Virtual Simulation Teaching Centre in Dental Education: a Report from Fujian Medical University, China

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This report gives a brief introduction to the Virtual Simulation Teaching Centre of Fujian Medical University School of Stomatology (VSFMUSS), China. As one of the best dental simulation laboratories in China, the VSFMUSS aims to train dental students and clinicians to be professionals who are able to provide optimal oral health care by giving them the best virtual patient care experience possible in a nonclinical setting. The features, achievements and future directions of the VSFMUSS are addressed. Moreover, the role of the VSFMUSS was evaluated and discussed based on the students' and faculties' perceptions, rate of employment after graduation, and so on.

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Fujian Province, which has a population of about 38m, is one of the largest provinces in China. As in other parts of China, there is a shortage of dental professionals in this province. Currently, the proportion of registered dental practitioners in China in relation to its entire population is on average 1:8000[1]. Compared with the average ratio of several developed countries (1:2000) China still has a long way to go. Fujian Medical University School of Stomatology (FMUSS), which was founded in 1984, is currently the only dental school providing undergraduate and postgraduate training in Fujian Province. To solve the problem of a lack of clinicians, FMUSS has increased the enrolment of undergraduate and postgraduate dental students since 2000. Currently FMUSS recruits approximately 100 undergraduate students, 50 postgraduate students and five doctoral students every year.

As the key provincial college, FMUSS aims to provide dental education and training to provide optimal oral health care. In modern health care, patient safety is of the utmost importance, so the irreversible nature of most operative procedures means that students must have the skills to safely perform procedures while providing treatment and care. Therefore, apart from a requirement for academic knowledge, dental students need to acquire a full range of precise manual and technical skills, including good hand-eye coordination, to enable them to visualise and understand how to undertake complex tasks such as placing restorations, preparing and scaling teeth[2].

To provide a smooth transition from schools to clinics, almost every dental school in China has a simulation laboratory for preclinical training and/or continuing education for further professional development. These schools have been using various types of simulations for many years as indispensable components of the curriculum. There are two state-level virtual simulation teaching centres located at West China School of Stomatology, Sichuan University and Fourth Military Medical University School of Stomatology. Furthermore, there are more than 20 province-level virtual simulation teaching centres located in different provinces of China.

In 2003, FMUSS, like other leading dental schools nationwide, unveiled its restorative dentistry simulation clinic, a preclinical educational laboratory housing 51 dental simulation units. It focuses on the requirement of training high-quality dental professionals, with the aim of "focusing on the province, impressing the whole nation, and competing at the international level". Since 2005, FMUSS has made annual upgrades

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to its simulation facilities. Based on the province-level key experimental teaching centre at FMUSS, the construction of the virtual simulation teaching centre of FMUSS (VSFMUSS) was launched in 2008 with funds and aid from the local government and Fujian Medical University. In 2010, the VSFMUSS was preliminarily established, with approximately 10 million CNY invested, and it began providing a combination of virtual education and laboratory courses. After 8 years' development, the VSFMUSS has become a province-level virtual simulation teaching centre and is recognised as one of the best simulation laboratories in China, as assessed by the overall strength of its training. This article gives a brief introduction of the present status and future vision of the VSFMUSS.

Teaching and assessment functions

In general, four types of people might be admitted to the VSFMUSS: undergraduate dental students, dentists in clinical practice refresher programmes (CPRPs), postgraduate dental students, and clinicians in general dentistry residency programmes (GDRPs).

Undergraduate and postgraduate students at FMUSS are introduced to all aspects of dentistry by performing various procedures in the VSFMUSS before entering their internship. Students must have successfully completed a clinical entrance exam before they begin treating patients in dental hospitals or clinics. In Bachelor of Dental Sciences (BDS) programmes provided by FMUSS, upwards of 620 h are devoted to simulation activities, including restorative dentistry (cavity preparation and the restoration of teeth), prosthodontic training (crown and bridge work) and oral surgery.

Each year, FMUSS offers various CPRPs in different aspects of dentistry, such as periodontics, oral mucosal diseases, endodontics, pedodontics, prosthodontics, orthodontics, and oral and maxillofacial surgery. Practitioners interested in these refresher programmes send their applications via mail or the internet, and the detailed schedules are arranged according to the information provided by an applicant regarding his clinical experiences, his continuing education lectures fulfilled, etc. Clinicians in the CPRPs have limited access to the laboratories in the VSFMUSS depending on the programmes provided by the different clinical departments of FMUSS.

