

Application of the Digital-Resource-Embedded Problem-Based Learning Model in Orthopedic Microvascular Anastomosis Training

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Abstract: This study aimed to explore the application effect of a digital-resource-embedded problem-based learning (PBL) model in microvascular anastomosis training for orthopedic postgraduates, so as to provide an evidence-based reference for the reform of precision surgical skill education. *Methods:* A total of 50 postgraduate students undergoing orthopedic clinical rotation training in our hospital were enrolled and randomly divided into an integrated teaching group and a conventional teaching group via the random number table method, with 25 students in each group. The integrated teaching group adopted the PBL teaching method embedded with digital teaching resources, while the control group received conventional single PBL teaching. Before and after the teaching intervention, unified theoretical knowledge examinations, simulated model operation skill assessments, and teaching satisfaction questionnaires were conducted to evaluate the teaching efficacy of the two groups. *Results:* After the teaching intervention, the scores of theoretical knowledge, practical operation skills, and teaching satisfaction in both groups were significantly higher than those before the intervention (all $P < 0.05$). Moreover, the integrated teaching group presented remarkably better improvement in all evaluation indicators than the control group, and the between-group differences were statistically significant (all $P < 0.05$). *Conclusion:* The digital-resource-embedded PBL model can effectively optimize the theoretical mastery and clinical operative skills of orthopedic postgraduates in microvascular anastomosis training, improve students' self-directed learning ability, and achieve better teaching outcomes than traditional PBL. This innovative teaching model is worthy of popularization and application in advanced technical training of orthopedic microsurgery.

Keywords: Digital resource embedding; Problem-based learning; Orthopedic postgraduates; Microvascular anastomosis; Surgical skill training

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1. Introduction

Orthopedics lies at the heart of postgraduate clinical training. Clinical teaching expects students to build a solid theoretical foundation and, at the same time, acquire disciplined operative skills^[1]. Microvascular anastomosis is an essential technique in tissue defect reconstruction, digital replantation, and free flap transfer—it places extraordinary demands on fine motor control, spatial judgment, intraoperative troubleshooting, and clinical decision-making^[2–3]. Training for orthopedic postgraduates, however, still centers on traditional lectures and PBL used in isolation. Students often remain passive learners, get too little hands-on practice, and find theory disconnected from real-world application; skill levels consequently vary widely from one trainee to another. Such deficiencies complicate efforts to teach standardized microvascular anastomosis reliably during a packed residency period^[4–5].

Over the past few years, there has been a very fast development of the internet, of big data, and of virtual simulation—each offering new ideas for medical education reform. Well-designed online classes, immersive VR setups, or simulated surgical tools can help to eliminate many spatial or temporal restrictions, to optimize the use of available teaching material, to clarify anatomy, and to give practical operative experience^[6–9]. Such tools seem appropriate for the fragmented, self-directed learning patterns typical of clinical postgraduates. Still, the current literature concerning Digital-resource-based medical education has mostly dealt with elementary facts or with the diagnosis and therapy of frequent ailments^[10–12]. There is no widely accepted model — nor any mature evaluation method — for training in complex, high-risk procedures like microvascular anastomosis.

Constructing a standardized teaching model that incorporates both digital tools and PBL with regard to teaching resources is of definite significance for the development of practical skills and of clinical judgment among orthopedic postgraduates, for the mitigation of shortages of hand microsurgeons, and for a more exact-oriented reform of orthopedic education. The present study analyzed such postgraduates during their rotation in an organized comparison.

2. Participants and methods

2.1. Participants

Fifty postgraduates rotating through our orthopedic department between June and July 2025 were enrolled. They were randomly assigned to a combined teaching group ($n = 25$) or a control group ($n = 25$). The combined group comprised 23 men and 2 women, with a mean age of (24.9 ± 0.67) years. The control group had 19 men and 6 women, and their mean age was (25.3 ± 0.47) years. Sex and age did not differ significantly between the two groups ($P > 0.05$), and the same faculty taught both groups, ensuring baseline comparability.

2.2. Method

2.2.1. Teaching material and textbook

Instructional content was drawn from the standardized residency training textbook Orthopedics. The total teaching time spanned three class hours.

