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# A Cloud Information Platform for 3D Printing Rehabilitation Devices

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## Abstract

Due to the problems of current population aging, occupational injuries and traffic accidents have led to an increasing number of elder people who are physically disabled in Taiwan. These persons, mostly seek medical treatment from medical institutions to help restore them to their premorbid level. Therefore the number of patients who go to medical institutions is gradually increasing and the splinting is largely applied in the medical cares. 3D printing technology has been widely used in the medical industry in recent years, especially in the development of rehabilitation devices. Up until now, to produce the customized splint requires either face to face communication or messaging software by relevant parties. Due to the complexity of the medical process, it is often time-consuming for occupational therapists to discuss the medical records with the splint design engineers via the above mentioned means. The other difficulty is that data management becomes a real problem. Medical communication and information management are thus the most urgent issues that need to be investigated. In this study, we applied the information technology and cloud-based technology to design a simple and user-friendly web-based interface for making 3D printing splint. This web-based interface utilizes cloud-based technology to provide an information platform for communication and co-management between the relevant stakeholders. The aim of this study is to make system management, retrieving patients' information and browsing 3D graphics be more convenient for users, and thus to improve the efficiency and effectiveness of producing splints based on the proposed system.

**Keywords:** 3D printing, rehabilitation devices, splint, cloud, information platform

## 1. Introduction

The 3D printing technology has been applied to the medical field in recent years. This technology has partially solved several problems raised from stuffiness, clothing, and uncomfortable level of wearing the traditional medical assistive devices, such as splints. Moreover, 3D printing technology has achieved a further breakthrough of advocating the effective of reducing patients' feelings of inferiority when wearing an assistive splint. Thus, 3D printing has become a feasible solution in solving the aforementioned problems through the production of improved splints.

Although there are many various medical information systems in medical applications, most of them are the kind of information sharing systems to share the patients' medical records. However, there are very few information system platforms developed for the purpose of medical device manufacturing and little information about functional treatment units. Therefore, doctors and occupational therapist must rely on paper works, telephones, face to face or additional use of communication software to communicate with each other so that such communication process is time consuming. With the 3D printing technology, the splint production method has been transformed from hand-made to digital production. Without the information, communication platform, to check the blue print of the splint on the platform by all the related medical care parties becomes

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impossible. It makes everyone have to communicate with each other by using traditional ways. The process for completing a customized splint by using 3D printing technology is complicated. At first, after diagnosis and medical treatment, doctor keys in all the diagnostic information on the window of patient rehabilitation treatment card through the computer. Next, based on the doctor's diagnosis, the 3D model of the splint has to be designed by the designers and then assessed by the therapist. While the 3D model is approved, the 3D printing process of the splint is then activated. However, during the process, the related personnel must communicate with each other, check the best parameter settings of the 3D graphic in details and discuss and amend repeatedly. The communication methods of the existing medical clinic are using the telephone, messaging software or face to face to communicate. Since the medical personnel are too busy to discuss freely in the scene. Using the current communication ways as described above without seeing 3D graphics, it will cause many difficulties in expression and make the related data is hard to be managed and stored properly.

Therefore, this study is to turn the workflow of the 3D Printed Rehabilitation products into the clouding computerized processes. The information sharing platform enables various parties to cooperate in making a more perfect splint for patients. Based on the proposed system, a multi-directional communication and information transmission pipeline can be built so that it makes all the operations with better efficiency and effectiveness. The purposes of this research are illustrated as follows:

(1) The electronic system has been adopted instead of using paper files to reduce the unnecessary waste of resources.

(2) To explore how to use the information platform to improve the original work situation in the hospital.

(3) Design the 3D printing assistive device splint cloud information platform to solve the previous problems such as management and communication inconveniences to enhance the efficiency of personnel.

## 2. Literature Review

A rehabilitation assistive device refers to any device or product used to maintain or improve the quality of life and movement ability of people with disabilities [1]. Among the several health care aids, splints have been widely used in medical departments, such as rehabilitation and orthopedics, due to time constraints [2]. A splint is a kind of rehabilitation equipment, used outside of the human body, mainly for the fixation, or protection limbs [3]. Splints are used not only to improve the discomfort of limbs, but also to help people to use their limbs normally. Compared to the splint made of plaster, we need a lighter, cleaner, and air-permeable splint. So, we can say that the plaster should be taken place by the good ones.

Creating splints are one of the professional skills of occupational therapists. A splint can be made from a wide variety of materials. A traditional splint is usually made of low-temperature thermoplastic medical materials [4] and can be tailored to individual limb curves. This feature solves the gypsum breathable problem, reduces the burden of patients wearing splint, and makes wound dressing or cleaning of the skin around the wound convenient [5]. However, the traditional splint materials are not waterproof, prone to allergies, difficult to shape on the limbs, and cannot hollow out any position on the splint surface [6].

