

Application Effect of Digital Virtual Simulation Combined with Traditional Teaching in Postgraduate Prosthodontics Course Instruction

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Abstract: *Objective:* To explore the application effect of digital virtual simulation combined with the traditional teaching mode in the postgraduate prosthodontics course instruction, providing practical and theoretical support for the reform of postgraduate prosthodontics education. *Methods:* Seventy-four postgraduate dental students enrolled in September 2023 were selected as the control group and taught using the traditional teaching mode; eighty-five postgraduate dental students enrolled in September 2024 were selected as the experimental group and taught using the digital virtual simulation combined with the traditional teaching mode for prosthodontics. After the instruction, the theoretical assessment scores, practical operation scores, clinical thinking ability scores, teaching satisfaction, and incidence of adverse events were compared between the two groups. *Results:* After the instruction, the average theoretical assessment scores and practical operation assessment scores of the control group were lower than those of the experimental group (both $P < 0.001$); the clinical thinking ability scores of the experimental group were significantly higher than those of the control group ($t = 14.196$, $P < 0.001$); the teaching satisfaction of the experimental group was significantly higher than that of the control group ($\chi^2 = 8.614$, $P = 0.003 < 0.01$); the incidence of adverse events during practical operations in the experimental group was significantly lower than that in the control group ($\chi^2 = 4.802$, $P = 0.028$). *Conclusion:* The digital virtual simulation combined with the traditional teaching mode can effectively enhance postgraduate students' mastery of prosthodontics theoretical knowledge, practical operation skills, and clinical thinking abilities, improve teaching satisfaction, and reduce the incidence of adverse events during practical operations. It is superior to the traditional single teaching mode and is worthy of promotion and application in postgraduate dental course instruction.

Keywords: Digital virtual simulation; Traditional teaching; Prosthodontics; Postgraduate teaching

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1. Introduction

The digitalization of education is an important strategic direction for the high-quality development of

education in China. The General Secretary explicitly pointed out during the fifth collective study of the Political Bureau of the Central Committee that the digitalization of education is a crucial breakthrough for opening up new avenues and shaping new advantages in educational development ^[1]. The 2024 World Conference on Digital Education further emphasized that digital technology will drive systemic changes in educational concepts, models, and methods, providing strong support for personalized learning and lifelong learning ^[2]. Prosthodontics is a discipline characterized by abstract theory and strong practicality, encompassing multidisciplinary knowledge in oral medicine, materials science, engineering technology, and aesthetics. With the widespread clinical application of technologies such as digital imaging, virtual simulation, CAD/CAM, and 3D printing, the traditional teaching model combining theoretical lectures with simulated head model operations can no longer meet the needs of graduate student training ^[3]. Currently, some medical schools in China have initiated digital teaching reforms in prosthodontics at the undergraduate level, but systematic research on the integration of digital virtual simulation with traditional teaching for graduate students remains relatively scarce ^[4]. As the future backbone of clinical and research work in oral medicine, graduate students must possess a solid theoretical foundation, proficient clinical skills, and innovative thinking. This study focuses on graduate students in oral medicine, aiming to construct a digital course resource library for prosthodontics and implement a hybrid teaching model combining virtual simulation with traditional methods. Through a controlled study, the teaching effectiveness is verified to provide references for educational reforms in oral medicine graduate education within the autonomous region and across the country.

2. Materials and methods

2.1. Study participants

Seventy-four graduate students in oral medicine who enrolled in September 2023 were selected as the control group, including 39 males and 35 females, aged 22 to 28 years, with an average age of 24.68 ± 1.35 years. Their average score in prosthodontics-related courses during their undergraduate studies was 80.56 ± 4.72 . Eighty-five graduate students in oral medicine who newly enrolled in September 2024 were selected as the experimental group, including 45 males and 40 females, aged 22 to 29 years, with an average age of 24.82 ± 1.41 years. Their average score in prosthodontics-related courses during their undergraduate studies was 80.73 ± 4.68 .