2.2.2. Combined teaching group (Digital-resource-embedded PBL model)

Before class, the instructor developed customized materials around the microvascular anastomosis case,

selected a representative example, and crafted five core questions tied to key operative steps and common pitfalls. These were shared with the students ahead of time for preview; they were asked to concentrate their preparation on anastomosis-related knowledge and search the literature in light of the questions. The students were randomly divided into five groups. A teaching assistant then coordinated preliminary discussions via an online conferencing platform, collected and synthesized the recurring issues, and helped pinpoint the focus of the upcoming session.

During class, the teacher opened with a targeted question-and-answer, guided the students through case-based analysis of microvascular anastomosis reasoning, facilitated group exchange and discussion, demonstrated the suturing technique, and added further explanation on the critical operative points. After the session, each group organized their main discussion findings and personal reflections on anastomosis and submitted them for review. PPT slides were distributed via the course management system platform, and a question bank covering the residency graduation exam content was made accessible for self-assessment and consolidation.

2.2.3. Control group (PBL alone)

The control group was taught using a standard PBL format. Printed questions and materials were handed out beforehand, and students prepared independently. The in-class session comprised a central Q&A, group discussion, and a live demonstration. No online platform was employed; there was no virtual pre-class discussion, nor was any digital review or self-testing offered after class.

2.3. Evaluation

Theoretical and hands-on assessments were carried out before teaching and again one week after. The theoretical exam comprised 50 multiple-choice questions set at a moderate difficulty, matched to the requirements of the standardized residency graduation exam; the pre-tests and post-tests used different questions. For the practical assessment, students performed a fine soft plastic tube suture using microsurgical instruments. Attending instructors scored them on a 100-point scale, applying a detailed rubric that covered the preparatory phase, the operative technique itself, and humanistic care.

An anonymous satisfaction survey was given to both groups before and one week after the teaching intervention. It tapped four dimensions: perceived improvement in theoretical knowledge, improvement in operative skills, enhancement of clinical case analysis ability, and acceptance of the digital-resource-embedded teaching format. Students rated their satisfaction with the traditional teaching model as well as with the model actually used in their own group. The questionnaire contained 20 items across the four dimensions, each scored 1 to 5, yielding a maximum total of 100 points—the higher the score, the greater the satisfaction.

2.4. Statistical analysis

All analyses were performed using SPSS 21.0. Quantitative data are reported as mean $\pm$ SD. Within-group comparisons were made with paired *t*-tests; between-group differences were assessed using independent-samples *t*-tests. A *P* value below 0.05 was taken to indicate statistical significance.

3. Results

3.1. Comparison of examination scores before and after teaching

Before the teaching intervention, there were no statistically significant differences between the two groups in either theoretical or practical scores ($P > 0.05$). After teaching, scores in both groups improved significantly ($P < 0.05$), and the combined teaching group achieved significantly higher scores than the control group ($P < 0.05$), as detailed in **Table 1** and **Table 2**.

Table 1. Comparison of theoretical scores before and after teaching between the two groups (mean $\pm$ SD, scores, $n = 25$)

Group	Initial Theoretical Score	Post-Teaching Theoretical Score	Intra-group t value	Intra-group P value
Combined teaching	63.64 $\pm$ 5.33	90.80 $\pm$ 5.64	32.03	< 0.001
Control	63.88 $\pm$ 4.27	89.08 $\pm$ 5.72	23.16	< 0.001
Inter-group t value	0.62	2.11	—	—
Inter-group t value	0.53	0.042	—	—

Table 2. Comparison of practical scores before and after teaching between the two groups (mean $\pm$ SD, scores, $n = 25$)

Group	Initial Theoretical Score	Post-Teaching Theoretical Score	Intra-group t value	Intra-group P value
Combined teaching	62.92 $\pm$ 4.52	91.92 $\pm$ 4.18	62.78	< 0.001
Control	63.16 $\pm$ 4.48	89.04 $\pm$ 4.47	27.36	< 0.001
Inter-group t value	0.18	2.17	—	—
Inter-group t value	0.851	0.036	—	—

3.2. Comparison of teaching satisfaction scores

Before the teaching intervention, satisfaction scores did not differ significantly between the two groups ($P > 0.05$). After teaching, satisfaction improved markedly in both groups ($P < 0.05$), with the combined teaching group reporting significantly higher satisfaction than the control group ($P < 0.05$; **Table 3**).