With 3D printing technology, all kinds of graphics can be generated directly through 3D graphics software design, without restrictions on size, shape, and color. It has a high degree of freedom and complexity in design, so it is more convenient for the production of small-scale limb splint, and can also improve the patient's fit and comfort when using a splint. With the advantage of 3D printing, the pre-opening hole position and the whole mesh pattern are corrected directly in the splint design, as shown in Fig. 1. This helps to improve splint's breathable and the waterproof function so that it will reduce the skin irritation or ulceration of the affected body area. Using 3D printing technology, it can avoid unnecessary waste of materials and reduce the production costs. After forming 3D printing splints, these splints do not need special maintenances [7]. So, 3D printing technology has become a significant issue of producing splint to an occupational therapist. The differences between the traditional splints and the 3D printing splints are illustrated in Table 1.

Fig. 1 The production process of 3D printing splint sequence diagram [7]

Table 1 Comparison of Traditional splints and 3D Printing splints

| | Traditional splints | 3D Printed splints |
|---|---|---|
| Production methods | Manual | 3D Printer |
| Time to use | Shorter | Longer |
| Breathable | Medium | Height |
| Customized | Low | Height |
| Waterproof | No | Yes |
| Suitability to smaller limbs | Low | Height |
| Complexity | Low | Height |

The introduction of 3D printing has brought many possibilities to the medical treatment. In recent years, various 3D printing medical devices have been developed in medical clinics, such as teeth, tracheal scaffold, splint and so on. These splints are the harness and used in the external body. The purposes of these devices are for treating, immobilizing, or protecting the function of damaged body parts [3]. During the manufacturing of 3D printing splints, all the assigned personnel need to discuss the 3D graphics with one another. However, the current method that uses considerable paperwork delivery fails to meet the demand to check the 3D graphics of splints. The process requires the use of messaging software, telephone call, or face-to-face discussion among personnel. These inefficient methods will cause communication inconvenience, management problems, and 3D graphics browsing difficulty. In the research on medical information transmission, Yang and Liu imported a device for the traditional manual work mode of nurses and developed a nursing information system [8]. This device assists in daily works by using a computer or network. The results showed that the device could reduce overtime rate and unnecessary waste of materials, make the patient information inquiry convenient, and improve work efficiency. Tian et al. showed that the use of electronics to improve medical image processing operations could reduce patient waiting time and accurately manage the medical graphics data to promote high-quality service [9]. Doel *et al.* combined medical image processing operations with cloud technology to assist the data storage, management, and analytical tasks of medical images on the web [10]. This process allows health care personnel and researchers to share the medical image data conveniently. As previously mentioned, electronics and cloud technology will be the necessary tools for future development in the medical industry. Recently, Umair and Kim proposed an online 3D printing service platform and cooperated with medical clinics who are interested in 3D printing [11]. Through this platform, the information about 3D printing medical-related data and medical clinics can be provided. Furthermore, the platform can provide knowledge and production of 3D printing medical material information to patients and medical clinics. However, the purpose of the present study is focused on the medical assistive device splint production in health care clinics without outsourcing. Therefore, we integrated the entire operation data of medical doctors, occupational therapists, and 3D printing engineers. These professionals could comfortably and easily use the platform for job processing and information sharing by using related technologies. In addition, we designed the splint cloud information platform of a 3D printing assistive device to improve the splint manufacturing efficiency.

Designing a web-based interface that allows the users to get started quickly and promote the usage intention must be investigated. If the system interface is poorly designed, it will reduce the usage intention of the users. Therefore, Laurel and Mountford proposed that human–computer design principles are mainly divided into: (1) User-oriented design. (2) Interfaces consistency. (3) Graphical representations. (4) Multiple views [12].

Li proposed that the expression clearly can enhance the usage intention of the users. Besides, before developing the system, the requirements should be clarified [13]. Booch proposed that Unified Modeling Language(UML) which is the visualized language for developing software and uses different diagrams to describe the system requirement through different viewpoints [14]. The diagrams of UML can be divided into: (1) Use case diagram. (2) Class diagram. (3) Component diagram. (4) Activity diagram. (5) Collaboration diagram. (6) Sequence diagram. (7) Statechart diagram. (8) Deployment diagram. UML is using the standard diagrams to simplify the lengthy text statements and allows the system developers, designers and users to understand the cognition of system framework, flow path, and all aspects quickly [15].

