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Construction and Application of a Whole-Process Management Model for Orthopedic Clinical Practice Teaching Assisted by Intelligent Supervision

Yang Liu[1]*, Shuang Hu[2], Hongwei Zhao[1], Haidan Chen[1], Bin Lu[1]

[1]The First College of Clinical Medical Science, China Three Gorges University; Department of Spinal Surgery, Yichang Central People's Hospital, Yichang 443000, Hubei, China

[2]School of Electronic Information, Hubei Three Gorges Polytechnic, Yichang 443000, Hubei, China

***Corresponding Author:** Yang Liu, 6032988@qq.com

Abstract: *Objective:* To explore the construction method and application effect of a whole-process management model for orthopedic clinical practice teaching assisted by intelligent supervision. *Methods:* A total of 60 students, including clinical medical interns and standardized residency training trainees rotating in the spinal surgery teaching unit from January to December 2025, as well as 6 clinical instructors, were included. A five-stage whole-process management model—"orientation education–task assignment–process recording–stage feedback–final evaluation"—was established based on the characteristics of orthopedic clinical practice teaching. Intelligent supervision was implemented using mobile information platforms, online forms, and electronic data integration tools. The effectiveness of the model was evaluated through indicators including task completion rate, process participation, Mini-Clinical Evaluation Exercise (Mini-CEX), Direct Observation of Procedural Skills (DOPS), case presentation quality, and teacher–student satisfaction. *Results:* After implementation, the overall task completion rate reached (91.3 ± 6.5)%, with relatively high completion in case learning and imaging interpretation. The overall participation score was 4.28 ± 0.52. Mini-CEX scores ranged from 7.6 to 8.3 across dimensions, and the DOPS overall score was 7.5 ± 0.8. The overall case presentation score was 4.22 ± 0.49. Satisfaction surveys showed that student satisfaction was 4.42 ± 0.51, with a satisfaction rate of 91.7%, while instructor satisfaction was 4.58 ± 0.49, with a satisfaction rate of 100.0%. *Conclusion:* The whole-process management model for orthopedic clinical practice teaching assisted by intelligent supervision can be effectively integrated into spinal surgery rotation teaching. It demonstrates positive effects in promoting task implementation, enhancing participation, improving clinical competence and procedural skills, and increasing satisfaction. This model does not rely on complex information systems and shows good feasibility and potential for broader application.

Keywords: Orthopedics; Clinical practice teaching; Whole-process management; Intelligent supervision; Formative assessment

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1. Introduction

Clinical practice teaching is a critical component of medical education, serving as a bridge between theoretical learning and the development of clinical competence. Its quality directly influences the formation of students' clinical reasoning

ability, practical skills, and professional attributes. However, in current clinical teaching practice, factors such as frequent rotation of students, fragmented learning tasks, and heavy clinical workloads of instructors often lead to problems including poor alignment between task assignment and implementation, discontinuous process recording, delayed feedback, and insufficient coordination among stakeholders. These issues are particularly prominent in orthopedic clinical practice teaching due to its high level of specialization, fast pace, and complex clinical scenarios [1,2].

In recent years, both domestic and international studies have actively explored clinical teaching evaluation and management approaches. Process-oriented management models based on formative assessment and workplace-based assessment have been increasingly applied in clinical teaching [1,2]. In addition, tools such as learning portfolios have been used to support reflective learning and continuous assessment [3,4]. As a continuous quality improvement method, the Plan–Do–Check–Act (PDCA) cycle has been widely applied in healthcare quality improvement and teaching management optimization [5]. Meanwhile, the Mini-Clinical Evaluation Exercise (Mini-CEX) and Direct Observation of Procedural Skills (DOPS), as commonly used workplace-based assessment tools, have been widely adopted in clinical education. However, most existing studies focus on single tools or isolated stages, and there is still a lack of systematic management models covering the entire teaching process.