The GDRPs in Fujian Province, China is a 1 to 3-year clinical education programme that offers clinicians access to advanced comprehensive clinical experience in a hospital environment. After 2010, all new dental school graduates are required to enter the GDRPs to strengthen their clinical skills. Each year FMUSS recruits 30 clinicians to the GDRPs, and the required clinical hours vary for each individual. Like practitioners in the CPRPs, those in the GDRPs also have limited access to the laboratories when there is a need.

Meanwhile, the VSFMUSS is also an indispensable part of continuing education programmes in Fujian Province, providing an ideal environment in which to teach advanced endodontics, orthodontics, prosthodontics and surgical and dental implant procedures. It also fulfils an important role as an educational partner in the practical training of local colleges by providing dental assistance training and hygiene programmes.

In addition to its teaching purposes, selected portions of the National Board Dental Exams in Fujian Province are held at the VSFMUSS every year.

Organisation and structure

The VSFMUSS is located in building F at Fujian Medical University's home base, covering an area of 2018 m^2. Its faculties include 20 full-time and 65 part-time teaching staff, as well as 12 teaching supervisors at the rank of associate professor or higher. The VSFMUSS provides an average of 200 h per student each semester for simulation activities in the existing dental curriculum.

In general, there are four main components in the VSFMUSS: the basic dental sciences learning platform, preclinical learning platform, a continuing education platform, and a distance learning platform. In the VSFMUSS, both conventional simulation equipment and virtual simulation equipment are available to fulfil all kinds of teaching needs for training in preclinical dental procedures. With the integration of advanced technology, the four platforms together give the students and practitioners the best virtual patient care experience possible in a nonclinical setting. Meanwhile, the VSFMUSS enables cyber-sharing and interaction with a disease-centred PBL case bank and 14 online courses, including four excellent province-level courses such as prosthodontics and oral and maxillofacial surgery. Furthermore, the VSFMUSS has developed a series of virtual teaching programmes, which has helped to seamlessly establish our modern teaching system using a combination of virtual education and laboratory courses.

Basic dental sciences learning platform

The basic dental sciences learning platform includes the virtual microscopy (VM) laboratory and dental anatomy laboratory. VM is a major area where simulation has

been successfully introduced into the foundation of the sciences underlying dental education[3].

The VM laboratory is equipped with 52 virtual slide microscopes (Motic, Xiamen, Fujian Province, China) to augment traditional microscopy in teaching oral biology, histology and pathology. Each student can use a computer to independently look up any image in a database that contains thousands of slides. Instructors can communicate either with the whole class or to selected students via a local network. Slide specimens are digitised at high resolution, which in turn allows the computer to mimic the workings of a light microscope as the student moves across the virtual specimen or magnifies selected areas.

The dental anatomy laboratory has 20 computers on which three-dimensional anatomy software (Rainer Network Technology, Beijing, China) is installed, allowing students to learn both dental anatomy and dental radiology. Meanwhile, all the computers have access to the ZygoteBody 3D anatomy viewer (Google, USA). These are all provided through FMUSS libraries under site licensing arrangements as a cost-effective means for their deployment at a large scale so that all students have identical opportunities to access these resources.

Preclinical learning platform

The preclinical learning platform contains a phantom head laboratory, computer literacy laboratory and clinical skill laboratory. The phantom head laboratory has multiple stations (105 in total), including 52 DSE Plus simulation units (Kavo, Biberach/Riß, Germany) and 53 NISSIM Type 1 simulation units (Nissin, Nakagyoku, Kyoto, Japan). Each unit is equipped with a simulated patient, including a head and torso, removable jaws and teeth, dental hand-pieces, air/water syringes, and a dental light. Moreover, each station contains an interactive computer monitor and electronic keypads for instant quiz results and instructor feedback and two-way microphones. The phantom head laboratory is used in periodontic, prosthodontic, endodontic, pedodontic and surgical education. In the computer literacy laboratory, computer-based self-instructional media can be easily accessed to increase the range of learning experiences available to students, thereby supplementing the dental curriculum at a relatively low cost. Meanwhile, trainees have access to an orthodontic imaging system (Dolphin Imaging Plus, Patterson Dental, Saint Paul, MN, USA) under the supervision of instructors on one registered computer. The imaging system, which provides simulated orthodontic procedures and the ability to predict results, has shown potential for having a significant impact on orthodontics education[4]. Furthermore, the VSFMUSS has developed eight virtual teaching programs in cooperation with Rainier Network Technology (Rainer Network Technology, Beijing, China). These programmes, majorly based on the XML language, can perform 3D simulations of common dental treatment procedures and operations, including bonding procedures, dental instrument identification, dental implant placement and so on. The VSFMUSS owns independent intellectual property rights for these programs, and the number of the virtual teaching programmes is increasing annually.