Table 3. Comparison of teaching satisfaction scores between the two groups (mean $\pm$ SD, scores, $n = 25$)

Group	Initial Theoretical Score	Post-Teaching Theoretical Score	Intra-group t value	Intra-group P value
Combined teaching	72.24 $\pm$ 4.10	91.24 $\pm$ 3.34	97.18	< 0.001
Control	72.64 $\pm$ 3.26	88.96 $\pm$ 3.34	23.829	< 0.001
Inter-group t value	0.721	2.33	—	—
Inter-group t value	0.474	0.024	—	—

4. Discussion

The rapid spread of digital technology, big data, and virtual reality is pushing healthcare toward ever-greater precision and intelligence^[13–15]. These same forces are reshaping medical education, nudging training models toward personalization and self-directed learning. When we align the digital-resource-embedded digital teaching toolbox with problem-based learning—and bring this combined approach to bear on a core microsurgical skill as demanding and high-stakes as microvascular anastomosis—the effort holds genuine theoretical value. It also carries real weight for clinical manpower development, particularly against the

backdrop of national health workforce policy directives.

Microvascular anastomosis sits at the very foundation of hand microsurgery—every orthopedic resident is expected to master it, and intraoperatively it directly dictates the success or failure of tissue replantation and reconstruction^[16–17]. Traditional teaching relies mostly on didactic lectures, intraoperative observation, and a sliver of hands-on practice. Residents, whose microsurgical fundamentals are often still shaky, cannot perform an anastomosis independently from the start^[18]. Real clinical opportunities are somewhat limited, so meaningful experience comes slowly; training is protracted, and one cannot easily give consistent, uniform instruction in a short time frame^[19].

When compared with the standard model, PBL treats problems openly and places the learner at the center—an approach that seems to help residents greatly in grasping—even mastering—the essentials of microvascular anastomosis. Yet if used alone, PBL runs into a number of difficulties. Pre-class study is rarely abundant, and self-initiated preparation often fails to be very productive. The sessions themselves may lack focus, with discussion not always centered on the principal aims. Knowledge is liable to terminate abruptly at class time, unconnected and unorganized rather than fully integrated. Such shortcomings become more serious in a skill such as microvascular anastomosis, where exactness of work and discipline are of vital importance^[20].

With a view to applying the digital resource embedded method alongside PBL in the teaching of microvascular anastomosis (in connection with orthopedics), this study analyzes what might be achieved by blending models. The results make it evident that, when compared with the control group, those who learned with the combined approach fared much better in tests of skill, in case studies, and generally speaking in competency evaluations — and were more satisfied with it.

With regard to the usual PBL framework, the experimental group added digital resources to its teaching methods. Before class, some form of discussion (online or otherwise) was planned, teaching assistants noted questions from the students, and the instructor analyzed likely sticking points. Preview items—such as pre-recorded anastomosis videos or formal anatomical atlases—were made available via the designated course management system.

Once the session was over, instructors began to send out course slides and procedure recordings as well as other wrap-up materials. Such additions formed a helpful complement to PBL—they gave students scope for partial or idle time to think ahead or back, to consolidate ideas, and to transform what they have learned into usable knowledge. This method seems to inspire them actively now, to a degree that eases or even removes old-fashioned shortcomings of teaching.

That said, online resources vary wildly in quality. Some instructional videos are outdated and due for an overhaul, and learning from non-standardized operative footage can easily spread incorrect techniques and engrain poor habits. At the same time, digital-resource-embedded teaching accumulates a large volume of students' personal learning data. There remains plenty of room to improve how we pinpoint truly high-quality resources while keeping personal privacy securely under wraps^[21].

5. Conclusion

The digital-resource-embedded PBL model significantly enhances the theoretical knowledge mastery of orthopedic postgraduates, hands-on skills, and satisfaction with the teaching process. It genuinely fuels

self-directed learning and fills the gaps left by conventional teaching or PBL used in isolation. The overall teaching effect is clearly superior, and the approach is well worth scaling up in high-precision orthopedic skill training.

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Disclosure statement

The authors declare no conflict of interest.

Authors’ contributions

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