With the development of digital technologies, mobile platforms, electronic documentation, and digital feedback tools have been increasingly applied in clinical training, demonstrating advantages in task reminders, process tracking, and feedback exchange [6,7]. Nevertheless, how to deeply integrate intelligent technologies into the entire process of clinical practice teaching and construct a systematic and operational management model remains to be further explored.

Therefore, this study takes orthopedic clinical practice teaching as the research context, constructs a whole-process management model assisted by intelligent supervision, and evaluates its application, aiming to provide a reference for optimizing clinical practice teaching management.

2. Methods

2.1. Participants

Participants included rotating trainees and clinical instructors involved in orthopedic clinical practice teaching in our institution. Clinical medical interns and standardized residency training trainees who rotated in the spinal surgery teaching unit from January to December 2025 were enrolled as student participants, along with clinical instructors responsible for teaching during the same period.

A total of 60 students were included, comprising 36 clinical medical interns and 24 standardized residency training trainees, as well as 6 clinical instructors.

2.1.1. Inclusion criteria

(1) Participation in spinal surgery rotation according to the teaching schedule;
(2) Completion of the required rotation period; and
(3) Full participation in teaching activities and related evaluations.

2.1.2. Exclusion criteria

(1) Insufficient rotation duration or withdrawal during the rotation; and
(2) Failure to complete major teaching tasks due to leave or other reasons.

2.1.3. Study details

All instructors had experience in orthopedic clinical teaching and participated in the implementation of the whole-process management model. This study was a teaching reform practice study with stable participant sources and consistent rotation tasks and teaching requirements.

2.2. Model construction

To address the common problems in orthopedic clinical practice teaching, such as poor alignment between task assignment and implementation, discontinuous process recording, delayed feedback, and insufficient coordination among students, instructors, and teaching management, this study constructed a whole-process management model for clinical practice teaching assisted by intelligent supervision, based on the characteristics of the spinal surgery teaching unit.

The model is guided by the core principles of "clear objectives, well-defined tasks, traceable processes, closed-loop feedback, and coordinated management", aiming to transform traditional fragmented teaching management into a continuous, standardized, and whole-process management approach.

Overall, the model was designed around the entire process of clinical practice teaching and consists of five sequential stages: orientation education, task assignment, process recording, stage feedback, and final evaluation, forming a closed-loop management framework with continuous improvement [1,5]. Specifically, orientation education is used to unify teaching requirements and clarify rotation objectives; task assignment translates clinical teaching content into structured and executable learning tasks; process recording documents students' participation, task completion, and performance; stage feedback provides timely evaluation and guidance based on process performance; and final evaluation integrates overall performance to generate summative results. These five stages are interconnected and jointly constitute the framework of whole-process management.

In terms of teaching content design, core competencies in orthopedic clinical practice were identified, and learning activities, including case learning, specialty physical examination, imaging interpretation, case presentation, and surgical observation, were incorporated into a structured task system. Through task lists, clinical learning was transformed from passive exposure during teaching into a goal-oriented and planned process. Meanwhile, to ensure continuity in formative assessment, supporting tools such as process record forms, stage feedback forms, and final evaluation forms were developed to enhance the standardization and operability of the teaching process [3,8].

On this basis, an intelligent supervision-assisted mechanism was introduced. Considering the practical clinical teaching environment, instead of developing a complex independent system, existing mobile information platforms, online forms, and electronic data integration tools were utilized to support task management, process data collection, feedback integration, and exception alerts [6,7]. Through intelligent supervision, task assignment and reminders became timelier, process recording more complete, feedback more centralized, and problem identification and intervention more efficient, thereby improving the continuity and refinement of whole-process management.

Ultimately, a whole-process management model for orthopedic clinical practice teaching was established, with the whole-process framework as the core, a structured task system as the carrier, and intelligent supervision as the support, providing a unified framework for subsequent teaching implementation and evaluation.