In addition, a clinical skills laboratory containing eight dental chairs (Sirona, Österreich, Germany) was established in September 2010. This laboratory allows for a number of activities to be well developed prior to clinical contact and includes case study evaluations and role-playing. In specific curriculum, students can work in small groups rotating between the roles of clinician and patient. The realism of the virtual environment is enhanced by each case being accompanied with medical and dental histories, X-rays, examination notes and the reasons for the diagnosis. In-person interactions with other students have been found to have advantages in building relationships, establishing professional identity, developing teamwork skills, and appreciating the need for coordination in providing optimal patient care[5]. With the increase in student numbers, the VSFMUSS plans to expand the clinical skills laboratory to 16 dental chairs in the near future.

Continuing education platform

More complex simulation systems are available within the continuing education platform. The virtual dental training laboratory was recently established in cooperation with our industry partner (Digital Health Care, Suzhou, Jiangsu Province, China). This laboratory has two virtual simulation units, and each unit consists of a phantom head, dental handpiece and light, infrared camera, and one computer. The manikin head and handpiece contain infrared emitters that allow the infrared camera to detect their orientation in space. Thus, the position and orientation of the handpiece and the drill can be identified. As a dental student or clinician prepares an artificial tooth in the manikin head, the computer forms a virtual image of the tooth being prepared on the computer monitor. The software evaluates the tooth preparation both immediately, and at the student's request. The virtual tooth can then be compared with the ideal preparation approved by the faculty. Real-time evaluations

of critical, non-correctable errors are given as immediate feedback, along with a grade. Generally, the virtual simulation units can be used for teaching operative dentistry, prosthodontic, endodontic, and pedodontic treatment procedures. The virtual simulation unit was designed based on an approach similar to the one used for the DentSim simulator (Imagine Navigation, New York, NY, USA). More importantly, the units in the VSFMUSS, being completely covered by independent Chinese intellectual property rights, can be obtained at much lower costs than the DentSim units (approximately half the retail price of DentSim units).

A dental implant module is also available within the above-mentioned station. With the dental implant module, full guidance can be given with regard to treatment planning and actual implantation procedures in a non-clinical environment. Guided implantology is specifically directed toward the teaching, diagnosis, treatment planning, and placement of implants. It uses the same technology as the virtual simulation unit mentioned above, but a virtual simulation composite of an individual patient can be obtained by entering the patient's cone-beam CT scan data into the unit. More excitingly, the unit includes a registration device that can be used at the time of the surgery, allowing the patient and the virtual patient's image to be coordinated during the actual surgery. If the computer recognises that the trainee is making a significant deviation from the implant placement treatment plan during the surgery, the unit will stop the handpiece, and the trainee will need to restart the implant placement procedure manually.

The digital simulation laboratory contains 21 computers (one for faculty and 20 for students and trainees). The faculty can project either essential information or the faculty members' own screen to students' screens. A toothguide training box (Nowak Engineering, Switzerland) is attached to the faculty's computer. It enables dental students to learn tooth colour recognition in a playful fashion, making it easier to teach this information and enabling a better understanding of problems in tooth colour perception[6]. Meanwhile, the students' computers are installed with the corresponding "Toothguide trainer" software. Although visual shade matching is the most frequent clinical procedure, it is rather difficult for students and trainees with little clinical experience and knowledge to understand the science behind tooth colour.

In a previous study, we found that both the toothguide training box and the toothguide trainer software had positive effects on tooth shade matching independent of the colour scale used[7]. Moreover, the faculty's computer has PROPLAN CMF Planning software (Materialise, Leuven, Belgium) installed on it. This software offers step-by-step planning tools for distraction, orthognathics, and mandible reconstruction. Simulations of end results can be performed using soft tissue simulations and photo mapping tools. In addition, virtual simulations of skeletal osteotomies and reconstructions can be performed by the faculty and shown to students and trainees.

