Application and Evaluation of Virtual Simulation Technology in Implant Dentistry Teaching

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Abstract. To assess the application and effectiveness of virtual simulation technology in implant dentistry, we conducted a study with 46 stomatological students from Hunan University of Medicine. The students were randomly divided into two groups: an implant model group and a virtual simulation group. The implant model group performed traditional implant model surgery, while the virtual simulation group received training using a virtual simulation dental teaching system and practiced methods for implant model surgery. After completion of the surgeries, senior doctors in the department evaluated the outcomes, followed by an evaluation of overall teaching satisfaction by the students. Results showed that students in the virtual simulation group achieved significantly higher assessment scores compared to those in the implant model group (P<0 05). Furthermore, overall satisfaction among students in the virtual simulation group was significantly higher than that among control group participants (P<0 05).

Keywords: Virtual simulation teaching; Implant dentistry ; Impact assessment

1 Introduction

The field of implant dentistry is an interdisciplinary subject that encompasses oral prosthetics, oral and maxillofacial surgery, and oral materials. It places high demands on the theoretical knowledge and clinical skills of practitioners. Traditional teaching methods primarily rely on model-based operations and clinical observations, which are costly and non-repetitive. However, in today's society, these traditional clinical teaching methods fail to meet the needs of contemporary dental students. Several studies have explored the innovative application of virtual simulation technology in dental education [1,2]. By establishing a virtual simulation training platform, trainees can practice essential steps in oral diagnosis and treatment while experiencing the use of instruments during specific surgical procedures. This system records real-time data generated by trainees' operations for subsequent analysis of human-computer interactions, enabling quantitative assessment in virtual reality (VR) based dental education. Therefore, this study aims to integrate virtual simulation technology with oral clinical teaching to enhance mastery of implant techniques and improve practical skills.

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2 Data and Methods

2.1 Virtual Simulation Planting Teaching System

The software component of the system consists of three parts: student operating software, teacher management software, and case editing software. This system is capable of simulating the entire process of oral implantation under virtual conditions, providing a clinical practice-like environment that can be repeated, and establishing an objective and systematic scoring system.

2.2 Teaching Object

The research subjects consisted of 46 stomatological students from Hunan University of Medicine. All students had completed the theoretical part on implant implantation and were randomly divided into two groups with 23 students in each group using a random number table method. The planting model group only performed traditional planting model practices, while the virtual simulation group underwent planting model practices after virtual simulation training.

2.3 Research Method

Implant Operation Skills Training

Initially, a senior implantologist led all 46 students to review theoretical courses related to implant implantation and provided detailed explanations on relevant clinical operation procedures as well as specific assessment standards for implant placement.

Subsequently, students in the planting model group practiced at one site on the implant model for 60 minutes based on instructions given by the teacher. They then completed the right first molar's implantation within 20 minutes.After listening to their teacher's explanation, students in the virtual simulation group accessed the dental teaching system (Fig. 1), identified surgical instruments (Fig. 2), engaged in simulated exercises for 60 minutes within the virtual simulation dental teaching system (Fig. 3), and subsequently completed the right first molar's implant placement within 20 minutes on an implanted model.Two senior practitioners who did not participate in this training were responsible for conducting systematic scoring.

