

Development of a Low-cost Simulator ORISIM (ORIF and OREF Simulator) as a Wound Care Learning Medium

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ABSTRACT

Postoperative wound care for Open Reduction Internal Fixation (ORIF) and Open Reduction External Fixation (OREF) is a core competency in medical–surgical nursing. However, access to task-specific and affordable simulators remains limited, particularly in low-resource educational settings. Low-cost simulation models have been shown to enhance clinical skill acquisition and self-efficacy among nursing students, yet challenges related to anatomical fidelity and wound realism persist in many existing models. This study aimed to develop and evaluate ORISIM, a low-cost, context-specific wound-care simulator designed for ORIF and OREF postoperative conditions, and to assess its feasibility, usability, and educational value in nursing skills training. This research employed a Research and Development (R&D) design consisting of five phases: needs identification, prototype design and construction, expert validation, model revision, and preliminary testing. Three experts participated in the validation process: one orthotics–prosthetics specialist and two wound-care nursing practitioners. Preliminary testing involved 20 undergraduate nursing students who had completed theoretical and demonstrative instruction on wound care. Quantitative data were collected using a modified Michigan Standard Simulation Experience Scale (MiSSES), while qualitative feedback was analyzed thematically. Expert validation indicated that ORISIM was feasible for educational use, with recommendations for improving anatomical fidelity and wound realism. Quantitative findings showed high levels of student acceptance across all MiSSES domains, with mean scores of 4.17 for self-efficacy, 4.23 for educational value, and 4.10 for simulation realism. Students reported increased confidence in performing wound-care procedures and highlighted the simulator's usability and durability. Qualitative analysis produced three themes: wound realism, material characteristics, and educational value with ease of use. Although some students noted limitations in anatomical detail and material elasticity, ORISIM was widely regarded as beneficial for structured and repetitive skills practice. In conclusion, ORISIM demonstrates strong potential as a cost-effective and educationally relevant simulator for ORIF and OREF wound-care training. While improvements in anatomical fidelity are warranted, the model effectively enhances students' self-efficacy and supports foundational clinical skill development. Future research should incorporate experimental or quasi-experimental designs to further evaluate ORISIM's effectiveness and compare its performance with commercial simulators.

Keywords: wound-care simulation; nursing education; low-cost simulator; clinical skills training; self-efficacy

INTRODUCTION

Fracture injuries continue to represent one of the most significant challenges in global healthcare systems. Each year, more than 500 million individuals experience traumatic injuries, and over one-quarter of these cases involve orthopedic trauma, reflecting the substantial burden of musculoskeletal injuries worldwide [1]. In Indonesia, national epidemiological data from Risesdas indicate that approximately 67.9% of all fracture cases involve the lower extremities, most commonly resulting from traffic-related accidents [2]. A considerable proportion of these patients require hospitalization and surgical intervention. Fracture management spans a continuum from non-invasive approaches such as immobilization with casts or splints to more invasive procedures. Surgical techniques frequently involve internal fixation, in which metal plates, screws, or intramedullary rods are used to stabilize the fractured bone, or external fixation, which employs external devices to maintain alignment and stability during the healing process [1,3].

The management of fractures extends beyond the application of fixation devices such as pins or rods; wound healing and wound care practices play a critical role in determining overall treatment success. Open wounds substantially increase the risk of complications related to contamination or infection by bacteria, viruses, and other microorganisms entering the systemic circulation [4]. Pin-site infections are among the most frequently reported complications in patients undergoing external fixation. Evidence shows that up to 72% of patients treated with Orthopedic External Fixation (OREF) develop grade II infections, underscoring the importance of meticulous wound care and strict adherence to aseptic techniques in achieving optimal healing outcomes [5].