Inclusion criteria: (1) Full-time graduate students in oral medicine; (2) Completion of foundational courses in prosthodontics; (3) Voluntary participation in this study and signing of informed consent. Exclusion criteria: (1) Students on leave, those with delayed graduation, or those who did not fully participate in the course; (2) Students whose clinical rotations interrupted learning for more than one-third of the class hours. There were no statistically significant differences between the two groups in terms of age, gender, previous academic performance, and faculty allocation ($P > 0.05$), indicating comparability.

2.2. Teaching methods

2.2.1. Control group

The control group adopted the traditional teaching model of “theoretical lectures + laboratory simulation operations.” Theoretical classes were primarily conducted through classroom lectures, with teachers using PPT presentations and blackboard writing to explain foundational theories, clinical techniques, and

operational norms. Laboratory classes were held in the oral laboratory, where students practiced using head models, models, and other consumables, with teachers demonstrating, guiding, and providing unified feedback. The course content followed traditional textbooks, focusing on core theories such as tooth defects, dentition defects/edentulism, oral implants, and periodontal prosthodontics, supplemented by a small amount of experimental guidance. Assessment employed a single mode, with final theoretical exams accounting for 60% (closed-book to evaluate theoretical mastery) and final practical operation exams accounting for 40% (on-site evaluation of operational skills, scored by two teachers and averaged for the final grade).

2.2.2. Experimental group

The experimental group adopted a hybrid teaching model combining digital virtual simulation with traditional methods, while optimizing course content, teaching methods, and assessment systems as follows:

Course Content Optimization: Building on traditional prosthodontics courses, new frontier topics such as digital scanning, CAD/CAM restoration, virtual occlusion design, and digital implant planning were added to strengthen the integration of theory, digital technology, and clinical practice. A course network resource library was simultaneously established, integrating courseware, teaching videos, virtual operation tutorials, clinical cases, and exercise resources to support students' autonomous learning anytime, anywhere.

Teaching Method Optimization: A hybrid teaching model of "traditional teaching + virtual simulation + clinical practice" was adopted. The theoretical phase combined classroom lectures with online resource-based autonomous learning; the virtual simulation phase relied on systems for repeated practice in tooth preparation, restoration design, and implant operations, with real-time scoring by the system and centralized Q&A sessions and one-on-one guidance from teachers; the clinical practice phase involved departmental internships to translate virtual skills into clinical abilities and cultivate clinical thinking.

Assessment System Optimization: A multi-dimensional and multi-level assessment system was established, emphasizing process-oriented and comprehensive evaluation. Process assessment accounted for 40%, including classroom performance, online learning, virtual operations, and clinical internship performance (10% each). Summative assessment accounted for 60%, including theoretical closed-book exams and practical operation exams (30% each). Practical assessments combined on-site operations with case analysis, scored by three teachers through blind review and averaged to comprehensively evaluate comprehensive abilities.

2.3. Observation indicators

- (1) **Academic Performance:** Unified theoretical exams and practical operation assessments were conducted after the course, each with a full score of 100.
- (2) **Clinical Thinking Ability Score:** The Clinical Thinking Ability Evaluation Scale was used for scoring, with a full score of 100. It included four dimensions: case analysis ability, diagnostic accuracy, rationality of treatment plan formulation, and risk assessment ability (25 points each). Three clinical instructors jointly scored and averaged the results to obtain the students' clinical thinking ability scores.
- (3) **Teaching Satisfaction:** A self-made questionnaire was used, covering eight dimensions such as teaching content, teaching methods, teaching effectiveness, and teachers' teaching levels. Each dimension was divided into four levels: very satisfied, satisfied, average, and dissatisfied. Very satisfied and satisfied were considered satisfactory, and the teaching satisfaction rates of the two groups were statistically analyzed.

(4) Incidence of Adverse Events in Practical Operations: Adverse events (including excessive tooth preparation, restoration detachment, instrument damage to simulated tissues or clinical patients' oral tissues) occurring during experimental operations and clinical internships in both groups were statistically analyzed to calculate the incidence of adverse events.