2.3. Model implementation

From January to December 2025, the constructed whole-process management model was implemented in the spinal surgery teaching unit. The model was applied to orthopedic clinical practice teaching, with each rotation cycle serving as a basic management unit. Clinical instructors were responsible for organizing teaching tasks, observing processes, and conducting stage evaluations, while teaching administrators handled rotation coordination, data collection, and process support, forming an operational mechanism characterized by instructor leadership, student participation, and coordinated management.

During the preparation phase, the research team clarified core learning contents based on teaching objectives and developed task lists accordingly. Supporting tools, including process record forms, stage feedback forms, and final evaluation forms, were designed simultaneously. At the beginning of rotation, instructors conducted standardized orientation sessions to explain rotation objectives, learning tasks, assessment requirements, and documentation methods, ensuring that students clearly understood learning priorities and expectations from the outset.

During the implementation phase, teaching tasks were advanced step by step according to the rotation schedule.

Students participated in activities such as case learning, specialty physical examination, imaging interpretation, case presentation, and surgical observation, and completed process records based on their learning experiences. Instructors observed and recorded students' task completion, clinical participation, and learning attitudes during ward rounds, case discussions, outpatient teaching, and surgical training, providing brief evaluations accordingly. To overcome traditional problems of "task assignment without follow-up" or "assessment without documentation", this study integrated task progression, process recording, and instructor feedback to ensure continuous traceability of the teaching process [9].

Regarding feedback, stage-specific feedback points were established according to the rotation schedule. Instructors provided targeted feedback based on students' task completion, participation, and identified problems, offering specific improvement suggestions. Feedback focused not only on knowledge and technical skills but also on learning initiative, clinical reasoning, and case analysis abilities, reflecting a formative assessment orientation. At the end of rotation, final evaluation results were generated by integrating process records, stage feedback, case presentations, and final assessments.

Throughout the implementation process, intelligent supervision mechanisms were continuously applied. Specifically, mobile platforms were used to release tasks and send reminders; online forms were used to collect process records and enable real-time data submission and aggregation; and electronic data tools were used to centrally manage task progress, participation, and feedback information. Delays in task completion, missing records, or insufficient participation could be identified and addressed promptly. This approach improved process traceability and management efficiency without increasing the burden of system development.

In addition, to ensure adaptability and sustainability, feedback from both students and instructors was continuously collected during implementation. The research team regularly analyzed the effectiveness of task design, recording methods, and feedback processes, and dynamically optimized them based on clinical teaching needs. Through iterative implementation, reflection, and improvement, the whole-process management model was progressively refined and better aligned with the realities of orthopedic clinical practice teaching.

2.4. Outcome measures

To evaluate the effectiveness of the whole-process management model assisted by intelligent supervision, outcome measures were established from multiple dimensions, including task implementation, process participation, clinical competence, procedural skills, case presentation performance, and teacher–student satisfaction. Data were analyzed based on process records, instructor evaluations, and questionnaire results.

2.4.1. Task completion rate

Task completion rate was used to reflect the extent to which students fulfilled assigned teaching tasks during rotation. Core activities, such as case learning, specialty physical examination, imaging interpretation, case presentation, and surgical observation were included in the task list. The completion rate was calculated as the ratio of completed tasks to total assigned tasks. Data were obtained from student process records and verified by instructors, and were used to assess the effectiveness of task implementation under the management model.

2.4.2. Process participation

Process participation was used to evaluate students' engagement in clinical practice teaching. It included participation in ward rounds, contributions to case discussions, involvement in procedural training, and overall cooperation in daily teaching activities. Instructors assessed participation based on daily observations using a 5-point Likert scale (1 = low participation, 5 = high participation), with higher scores indicating greater engagement and initiative.