## 3. Research Approach

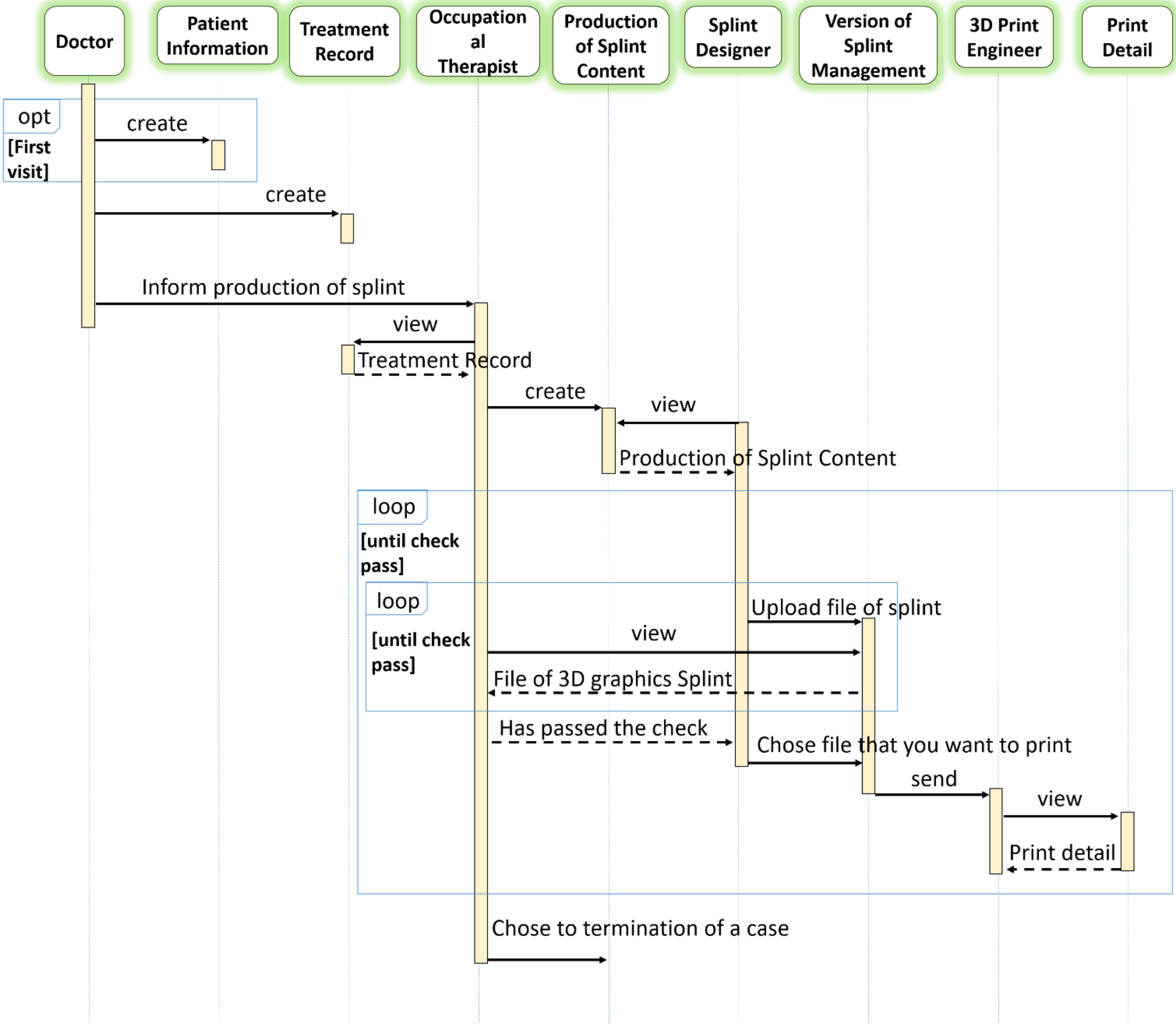


Fig. 2 The production process of 3D printing splint sequence diagram

The present day, there was no jointed managed pipeline for the transmission of the splints production information, so this study cooperated with the medical clinics and learned the current processes and methods of producing 3D printing splint in person in a medical clinic. We used the information technology and cloud technology to solve the previous paper waste, both sides communication, browsing 3D graphics and managing medical data difficultly and other problems.

We explored the workflow of producing splints in the hospital in this study. The basic functional items in the workflow for producing the 3D printing rehabilitation splints are: (1) Patient data records (2) Medical records (3) Information about the splint creation (4) Upload 3D splint drawing file (5) Execution of 3D printing (6) Query 3D printing splint information (7)

Account management (8) Splint category (9) Message bulletin (10) Permission control. Based on the above functions are defined for each item, the users of the system are then clarified with the corresponding various authorities. They are as follows: (1) Medical unit - doctor. (2) Medical unit- nurse. (3) Medical unit - occupational therapist. (4) Splint design units- 3D graphics engine. (5) 3D printing unit - 3D printing engineer. (6) Platform System Manager - administrator.

In this study, the system demand analysis and design use the UML to explain the platform design, as described as follows. During the initial visit of the patient, the doctor must collect the patient's basic data. Then, the doctor creates a patient treatment record and selects the suitable splint. Subsequently, the occupational therapists establish the splint production contents in accordance with the splint specification, which is established by the doctor, and assist in splint production. Next, the splint designer starts to draw the 3D graphics of the customization splint based on the splint production contents. Following design completion, the 3D graphics are uploaded into the splint version management in the platform. The occupational therapists will check whether the design is a 3D graphics; otherwise, the splint designer must upload again the data after correction until it passes the verification stage. After passing the verification, the splint designer sends the 3D graphics to the 3D printing engineers. The engineers will receive the printing details and produce it. Afterward, the generated splint will be checked by the occupational therapists. If the splint is not in accordance with the specifications, it must be returned to the splint designers, who will upload the 3D graphics files until the finished product passes verification. Finally, the case is terminated by the occupational therapists. The 3D printing splint production process is shown in Fig. 2.