2.4. Statistical methods

SPSS 27.0 statistical software was used to analyze and process the research data. Measurement data were expressed as (\pm s), and intergroup comparisons were conducted using t-tests. Count data were expressed as rates (%), and intergroup comparisons were conducted using χ^2 tests. A P -value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of academic performance between the two groups

After the teaching intervention, the average scores of the control group in both theoretical and practical assessments were lower than those of the experimental group (both $P < 0.001$). Specific data are shown in **Table 1**.

Table 1. Comparison of academic performance between the two groups

Group	Theoretical Assessment Mean Score (\pm SD, points)	Practical Operation Mean Score (\pm SD, points)
Control Group ($n=74$)	81.34 \pm 5.16	82.45 \pm 4.78
Experimental Group ($n=85$)	88.65 \pm 4.23	90.12 \pm 3.87
t	9.813	11.187
P	<0.001	<0.001

3.2. Comparison of clinical thinking ability scores between the two groups

The clinical thinking ability score of the experimental group was significantly higher than that of the control group ($t = 14.196$, $P < 0.001$). Specific data are shown in **Table 2**.

Table 2. Comparison of clinical thinking ability scores between the two groups

Group	Average Clinical Thinking Ability Score (\pm s, points)	t	P
Control Group ($n=74$)	80.23 \pm 4.89	14.196	<0.001
Experimental Group ($n=85$)	89.76 \pm 3.54		

3.3. Comparison of teaching satisfaction between the two groups

The teaching satisfaction of the experimental group was significantly higher than that of the control group ($\chi^2 = 8.614$, $P = 0.003 < 0.01$). Specific data are shown in **Table 3**.

Table 3. Comparison of teaching satisfaction between the two groups

Group	Very Satisfied	Satisfied	Fair	Dissatisfied	Overall Satisfaction (%)	χ^2	P
Control Group (n=74)	28 (37.84)	33 (44.59)	10 (13.51)	3 (4.05)	61 (82.43)	8.614	0.003
Experimental Group (n=85)	46 (54.12)	36 (42.35)	3 (3.53)	0 (0.00)	82 (96.47)		

3.4. Comparison of the incidence of adverse events in practical operations between the two groups

The incidence of adverse events in practical operations in the experimental group was significantly lower than that in the control group ($\chi^2= 4.802, P = 0.028$). Specific data are shown in **Table 4**.

Table 4. Comparison of the incidence of adverse events in practical operations between the two groups

Group	Number of Adverse Events(n)	Incidence of Adverse Events(%)	χ^2	P
Control Group (n=74)	8	10.81	4.802	0.028
Experimental Group (n=85)	2	2.35		

4. Discussion

Prosthodontics is a discipline that integrates theory and practice extremely closely. The core of graduate-level teaching is to cultivate students' practical skills, clinical thinking abilities, and knowledge application capabilities to meet the demand for high-quality prosthodontic professionals in clinical practice^[5]. Traditional teaching models have been widely used in graduate oral medicine education for a long time. While they can fulfill basic teaching tasks, they suffer from issues such as a disconnect between theory and practice, insufficient practical operation practice, and a single-dimensional assessment approach, making it difficult to meet the training requirements for prosthodontic graduates in the new era. With the widespread adoption of digital technologies in medical education, digital virtual simulation technology offers a new pathway for prosthodontic teaching reform. Combining it with traditional teaching models can achieve complementary advantages, optimize the teaching process, and enhance teaching effectiveness^[6].