Distance learning platform

There are two distance-learning laboratories in the VSFMUSS. These laboratories allow for high-definition distance learning in a sound- and voice-controlled classroom. Each laboratory contains six 65'' Philips professional displays, two HD integrated cameras with high-definition output, and sub-compact live switchers with built-in multi-viewers. Based on the present video production system, HD telepresence deliveries are available for dental education. In the distance-learning laboratories, students and trainees can observe real-time operational procedures performed by senior specialists from the Hospital of Stomatology and other teaching hospitals at Fujian Medical University. Parts of the continuing education courses are also held in the distance-learning laboratories; thus, the live videos can be delivered with broadcast production quality through the university's public access channel. Distance learning also offers opportunities to interact with other students in dentistry, both locally and globally, and with students on other health care courses.

The VSFMUSS maximises its superior digitization and networking capacities to establish distance education that mainly consists of distance dental lectures, live videos of surgeries and distance dental consultations. It also enables the dissemination of excellent virtual teaching resources out to the whole province and the whole nation in the form of refresher programs and lectures combined with dental education. Professionals can display and explain the entire treatment procedure for typical cases via live broadcasts of surgeries and a recorded broadcast system, as well as a distance teaching and consultation system. To date, the VSFMUSS has successfully held more than 50 continuing education programmes, including the China-Japan-Korea Dental Science Symposium, International Advanced Course on Treatment for Occlusion Disorders, Sino-American Dental Education Forum using these advanced equipment systems. According to a rough estimation, more than 1200 trainees have participated in these courses, including more than 600 online trainees. The centre promises to expand its influence to primary hospitals,

aiming to solve the long-standing problem of the slow spread of knowledge and updated technology to primary dentists.

Distinguishing features and achievements

It has been found that virtual simulation technology can be used to improve and refine students' learning and performance[8]. It makes the learning process more effective and allows for advanced clinical and theoretical training of students, thus making them better dental professionals.

Over many years of teaching practice, the VSFMUSS has become more and more experienced and innovative, developing its distinctive features. The VSFMUSS built up its teaching system with the key focus on treating diseases to foster the development of outstanding professionals in dentistry, using both theoretical and practical resources, as well as virtual and real facilities. Our virtual teaching programmes based on proprietary intellectual property have filled the gap in this industry in China and have received high marks from dental professionals both at home and abroad. In the VSFMUSS, with its abundant clinical and scientific resources, our teams are able to perform scientific studies that are in line with clinical demands and that utilise innovative products that are suitable for clinical application, eventually transforming these studies into timely dental education. Students are able to access, critically evaluate, and apply knowledge from diverse fields to real-world clinical problems[9]. After 8 years of implementation, we are still refining and adding more features to the VSFMUSS. While there have been considerable costs, it has been a tremendous help to dental education in Fujian, China.

Continuous expansion and improvement of virtual simulation teaching resources enables concept visualisation and the simplifying of operations, which fully arouse students' interests under virtual circumstances. According to feedback from faculty members, students received virtual simulation training make remarkable progress in both learning incentives and perceptions.

At the same time, virtual simulation educational resources make it possible to greatly increase the proportion of practical training students receive, while decreasing the cost of laboratory consumables and animals. Currently, the ratio of practical courses to theoretical courses has increased from 0.75:1 to 1.2:1, and in some specific subjects, to 2.5:1. Adequate training provides good preparation for internship and continuing education, which is demonstrated by the fact that patient satisfaction has risen from less than 80% to more than 95% and complaint rates have been greatly reduced (FMUSS internal data). We can achieve a win-win situation via the training that the VSFMUSS provides as students obtain sufficient practice and patients' needs are met. More importantly, the teaching resources of the VSFMUSS are open to the public and can therefore satisfy the learning demands of dental practitioners of various statuses. With its extensive influence and well-demonstrated results the VSFMUSS promises to make significant contributions in promoting the development of dental education in Fujian, China and in improving the oral health of the general population. The VSFMUSS fully put its excellent virtual simulation educational resources to good use, serving as an outstanding model of dental education in Fujian, China.

Conflicts of interest

The authors reported no conflicts of interest related to this study.

Author contribution

Dr Hao YU designed and prepared the manuscript; Drs Chang Yuan ZHANG and Si Hui ZHANG collected data and provided essential information; Drs Hui CHENG and Jiang CHEN revised the manuscript.

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