Nurses hold a central role in the assessment and management of fracture-related wounds. Their responsibilities include evaluating wound characteristics—such as depth, shape, exudate, odor, and tissue condition—and implementing appropriate care plans to support healing and prevent complications. Despite this critical role, existing evidence highlights a persistent gap in nurses' knowledge, confidence, and clinical competence related to wound assessment and wound care practices [6]. Nursing education laboratories serve as essential environments where students can safely develop and refine clinical skills before entering real clinical settings. These laboratories provide structured opportunities for hands-on practice, simulation, and competency development [7]. However, several challenges have been documented in clinical education, including limited availability of phantoms or practice models and communication barriers that hinder effective learning experiences [8].

In recent years, low-cost simulators have emerged as promising alternatives to commercial simulation models, offering functional, contextually relevant learning tools at a fraction of the cost. Although these models are significantly more affordable and can be adapted to specific procedures, the majority of their development has been concentrated in high-income countries. More than 80% of published low-cost medical simulators originate from North America and Europe, while contributions from Asia and other regions remain limited [9]. This disparity poses challenges for nursing education laboratories in Indonesia, where access to specialized phantoms, particularly those designed for ORIF (Open Reduction Internal Fixation) and OREF (Open Reduction External Fixation) wound care remains scarce. Laboratory managers responsible for facilitating clinical skills training often struggle to obtain models that accurately represent the complexity of orthopedic postoperative wounds.

To date, the development of wound-care simulators in nursing education has been dominated by general models that focus on superficial wounds or basic procedures, without specifically representing the unique characteristics of postoperative fracture wounds managed with ORIF or OREF techniques. Commercially available simulators tend to lack contextual relevance to orthopedic wound-care competencies, limiting their educational value for nursing students who must master these specialized skills. The novelty of the present study lies in the development of

ORISIM, a low-cost, context-specific simulator designed explicitly to replicate ORIF and OREF wound-care scenarios. ORISIM aims to address the existing gap by providing a realistic, accessible, and pedagogically relevant tool for nursing education. This study also includes an initial evaluation of the simulator's feasibility and educational value as a clinical skills learning medium within nursing laboratories.

METHODS

This study was conducted between January and March 2025 in the Nursing Skills Laboratory of Poltekkes Kemenkes Malang, where all stages of development, expert validation, and preliminary testing were carried out. The research employed a Research and Development (R&D) approach, structured into five sequential phases: (1) needs identification, (2) prototype design and construction, (3) expert validation, (4) model revision, and (5) preliminary user testing. This approach was selected to enable the systematic development of a context-specific, low-cost wound-care simulator tailored to orthopedic postoperative conditions, particularly ORIF and OREF wound management.

The initial phase involved identifying the educational gap in nursing clinical skills training, particularly in postoperative wound care for ORIF and OREF cases. Wound management in orthopedic postoperative settings is a core competency in medical-surgical nursing, requiring students to master assessment, aseptic technique, and device-related wound care. However, commercially available simulators remain limited, especially those designed specifically to represent orthopedic fixation devices and the unique wound characteristics associated with ORIF and OREF procedures. Existing simulation resources predominantly focus on general wound care and do not adequately represent the complexity of orthopedic postoperative wounds. Given that clinical skill acquisition requires repeated practice in a safe and controlled learning environment, there is a clear need for a task-specific, low-cost simulator to support structured and repetitive wound-care training before students encounter real patients.

The second phase involved designing and constructing the ORISIM prototype using readily available, low-cost materials to ensure accessibility and replicability. The design process focused on accurately representing anatomical structures relevant to ORIF and OREF wound care, including skin layers, soft tissue, fixation devices, and pin-site configurations. The construction process emphasized durability, stability during procedures, and the ability to simulate realistic wound characteristics such as depth, exudate pathways, and tissue texture. The prototype was iteratively refined to ensure that it could withstand repeated manipulation during laboratory practice sessions.