The results of this study indicate that the experimental group significantly outperformed the control group in theoretical assessment scores, practical operation scores, clinical thinking ability scores, and teaching satisfaction, while exhibiting a significantly lower incidence of adverse events in practical operations. These findings suggest that the hybrid teaching model combining digital virtual simulation with traditional methods is superior to the traditional single-dimensional teaching model, aligning with conclusions from relevant domestic studies. Its advantages are primarily manifested in the following four aspects. First, virtual simulation technology addresses the shortcomings of traditional practical teaching. Prosthodontic procedures are precise and irreversible, while traditional head model practice involves high material costs, difficulties in observing internal structures, and challenges in promptly correcting errors. The virtual simulation system can create highly realistic clinical scenarios, support repeated practice without material or error risks, and provide real-time feedback on operational compliance, helping students promptly correct errors and standardize procedures, thereby significantly improving practical skills^[6]. Second, hybrid teaching achieves deep integration of theory and practice. The experimental group adopted a model of "virtual simulation + traditional lectures + clinical practice", breaking the disconnect between theory and

practice. The theoretical phase relied on online resource libraries to support autonomous learning; the virtual operation phase translated theory into skills; and the clinical phase further connected with real-world cases. This progressive teaching approach encouraged students to shift from passive reception to active practice, consolidating theoretical foundations while enhancing knowledge application and autonomous learning abilities. Third, multi-dimensional and multi-level assessments stimulate learning initiative. Traditional teaching relies heavily on final summative assessments, which can lead to cramming before exams and one-sided evaluations. This study combined process-oriented assessments with summative assessments, covering dimensions such as classroom performance, online learning, virtual operations, and internship performance. The summative assessment considered theory, practical skills, clinical thinking, and communication abilities, providing a more comprehensive and objective evaluation. This approach guided students to value the learning process, increasing participation and improving learning outcomes. Fourth, the course network resource library meets individualized learning needs. Graduate students have varying foundations, making it difficult for uniform classroom instruction to accommodate individual differences^[7]. The resource library integrates courseware, videos, tutorials, cases, and question banks, supporting students in learning according to their needs and addressing knowledge gaps. Additionally, timely updates to resources kept pace with cutting-edge technologies and clinical concepts, broadening academic perspectives and laying a solid foundation for clinical practice.

Although the hybrid teaching model combining digital virtual simulation with traditional methods has demonstrated favorable application effects in prosthodontic courses for oral medicine graduates, several challenges persist in practice: First, the construction cost of digital virtual simulation teaching systems is high, and some institutions may struggle to afford comprehensive virtual simulation equipment and systems due to financial constraints^[8]. Second, some teachers lack proficiency in digital teaching, making it difficult for them to effectively utilize virtual simulation systems in instruction, thereby affecting teaching outcomes. Third, there remains a gap between virtual simulation scenarios and real clinical settings, with some students performing well in virtual operations but struggling to adapt quickly to actual clinical work. To address these issues, the following improvement measures can be implemented in the future: First, increase teaching investment, secure funding support, and improve digital virtual simulation equipment and systems, while strengthening collaboration among institutions to share resources and reduce costs. Second, enhance teacher training by organizing regular digital teaching training programs to improve teachers' digital teaching abilities and operational skills, ensuring the smooth implementation of virtual simulation teaching. Third, continuously optimize virtual simulation scenarios by incorporating real clinical cases to enrich teaching content and narrow the gap between virtual and clinical settings. Additionally, strengthen clinical supervision to guide students in rapidly adapting to actual clinical work.

The quality of graduate training in oral medicine directly influences the development level of China's prosthodontic healthcare sector, with teaching model reform and innovation serving as key to enhancing graduate training quality^[9]. The hybrid teaching model combining digital virtual simulation with traditional methods integrates digital technologies with the strengths of traditional teaching, optimizing teaching content and methods, improving assessment systems, and effectively enhancing students' theoretical knowledge, practical skills, and clinical thinking abilities. It also increases teaching satisfaction and reduces the incidence of adverse events in practical operations, providing a new practical pathway for teaching reform in oral medicine graduate education.

In summary, the hybrid teaching model combining digital virtual simulation with traditional methods has demonstrated significant application effects in oral medicine graduate course teaching, outperforming the traditional single-dimensional teaching model. It better meets the training needs of oral medicine graduates, cultivating high-quality prosthodontic professionals with solid theoretical foundations, proficient operational skills, and strong clinical thinking abilities. This model is worthy of wider promotion and application in oral medicine graduate course teaching.

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Disclosure statement

The authors declare no conflict of interest.

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