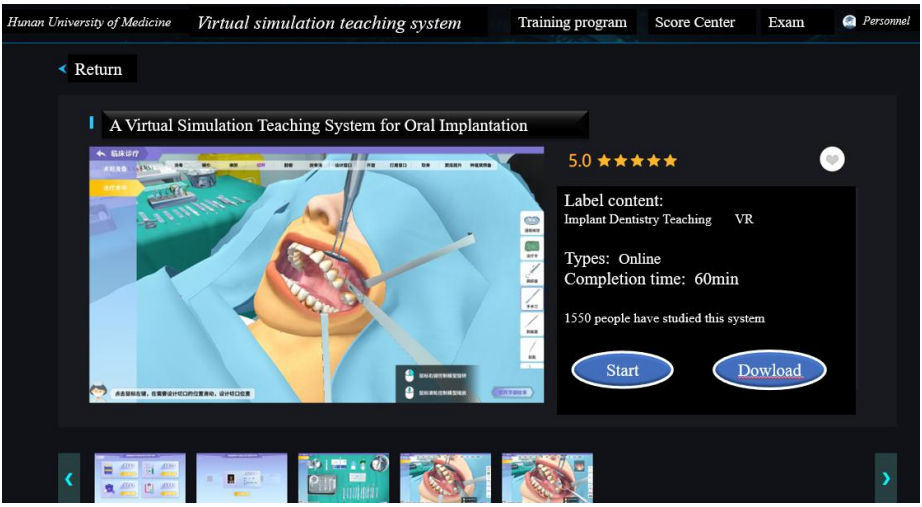

Fig. 1. Dental implant virtual simulation login system

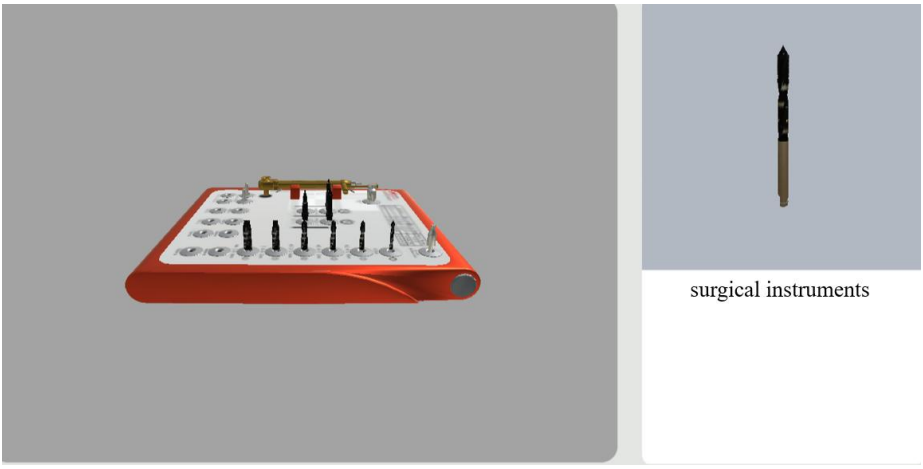

Fig. 2. Identifying surgical instruments

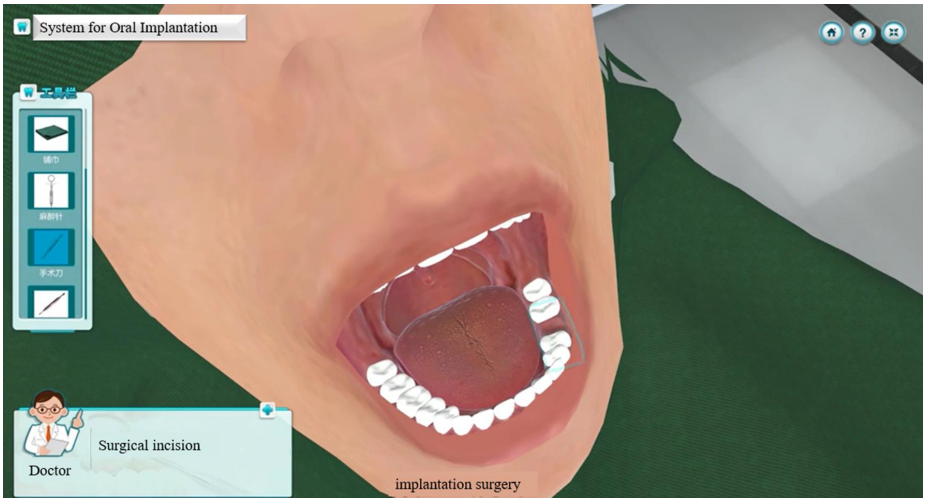

Fig. 3. Practice implantation surgery

Grading Rules

In accordance with the requirements specified in the oral implantology teaching syllabus, a comprehensive scoring system was established encompassing seven aspects: drill needle selection (10 points), rotation speed setting (10 points), operation procedure (20 points), implant depth (15 points), implant axis (15 points), and implant site (30 points). The total score amounted to 100 points, reflecting a comprehensive evaluation of the entire implantation process. Considering variations in clinical difficulty, different weight scores were assigned accordingly, with emphasis placed on precise and accurate execution. Deductions were made for deviations from the ideal set point based on the magnitude of error. A total of 46 students assessed their overall satisfaction with virtual simulation teaching and model-based teaching using a five-point scale ranging from very satisfied to very dissatisfied, evaluating factors such as teaching experience, operation accuracy, and operational flexibility.

2.4 Statistical Methods

Statistical analysis was conducted using SPSS 26.0 software. Two independent sample T-tests were performed to compare assessment scores between the two groups, while chi-square tests were employed to assess course satisfaction among students. A significance level of $P<0.05$ was considered statistically significant.