## 4. Platform Design

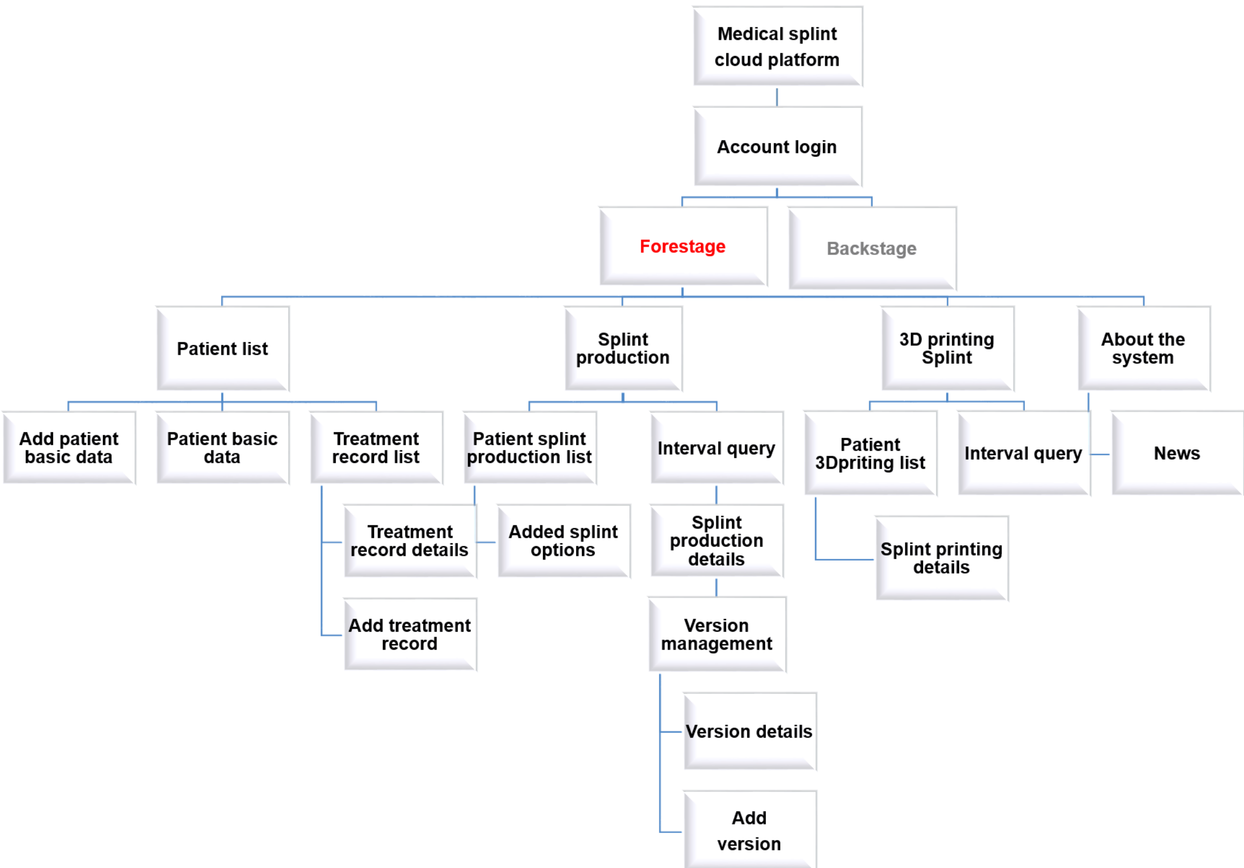

Fig. 3 Forestage platform framework diagram

The proposed system platform in this study is divided into two major parts, namely, the forestage system and backstage management. When entering the proposed system, the platform will lead the users to the forestage or backstage screen on the basis of the users' status. The users of the cloud information platform forestage of the 3D printing rehabilitation device are doctors, nurses, physical therapists, and 3D graphics and printing engineers. The process structure of the system forestage is shown in Fig. 3. There are four functional sections in the forestage, they are “Patient list”, “Splint production”, “3D printing splint”, and “About the system” respectively. The corresponding web interface is shown as Fig. 5. Moreover, the system platform administrator has the highest login authority of the backstage. The backstage structure is illustrated in Fig. 4, and there are four main functional sections including “Splint kind setting”, “Account management”, “Web page function setting” and “About the system”. The two major functions (forestage and backstage) describe the structure of the proposed cloud information platform, for which all the different roles of users can use the platform to produce the customized splint for each of the patients.