2.4.3. Clinical competence assessment (Mini-CEX)

The Mini-Clinical Evaluation Exercise (Mini-CEX) was used for stage-based assessment of students' clinical competence. Evaluation domains included history taking, physical examination, clinical judgment, communication skills,

professionalism, and overall competence. Assessments were conducted by instructors in real clinical settings based on students' actual performance [10,11]. Each domain was scored on a 9-point scale (1–3 = below expectations, 4–6 = meets expectations, 7–9 = above expectations).

2.4.4. Procedural skills assessment (DOPS)

Direct Observation of Procedural Skills (DOPS) was used to evaluate students' specialty examination and procedural skills. Assessment items included preparation, procedural accuracy, aseptic technique and safety awareness, technical proficiency, and post-procedure management. Instructors conducted real-time observations during training or clinical practice and scored performance on a 9-point scale, with higher scores indicating better skill acquisition [12,13].

2.4.5. Case presentation quality

Case presentation quality was used to assess students' ability in case organization and clinical reasoning expression. Evaluation included completeness of case data, logical structure, diagnostic reasoning, treatment planning, and response performance during presentation. Instructors provided comprehensive scores using a 5-point Likert scale, with higher scores indicating better performance.

2.4.6. Teacher–student satisfaction

At the end of rotation, satisfaction surveys were conducted among students and instructors to evaluate acceptance and user experience of the management model. Survey items included clarity of learning objectives, rationality of task design, convenience of process recording, timeliness of feedback, organization of teaching activities, and overall acceptance. A 5-point Likert scale was used (1 = very dissatisfied, 5 = very satisfied), with higher scores indicating greater satisfaction.

3. Results

3.1. Task completion

After implementation of the whole-process management model, overall task completion among students was satisfactory, and all core teaching tasks were carried out in an orderly manner according to the rotation requirements. In general, case learning and imaging interpretation showed relatively high completion rates, while specialty physical examination, case presentation, and surgical observation also met expected standards. These findings suggest that structured management based on task lists helps clarify learning objectives and promotes task fulfilment. Detailed results are shown in Table 1.

Table 1. Task completion among students (n = 60, %, mean ± SD)

Item	Completion rate
Case learning	93.5 ± 5.2
Specialty physical examination	89.8 ± 7.1
Imaging interpretation	94.2 ± 4.8
Case presentation	88.7 ± 6.9
Surgical observation	90.1 ± 7.4
Overall completion rate	91.3 ± 6.5

Note: Completion rate = (number of completed tasks / total assigned tasks) × 100%.

3.2. Process participation

Instructors evaluated students' participation in teaching activities such as ward rounds, case discussions, and procedural training. The results showed generally high levels of participation across all items, indicating that most students were

actively engaged in clinical teaching activities and maintained a good level of involvement. Detailed results are presented in Table 2.

Table 2. Process participation scores (n = 60, mean ± SD)

Item	Score
Participation in ward rounds	4.31 ± 0.54
Participation in case discussions	4.22 ± 0.57
Participation in procedural training	4.18 ± 0.55
Overall participation	4.28 ± 0.52

Note: Scores were based on a 5-point Likert scale (1 = low participation, 5 = high participation).

3.3. Mini-CEX outcomes

Mini-CEX was used to assess students' clinical competence at different stages. The results showed that students achieved good performance across all domains, including history taking, physical examination, clinical judgment, communication skills, professionalism, and overall competence. Among these, communication skills and professionalism scored relatively higher, suggesting a positive impact of the management model on comprehensive clinical competence. Detailed results are shown in Table 3.

Table 3. Mini-CEX scores (n = 60, mean ± SD)

Domain	Score
History taking	7.8 ± 0.9
Physical examination	7.6 ± 0.8
Clinical judgment	7.7 ± 0.9
Communication skills	8.1 ± 0.7
Professionalism	8.3 ± 0.6
Overall competence	7.9 ± 0.8

Note: Mini-CEX scores range from 1 to 9 (1–3 = below expectations; 4–6 = meets expectations; 7–9 = above expectations).