3 Results

3.1 After undergoing training with the simulation system, there was no statistical significance in drill needle selection and rotation speed setting. While the students in the virtual simulation group achieved significantly higher scores compared to those in

the implant model group ($P< 0.05$) across various aspects including operation procedure (t=11.63, $P< 0.01$), implantation depth(t=4.32, $P< 0.05$), axial orientation(t=25.00, $P< 0.01$), and implant site(t=29.45, $P< 0.01$). Furthermore, the overall scores of the virtual simulation group [(95.45 ±0.76) score] were significantly higher than those of the implant model group [(92.58 ± 0.38) score] ($P< 0.05$) (Table 1).

Table 1. Practical evaluation score of implant implantation model (x±s)

Group	drill needle selection	rotation speed setting	operation procedure	implant depth	implant axis	implant site	Total points
Planting model group(n＝24)	10.0± 0.0	10.0± 0.0	17.77±0.40	13.9±0.20	13.47±0.31	27.45±0.30	92.58±0.98
Virtual simulation group(n＝24)	10.0± 0.0	10.0± 0.0	18.50±0.30	14.35±0.15	14.30±0.26	28.30±0.26	95.45±0.76
t	—	—	11.63	4.32	25.00	29.45	4.02
P	—	—	＜0.01	＜0.05	＜0.01	＜0.01	＜0.05

3.2 The satisfaction survey of 46 students on the course of oral implant implantation revealed that the overall satisfaction level was significantly higher in the virtual simulation group compared to the implant model group ($\chi 2 = 16.04$, $P < 0.01$) (Table 2).

Table 2. The satisfaction degree of stomatology students to the experimental teaching of implant

Group	Very satisfied	Relatively satisfied	normal	Less satisfied	Very dissatisfied
Planting model group(n＝23)	5	8	10	0	0
Virtual simulation group(n＝23)	18	4	1	0	0

4 Conclusion

These findings demonstrate that combining digital simulation training systems with traditional implant model teaching can greatly enhance both teaching effectiveness and student satisfaction regarding oral implantation surgery.

5 Discussion

The field of oral implantology is highly practical, with implant placement serving as the surgical foundation. The success of oral implantology directly hinges on the precision and adherence to standardized procedures in this technology. Currently, experimental and pre-clinical training for implant placement primarily relies on practical exercises using simulated models[3]. However, there are several factors that impact the efficacy of model-based training. For instance, these models can be costly and cannot be repeatedly utilized for practice purposes, posing challenges for students aiming to attain proficiency[4,5]. The differences between the material of the model and natural bone tissue still exist, which hinders the accurate simulation of clinical implantation surgery and affects the teaching effectiveness. The virtual simulation dental teaching system is a comprehensive model for teaching and training that combines digital software, virtual three-dimensional vision, and force feedback haptic platform. It effectively addresses several shortcomings in traditional oral experiment teaching processes, such as significant disparities between pre-clinical training modes and clinical operations, expensive simulation models, and inadequate student practice intensity[6]. Compared to traditional clinical teachings or videos on oral implantology surgery, virtual simulation teaching enables students to engage in pre-operative preparation, instrument selection, and simulated implant surgery within a virtual environment using virtual reality technology[7,8].This allows them to become familiar with surgical instruments, steps/procedures while avoiding mistakes during actual operations.

In this manner, students can not only experience the surgical process in an immersive way and gain a realistic sensory encounter but also acquire a comprehensive understanding of the surgical scene prior to actual operations, thereby enhancing their comprehension and retention of implant surgery. Through virtual experiences and interactions, students are empowered to better comprehend and master planting techniques, thus actively engaging in the learning process.

The findings of this study demonstrated that, following initial practice with the virtual simulation training system, the outcomes of the implant operation procedure, implant placement site, and axis were superior to those of the traditional practical operation group using an implant model. This improvement can be attributed to students' repeated exercises on the virtual simulation training system, which enhanced their comprehension of the implant placement site and axis. However, due to limited opportunities for training in the model group, it fails to enhance students' proficiency. In contrast, students in the virtual simulation training group can promptly observe operational issues, make necessary adjustments in real-time, and develop a refined "feel" that better guides clinical operations during preparation for dental implants. Regarding student satisfaction levels, they express greater contentment with the virtual simulation dental teaching system as it allows for repetitive exercises while retaining operation results and providing graded assessments. Additionally, it offers realistic virtual clinical scenarios that enable students to experience a more authentic clinical diagnosis and treatment process.

Therefore, the utilization of virtual surgical simulation and practical guidance can enhance students' comprehension of surgical procedures and operational skills, thereby augmenting teaching effectiveness and mitigating patient risk. Currently, the virtual instruction in oral implantology encounters certain challenges, such as exorbitant equipment costs and intricate technology implementation, necessitating further research on technological advancements and instructional approaches.

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