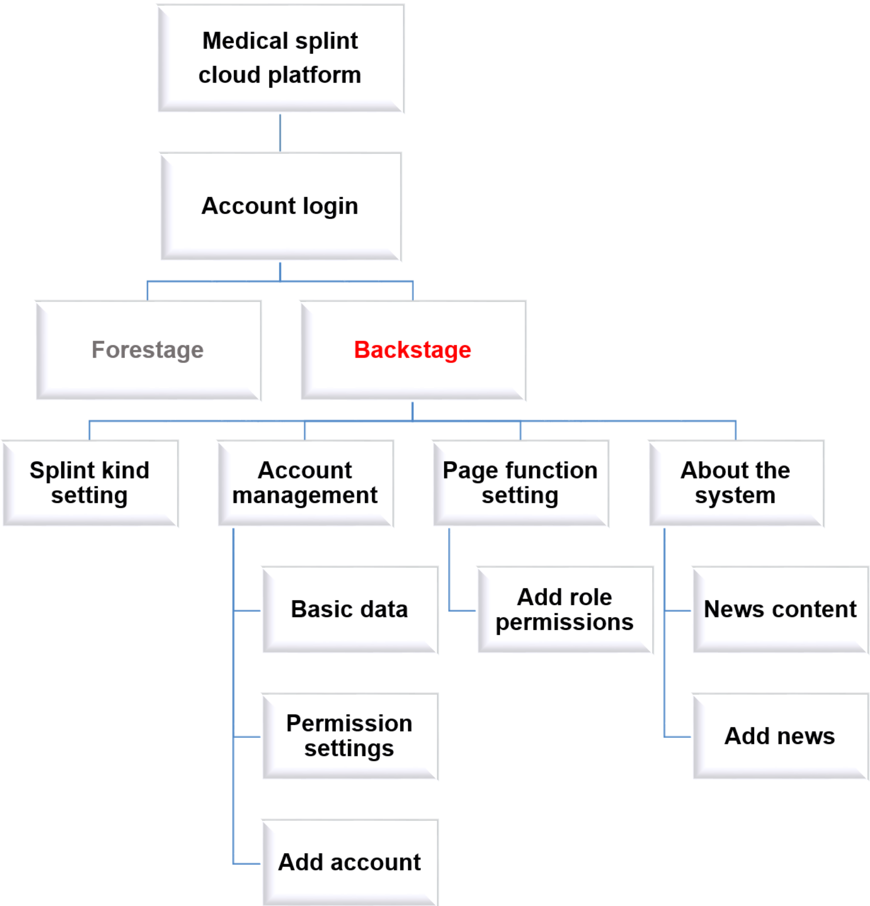


Fig. 4 Backstage framework diagram

The system requirements in this study are presented on the Web platform. In general, the planning of the platform includes the following five major parts which are described in the forestage and backstage of the cloud information platform as follows:

(1) Basic data about Patient management: all the medical care data of the patient, including the following four functional pages as shown in Fig. 5.

(a) The basic data of patients: the basic data for recording the patients.

(b) Treatment record: the treatment records of the patients, including medical information, diagnostic logs out and treated areas for the occupational therapist to know the treatment demands of patients.

(c) Splint production: Records of splint specification and 3D graphics file management for every patient. This information also provides 2D and 3D graphics uploading, browsing, and leaving a message. The details are illustrated in Fig. 7.

(d) 3D printing splint: 3D printing splint for the 3D printing engineer to receive the 3D model printing information.

(2) Categories of splint setting: Manage the information of various 3D printing splint. See Fig. 6.

(3) Account management: it is the basic users' data and the authority in the platform as shown in Fig. 8.

(4) Permission settings of pages and function: for setting the permission of all users as shown in Fig. 9.

(5) About the system: it is the announcement pages of the internal information and its declaration of the internal information and its records the usage condition of the platform.

In the process of making a splint for a patient, all the data are divided into four major items, one of which is the patient's basic information, the second is the patient's medical record, the third is the splint production menu, and the fourth is the 3D printing detailed information. The medical personnel can view the contents of the patient's case as needed. In terms of interface design, the button conforms to the "representation of content in graphics" and "content must be clear" as mentioned in the literature, as shown in Fig. 5.