3.4. DOPS outcomes

DOPS was used to evaluate students' procedural skills and specialty examination performance. Results indicated that students performed well in preparation, procedural accuracy, aseptic technique and safety awareness, technical proficiency, and post-procedure management. Overall, students demonstrated a solid level of basic procedural skills and clinical safety awareness. Detailed results are presented in Table 4.

Table 4. DOPS scores (n = 60, mean ± SD)

Domain	Score
Preparation	7.6 ± 0.8
Procedural accuracy	7.4 ± 0.9
Aseptic technique and safety awareness	7.8 ± 0.7
Technical proficiency	7.3 ± 0.8
Post-procedure management	7.5 ± 0.8
Overall score	7.5 ± 0.8

Note: DOPS scores range from 1 to 9, with higher scores indicating better procedural performance.

3.5. Case presentation quality

Students' case presentation performance was evaluated in terms of completeness of case data, logical structure, diagnostic reasoning, treatment planning, and response performance. The results showed overall good performance across all domains, suggesting that students had developed a certain level of competence in case organization, clinical expression, and integrated clinical reasoning. Detailed results are shown in Table 5.

Table 5. Case presentation quality scores (n = 60, mean ± SD)

Item	Score
Completeness of case data	4.32 ± 0.51
Logical structure	4.25 ± 0.54
Diagnostic reasoning	4.18 ± 0.56
Treatment planning	4.21 ± 0.53
Response performance	4.16 ± 0.58
Overall score	4.22 ± 0.49

Note: Scores were based on a 5-point Likert scale (1 = poor, 5 = excellent).

3.6. Teacher–student satisfaction

Satisfaction survey results indicated a high level of acceptance of the model among both students and instructors. Most students reported that the model helped clarify learning objectives, standardize the learning process, and enhance clinical engagement. Instructors believed that the model improved teaching organization, strengthened process management, and enhanced feedback quality. Detailed results are presented in Table 6.

Table 6. Teacher–student satisfaction

Group	n	Satisfaction score (mean ± SD)	Satisfied or above, n (%)
Students	60	4.42 ± 0.51	55 (91.7%)
Instructors	6	4.58 ± 0.49	6 (100.0%)

Note: Scores were based on a 5-point Likert scale (1 = very dissatisfied, 5 = very satisfied). "Satisfied or above" includes "satisfied" and "very satisfied".

3.7. Overall findings

Overall, the whole-process management model for orthopedic clinical practice teaching assisted by intelligent supervision was effectively integrated into the spinal surgery rotation workflow. It demonstrated favorable outcomes in task implementation, process participation, clinical competence development, procedural skill training, case presentation quality, and satisfaction among both students and instructors. In general, the model showed strong practical value in improving teaching standardization, continuity of process management, and teaching organization efficiency.

4. Discussion

Clinical practice teaching serves as a crucial bridge between theoretical learning and the development of clinical competence in medical education. Its quality directly affects students' clinical reasoning ability, procedural skills, and professional attributes. Orthopedic clinical practice teaching is characterized by high specialization, a fast-paced environment, and complex clinical scenarios. In real-world teaching settings, factors such as limited rotation duration, fragmented learning tasks, and heavy clinical workloads of instructors often result in insufficient task implementation,

discontinuous process management, and delayed feedback. Therefore, exploring an effective process-oriented management model suitable for frontline clinical teaching units is of great practical significance [1].

In this study, a whole-process management model for orthopedic clinical practice teaching assisted by intelligent supervision was constructed and implemented. The results showed that the overall task completion rate reached 91.3%, the process participation score was 4.28, and both Mini-CEX and DOPS scores were at a favorable level. In addition, case presentation quality and teacher–student satisfaction was relatively high. These findings suggest that integrating clinical teaching activities into a structured task system, combined with process recording and stage-based feedback to form a closed-loop management framework, can effectively improve teaching implementation and student engagement. This is consistent with the principles of workplace-based assessment, which emphasize continuous observation, timely feedback, and longitudinal evaluation [1,2].

