient information data and electronic health records. However, the current weakness of health management is that important physiological parameters of patients cannot be continuously and remotely monitored, mainly due to the limitation of only being able to visit a hospital or participate in a health check-up at set times[9].

The current approach of scholars at home and abroad to this problem has focused on the development of patient-friendly mobile apps, public numbers, and apps that combine hospital medical resources. These programs have similar functions and are designed to facilitate patients' access to medical resources. The common ones are telemedicine systems that use computers and network communication networks to transmit and send audio and video information, query and display, store and back up, and realise the functions of network clinics, remote consultations, and health consultations[10]. There is a cloud-based medical information service platform that utilizes communication and audio technology to transmit, query, share, store, and display information. This platform realizes remote access, medical queries, booking appointments, electronic medical records, and health analysis functions[11]. There is also a database that enables patients to access their medical records through mobile internet technology, making it convenient for patients to access their records without having to visit the hospital.

Currently, intelligent service in Chinese hospitals is relatively widespread, and Internet hospitals in large hospitals have comprehensive functions. However, research on certain specialties is not very extensive. For the intelligent medical module of hallux valgus, it is possible to book an appointment and have a remote consultation, but diagnosis still requires an X-ray image to be taken in hospital.

Research Methods.

1. Research Methodology

The diagnosis and recovery of hallux valgus require patients to return to the hospital for follow-up appointments. Recovery training is different depending on the stage of recovery. To design an intelligent recovery system for hallux valgus, an online terminal with a small program is proposed to achieve hallux valgus severity recognition, patient foot recovery database construction, and re-

covery program recommendation. This approach will address the limitations of patient physiological parameters not being able to be continuously and accurately monitored, and patients being limited to fixed visiting times or physical exams. Currently, there is no personal database system for patients in the market. This project provides ideas for the design of an online terminal for hallux valgus.

2.Basic Methods of Project Research

(1) Structured Programming Method

The design of the hallux valgus intelligent recovery system terminal uses a structured programming method based on three structures: branch structure, loop structure, and sequence structure. The program has clear modular characteristics, with each program module having a unique exit and entry statement. Structured programming is simple, clear, and modular, and its description is close to the reasoning-oriented thinking style that people are used to.

(2) Data Analysis and Theory Summary Method

CT and MRI imaging technology is used to collect necessary foot image data for the experiment, computer simulation process, and results. Data analysis and theory summary are used to explore the measurement theory of hallux valgus angles, standardize hallux valgus angle measurement, and provide corresponding theoretical support for the design of a hallux valgus angle measurement device in the future.

Research results. The construction of a WeChat mini program can be divided into two parts: the front-end and the back-end. The front-end uses WeChat mini programs to present various function pages and accept user inputs, using the MINA framework structure. WeChat uses JavaScript script programs to call the components and API interfaces of WeChat mini programs, obtaining user operations information. The https requests of WeChat mini programs to access the Bmob database are called through JavaScript scripts, which call the API interfaces of the Bmob backend cloud. The JSON format data returned by the Bmob backend cloud is parsed by JavaScript and presented to users through HTML. The back-end runs on the server and responds to interactive information sent by the front-end, executing specific functions such as calling recognition scripts, reading database information, and returning corresponding results, and interfaces with the MySQL database externally.

The severity of hallux valgus is often determined through X-ray images. The Hallux Valgus Angle (HVA) and Inter Metatarsal Angle (IMA) are measured on a foot X-ray to objectively and quantitatively determine the degree of deformity. **Fig.2** shows the radiological representation of the hallux valgus angle.

Fig.2 Representation of HVA and IMA.

Five randomly selected samples were selected, and the line connecting the midpoint of the thumb to the midpoint of the second toe (line E in the figure) and the line connecting the midpoint of the second toe to the center of the ankle (line F in the figure) were measured on the right foot. The angles formed by these lines were compared with the hallux valgus angle (the angle formed by lines C and D in the figure). As shown in **Fig.3**, the angle measured on the line connecting the midpoint of the thumb to the medial side of the foot and the line connecting the center of the ankle to the plantar side of the foot was always 3 degrees greater than the hallux valgus angle. The hypothesis was correct and consistent with the theory of measuring hallux valgus angles. However, further experimental results are needed to validate the theory.

Fig.3 The test chart for conjecture.

The above sample data was obtained from 21 pairs of right and left feet randomly selected, as shown in Table 1. After verification, the theory was found to be correct.

Table 1

21 sets of hallux valgus angle data.