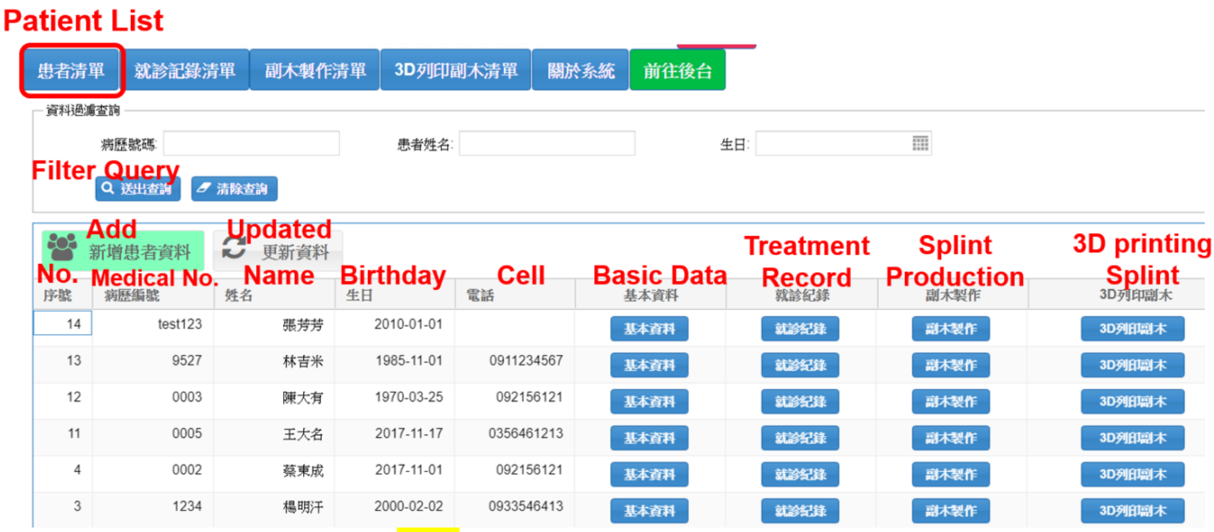


Fig. 5 Basic data of Patient management

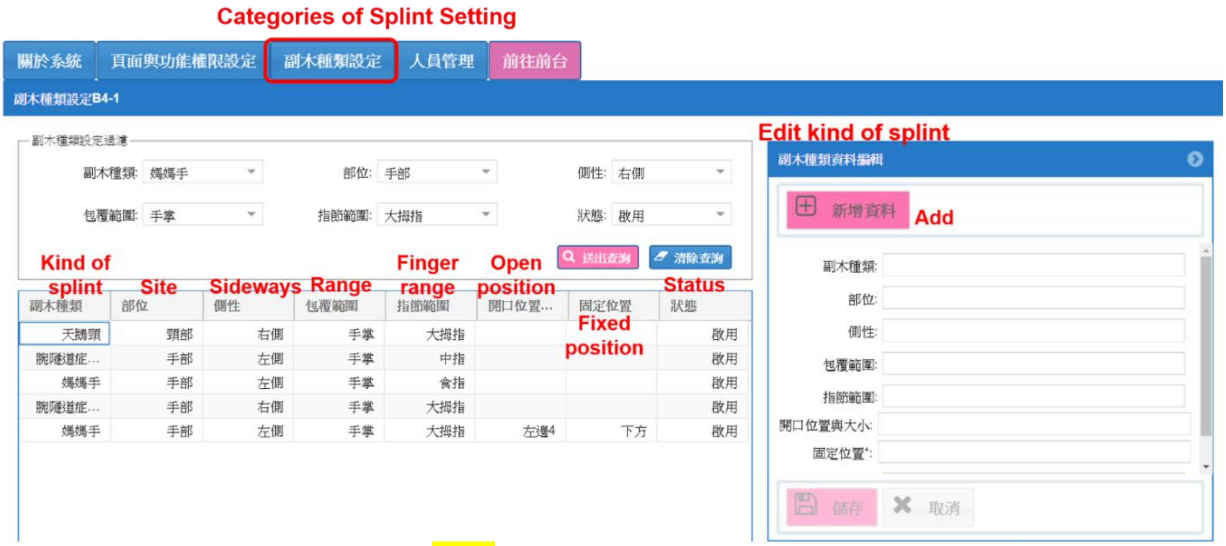


Fig. 6 Categories of splint setting

This content in Fig. 6 is designed as a backstage administrator to manage the information of the 3D printed splint category. From this page, the administrator can edit and add the type, location, laterality, coverage, knuckle range and whether the secondary wood is still in use to provide the front-end medical staff to select the appropriate splint for the patient. When making a secondary wood, it needs to be revised after discussion. A secondary wood production requires several versions.

Therefore, this study divides the splint production menu into two parts: the secondary wood production content and the secondary splint production version management, so as to reduce the complexity of the user browsing.

The contents of the splint production include the name of the physical therapist responsible for the case, the functional therapist number, the medical institution, the functional therapist's diagnosis, the type and side of the splint, the printing materials of the splint, and the uploaded image of the injured part of the patient, delete, download, and provide image zoom browsing, physical therapist notes, and status display. And we also need to consider the possibility that the patient temporarily changed his/her mind not to use 3D printed splint during the production process. Therefore, the "void button" is given to stop the subsequent actions, as shown in Fig. 7.