Previous studies have indicated that, in the absence of clear task orientation and continuous process management, student participation and task completion in clinical learning can vary considerably. Learning outcomes in traditional teaching models often depend heavily on individual instructors, resulting in inconsistent teaching quality. By adopting a task list–driven approach combined with process tracking, the present study clarified learning pathways and enhanced learning consistency. The relatively high task completion rate and participation scores observed in this study support previous findings that formative assessment and structured management can improve student engagement and standardization of teaching outcomes [2,14].

Regarding the development of clinical competence, Mini-CEX has been widely validated as an effective tool for assessing clinical performance, while DOPS has been shown to be a reliable method for evaluating procedural skills [12,15]. Studies have demonstrated that incorporating workplace-based assessment tools into clinical teaching promotes the development of standardized clinical behaviors in authentic clinical environments [16]. In this study, students achieved good performance across all Mini-CEX domains, particularly in communication skills and professionalism, and DOPS results indicated satisfactory procedural competence. Furthermore, improvements in case presentation quality suggest enhanced clinical reasoning and communication abilities. These findings are consistent with previous studies demonstrating that Mini-CEX and DOPS contribute to improved learning performance and feedback quality [17,18], indicating that the whole-process management model provides sustained support for clinical competence development.

It is noteworthy that the intelligent supervision approach adopted in this study did not rely on complex information systems. Instead, it utilized mobile platforms and online tools to support task management, process documentation, and feedback integration. Previous research has shown that the effectiveness of digital tools in clinical education depends less on system complexity and more on their ability to be embedded into teaching workflows and improve feedback efficiency [6,7]. In this study, continuous tracking of teaching processes was achieved through task reminders, process recording, and integrated feedback. The high levels of participation and satisfaction observed suggest that such lightweight digital support methods are both feasible and effective in enhancing teaching execution, which aligns with the notion that low-cost digital solutions are more suitable for widespread implementation in clinical teaching settings.

In addition, both students and instructors reported high levels of satisfaction with the model. Previous studies have indicated that the acceptability of teaching models and assessment tools among users is a key factor influencing their sustainability [4,19]. In the present study, students perceived the model as helpful in clarifying learning objectives and enhancing engagement, while instructors found it beneficial for improving teaching organization and process management. These findings suggest that the model achieves a balance between educational effectiveness and practical feasibility.

Several limitations of this study should be acknowledged. First, this was a single-center study with a relatively small sample size, which may limit the generalizability of the findings. Second, no control group was included, and the results were primarily based on descriptive analysis and comparison with existing literature, lacking higher-level evidence. Third, the intelligent supervision applied in this study mainly involved lightweight digital tools and did not incorporate advanced data analytics or artificial intelligence algorithms. Future studies should consider multi-center designs with control groups to further validate the effectiveness of this model and explore more advanced intelligent support strategies.

Overall, the whole-process management model for orthopedic clinical practice teaching assisted by intelligent supervision, through the integration of structured task systems, traceable process mechanisms, and formative assessment tools, demonstrated favorable outcomes in improving teaching standardization, student engagement, and clinical competence development. The model is practical, feasible, and has potential for broader application in clinical teaching settings[6].

5. Conclusion

This study constructed and implemented a whole-process management model for orthopedic clinical practice teaching assisted by intelligent supervision. The findings indicate that the integration of structured task systems, process recording, and stage-based feedback can effectively promote task implementation, enhance student participation, and improve clinical competence and procedural skills, while achieving high levels of satisfaction among both students and instructors.

Notably, the model does not rely on complex information systems, yet successfully achieves standardized teaching processes and continuous process management. It demonstrates good feasibility and potential for wider application in clinical teaching practice. Further multi-center studies with controlled designs are needed to validate its effectiveness and explore more advanced intelligent support approaches.

Disclosure statement

The authors declare no conflict of interest.

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