Part	First Included Angle	Second Included Angle	Angle Between The First Metatarsal Bone and The Highest Point of The Thumb	Included Angle Between Second Metatarsal Bone and Ankle Center	HVA
Right Foot	0	2	6	3	21
Right Foot	6	3	6	3	18
Right Foot	9	5	6	3	18
Left Foot	3	5	6	3	20
Left Foot	6	10	6	3	15
Left Foot	9	5	6	3	20
Right Foot	6	8	5	3	19
Left Foot	5	2	7	3	15
Left Foot	7	8	6	3	15
Left Foot	8	8	7	3	11
Right Foot	9	14	7	3	14
Left Foot	5	10	6	2	30
Left Foot	2	10	7	3	23
Left Foot	4	0	6	3	19
Left Foot	5	5	5	3	12
Right Foot	1	5	7	3	14
Left Foot	2	0	6	3	19
Left Foot	1	2	6	3	11
Left Foot	2	5	5	3	14
Right Foot	3	8	6	3	9
Right Foot	5	2	5	3	12
Average Value	4.5	5.4	6.1	3.0	/

The hardware construction of the valgus angle measurement device consists of a rotatable potentiometer and a ESP-wroom-32 control board with a Bluetooth transmission module, as well as a 3D printed case. The device is used to measure the valgus angle of the affected foot by rotating the rotatable potentiometer into contact with the patient's foot, and the data is then uploaded to a WeChat mini program built using the Bluetooth 4.2 transmission protocol. The database stores the historical measurement data of the patient, and a graph is displayed to provide feedback on the patient's recovery progress.

The hardware and serial port debugging simulation are built using the wokwi online platform, using virtualization technology to simulate the main components of the valgus angle measurement device, which are the ESP-wroom-32 development board and rotatable potentiometer. The platform's own serial port monitor is used to help view the feedback angle, as shown in **Fig.4**.

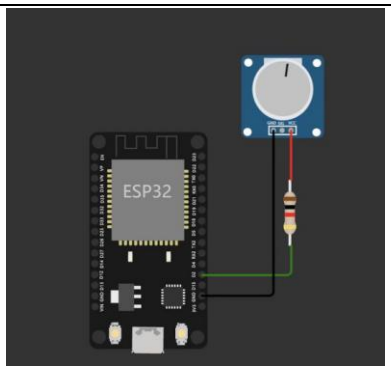

Fig.4 Wokwi online platform simulation.

The construction of the hallux valgus angle measurement device has shifted from simulation to reality, as shown in **Fig.5**. A preliminary shape has been modeled, as shown in **Fig.6**. In the future, 3D printing technology will be used to produce the outer components of the hallux valgus angle measurement device, and experimental verification will be performed to test the theory of hallux valgus angles obtained in previous research.

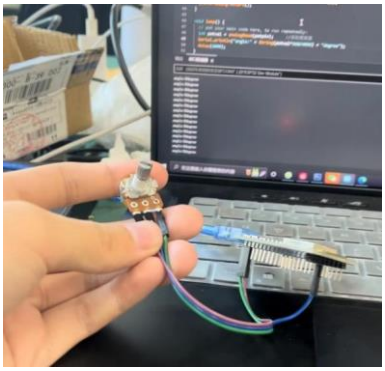

Fig.5 Main components of the hallux valgus angle measuring device.

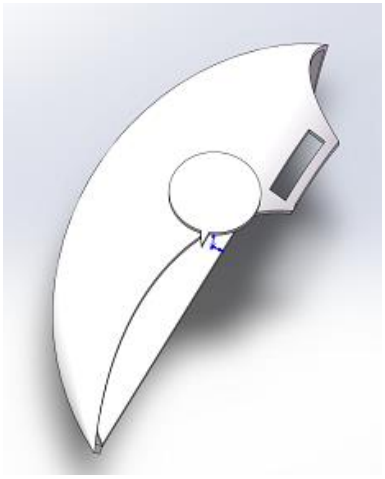

Fig.6 Preliminary morphological modeling of hallux valgus angle measuring device.

The innovative points of this study include:

1. The design of an intelligent recovery recognition system with a patient's personal database, which provides real-time and continuous monitoring for pa-

tients during follow-up appointments and is limited by time and location. The system provides different training programs based on the patient's recovery status, further improving treatment efficiency.

2. The design of a Bluetooth transmission module-equipped hallux valgus angle measurement device, which consists of a rotatable potentiometer and a ESP-wroom-32 control board with a Bluetooth transmission module, plus a 3D printed case.

The difficulties encountered in this study include:

1. The official Bluetooth of the WeChat mini program does not support external Bluetooth access, so new Bluetooth small programs need to be written to connect with the Bluetooth transmission module of the ESP-wroom-32 control board, achieving communication functions.

2. The theory of measuring the hallux valgus angle without using X-ray images is not yet complete and needs to be further studied through experimental verification to obtain the most accurate and minimal error measurement method.

Conclusion. The present study designed and developed an easy-to-use device for angle measurement, as well as a comprehensive application for hallux valgus recovery, which can provide patients with more convenient and efficient recovery solutions, enabling them to recover their feet's health as soon as possible.

The designed product of this study was also evaluated through design assessment and experimental verification, demonstrating its rationality and reliability. We hope that this study can continue to contribute to the research field of hallux valgus, provide ideas and references, and hope that it can provide better and more effective recovery solutions for more hallux valgus patients in the future.

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