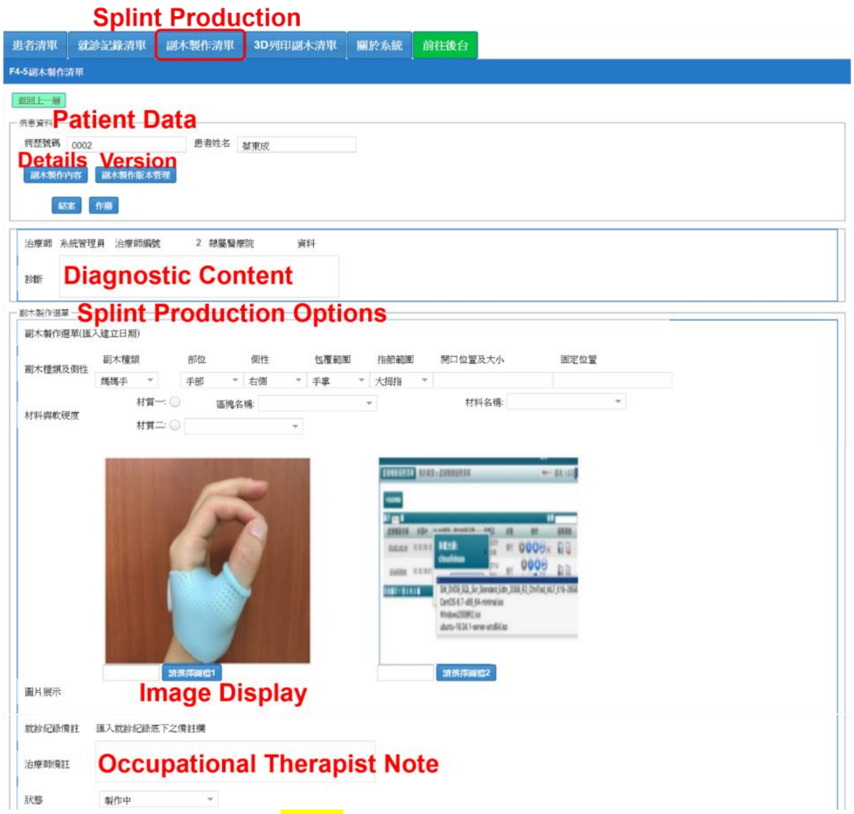


Fig. 7 Production of splint

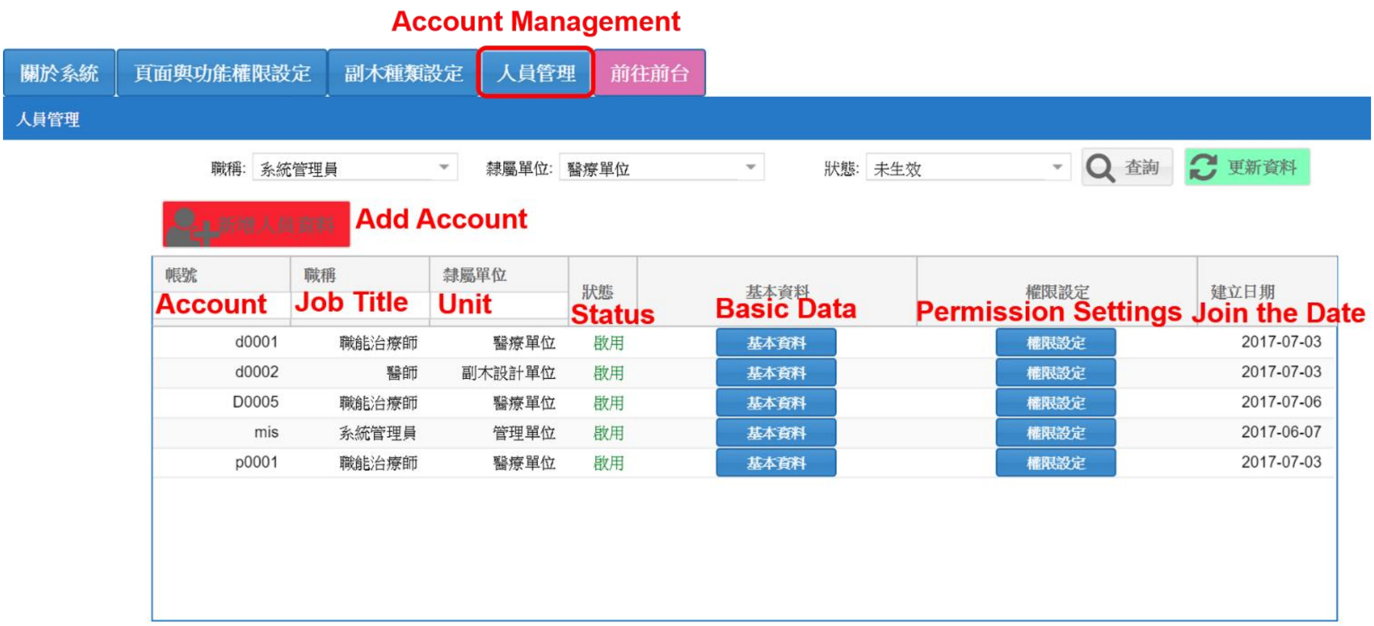


Fig. 8 Account management

This function page in Fig. 8 is a page for the background manager to manage employee data, which is divided into two parts: the employee's basic data and permission settings. Employee basic information includes user account information and employee basic information. The account information includes the employee account number, password setting, and consideration of personnel transfer. Therefore, the user status field is provided to control whether the user has the right to use the platform, and the corresponding authority is given to the user. The way to query personnel is to query the name, account number, job title, subordinate unit and status, so that the user can quickly search for the required information.