The third phase consisted of expert validation to assess the feasibility, accuracy, and educational relevance of the prototype. Three experts participated in this process: one orthotics–prosthetics specialist, who evaluated anatomical accuracy and structural integrity, and two wound-care nursing practitioners, who assessed clinical relevance, wound realism, and the suitability of the simulator as a teaching medium. Validation criteria included anatomical appropriateness, realism of wound representation, ease of use, stability during procedures, and alignment with clinical learning objectives. Experts provided structured feedback, which served as the basis for subsequent revisions.

Based on expert input, the prototype underwent refinement to improve anatomical fidelity, enhance the realism of wound features, and optimize usability during laboratory sessions. Adjustments included reinforcement of structural components, modification of wound contours, and improvement of fixation-device representation to ensure that the simulator accurately reflected ORIF and OREF postoperative conditions. The revision process aimed to produce a final prototype that met both clinical and pedagogical standards.

The final phase involved preliminary testing with 20 fourth-semester undergraduate nursing students who had previously completed theoretical instruction and demonstrations on wound care. Inclusion criteria required participants to be active nursing students, to have completed wound-care coursework, and to provide informed consent. During the laboratory session, students performed simulated ORIF and OREF wound-care procedures using the ORISIM model. Observations focused on usability, clarity of anatomical landmarks, realism of wound presentation, and the simulator's ability to support skill acquisition. Student feedback was collected to evaluate the educational value and practicality of the simulator in a real training environment.

RESULTS

The study involved three experts in the validation phase, each contributing specialized perspectives essential for assessing the feasibility and educational relevance of the ORISIM prototype. One orthotics–prosthetics specialist evaluated the anatomical accuracy, proportionality, and structural integrity of the model, ensuring that the simulated limb and fixation components reflected clinically appropriate configurations. In parallel, two wound-care nursing practitioners, both experienced clinicians and educators assessed the clinical relevance of the simulator, the appropriateness and realism of the wound representation, and the overall feasibility of integrating the model into structured instructional activities. Their combined expertise provided a comprehensive appraisal of both the technical and pedagogical dimensions of the simulator.

A total of 20 fourth-semester undergraduate nursing students participated in the preliminary trial. These students represented the target user group for whom the simulator was designed, making their feedback particularly valuable for evaluating usability and educational impact. All participants had previously completed theoretical coursework and attended demonstrations on wound-care procedures, ensuring that they possessed the foundational knowledge required to engage meaningfully with the simulation activities. Inclusion criteria required students to be actively enrolled in the nursing program, to have completed prior wound-care learning experiences, and to provide informed consent before participating in the study. This ensured that the sample reflected learners with comparable baseline competencies and that participation adhered to ethical standards for educational research.

The implementation of research and development

In needs identification, wound-care management, particularly in postoperative ORIF and OREF cases, is a core competency in medical–surgical nursing. However, access to commercially available simulators specifically designed for ORIF and OREF wound-care training remains limited. Existing simulation resources predominantly focus on general wound management and do not adequately represent fixation devices or the unique characteristics of orthopedic postoperative wounds. Given that clinical skill acquisition requires repeated practice in a safe and controlled learning environment, there is a clear need for a low-cost, task-specific simulator that supports structured and repetitive wound-care training prior to real patient exposure.

In prototype design and construction, the phantom was constructed using simple and easily accessible materials. The materials and estimated costs are presented in Table 1. The construction process consisted of several stages to produce a durable and realistic wound-care training model. The first stage involved creating a lower-limb mold using gipsroll (Figure 1). The model's leg was wrapped in plastic to protect the skin, followed by bandaging from the femur to the foot. Once dry, the cast was removed using a cutter to obtain a negative mold. The second stage involved casting the foot profile. The negative mold was reassembled, filled with a mixture of gypsum powder and water, and reinforced with an iron rod. After drying, the cast was refined to form a positive foot profile resembling human anatomy. The next stage involved constructing the resin-based limb through layered lamination using PVC sheets, stockinette, fiberglass, resin, and catalyst. After curing for 24 hours, the resin profile was cut

along the medial and lateral sides, rejoined with additional resin lamination, and covered with vinyl to enhance realism. A simulated surgical incision was then created on the medial calf, with red coloration added to mimic postoperative tissue. The final stage involved constructing the OREF component by drilling into the artificial bone and inserting metal rods measuring 15–20 cm to replicate external fixation hardware.