Since this platform has many patient privacy information, it is necessary to provide permission settings for the administrator to control. Therefore, we make the platform users use the functionality of the page to be restricted by permissions. Each person's authority is given the corresponding authority according to the set role. The page and function permissions are based on the content of the function, such as basic patient information, medical records, splint production, 3D printed splint, the backstage of the about system, the splint settings, personnel data management, role permissions settings. If there are special functions, the extended permission function is given to the user for additional settings, as shown in Fig. 9.

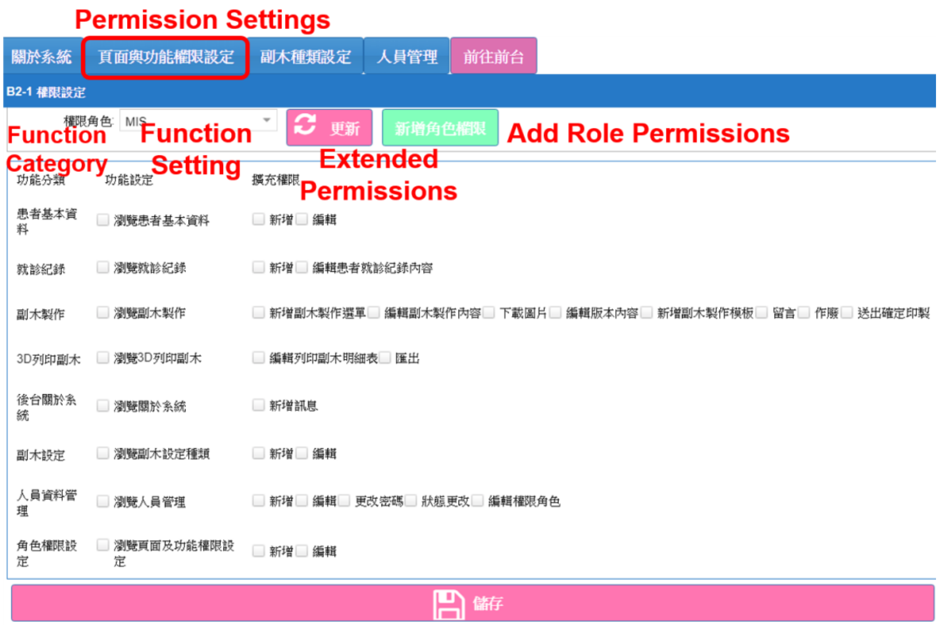


Fig. 9 Permission settings of pages and function

## 5. Conclusions and Future Researches

Three-dimensional printing is a digitized manufacturing technology; thus, manufacturing using such technology is made by computer drawing software and then produced by using the 3D printing machine. The assigned personnel need to browse the 3D graphics files in the manufacturing process; however, the personnel must face several unpleasant situations, such as unnecessary resource waste, 3D graphics management, information transmission, and communication without the use of the information platform. It will be very easy to cause the mistakes during the communication and file transmission. Therefore, in this study, we introduce the flow of utilizing 3D printing device in hospital, and utilize the cloud technologies and UML to design the information platform and then constructed it.

In this study, the cloud information platform for 3D printing assistive device splint can provide browsing functions of 3D graphics, feedback mechanism, and automatic managing function efficiently. This platform can prevent un-necessary wastes of the paperwork in delivery of documents, mistakes caused by browsing 3D graphics with wrong patient, and the difficulties in communication and document management. The proposed platform can also improve the splint production efficiency (see Table 2). From Table 2, we can see the comparison of before and after while using the proposed information platform.

Table 2 Comparison table of before and after use the information platform

| | Before Implementing of Information Platform | After Implementing of Information Platform |
|---|---|---|
| Information transfer method | Paper | Network |
| Browse 3D graphics method | Face to face communication / Other web-based | Browse in this study platform |
| Communication channel | Face to face communication / telephone/ messaging software | In this study platform |
| Data management | The manual way of management | An automatic way of management |

In this study, the cloud information platform of the 3D printing rehabilitation device is designed and constructed with the cooperation of many doctors in the medical clinics. In literature, many scholars have confirmed that the use of electronic and cloud technology in medical operations can effectively help medical personnel to file, find, save and operate their daily operations. However, the effectiveness of using the platform in medical clinics should be investigated in the future. And it needs to verify whether the process of introducing 3D printed rehabilitation device in medical care is suitable or not. Thus, we aspire that the use of the system can be used in medical clinics in future research and perform further verification and improve the operating efficiency of the splint production.

## 6. Acknowledgments

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## Conflicts of Interest

The authors declare no conflict of interest.

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