Table 1. Materials and estimated cost for constructing the ORISIM (ORIF and OREF Simulator), 2025

| Material | Quantity | Estimated cost per simulator (IDR) |
|---|--------------------------|------------------------------------|
| 1. Gipsroll | 5 rolls | 75,000 |
| 2. Gypsum powder | 2 kg | 40,000 |
| 3. Iron rod | 1 piece | 20,000 |
| 4. Plastic wrap | 1 roll | 10,000 |
| 5. Cutter | 1 piece | 15,000 |
| 6. PVC sheet | 1 sheet (50 cm × 50 cm) | 25,000 |
| 7. Stockinette | 4 layers (±80 cm) | 30,000 |
| 8. Fiberglass sheet | 1 sheet (40 cm × 40 cm) | 20,000 |
| 9. Resin | 2 kg | 100,000 |
| 10. Catalyst | 25 ml | 10,000 |
| 11. Vinyl sheet | 1 sheet (40 cm × 40 cm) | 15,000 |
| 12. Cotton | 50 g | 5,000 |
| 13. Red paint | 10 ml | 3,000 |
| 14. Small metal rods for OREF frame | 4 pieces (15–20 cm each) | 40,000 |
| 15. Bolts and metal connectors | 1 set | 10,000 |
| 16. Additional tools (vise, scissors, etc.) | 1 set | 25,000 |
| Total estimated cost | — | 443,000 |



Figure 1. Process of constructing the lower-limb mold for the ORISIM



Figure 2. Final ORISIM model as a wound-care simulation medium



Figure 3. Trial implementation of the ORISIM phantom

Expert evaluation indicated that the ORISIM phantom was feasible for use as a wound-care training medium, with several recommendations for improvement. In anatomical accuracy, the orthotics–prosthetics expert noted that the shape, proportions, and placement of the OREF pins were sufficiently representative of clinical conditions but recommended reinforcing the external frame to improve stability during wound-care procedures. In wound realism, wound-care practitioners suggested enhancing the color and texture of the ORIF wound, particularly at the wound edges and areas representing inflammatory tissue, to improve clinical realism. In ease of use, experts agreed that the phantom supported aseptic technique practice, wound cleansing, and dressing application. However, they recommended strengthening the wound area to prevent damage during repeated use. In stability during procedures, experts observed that the phantom tended to shift during cleaning or dressing changes, which disrupted procedural precision. They recommended adding a non-slip base or stabilizing mechanism.

Revisions were made based on expert feedback, including: 1) reinforcing the external fixation structure and the phantom's base to improve stability; and 2) enhancing the visual details of the ORIF wound, including coloration and texture. The revised ORISIM prototype was then prepared for student testing (Figure 2).

The preliminary trial involved 20 sixth-semester undergraduate nursing students who had previously received theoretical instruction and demonstrations on wound care. Students performed simulated ORIF and OREF wound-care procedures using the ORISIM phantom during laboratory practice sessions. After the session, students completed an evaluation questionnaire and provided comments regarding their

experience. The survey instrument was a modified version of the Michigan Standard Simulation Experience Scale (MiSSES), consisting of nine items rated on a five-point Likert scale assessing self-efficacy, simulation realism, and educational value. The instrument was adapted to the context of ORIF and OREF wound-care simulation, and its content validity was reviewed by the expert validators. Reliability testing was not conducted and is acknowledged as a limitation of the study.

Quantitative findings

Student evaluations of the ORISIM simulator were obtained using a modified version of the Michigan Standard Simulation Experience Scale (MiSSES). All items demonstrated high levels of acceptance, with mean scores ranging from 3.8 to 4.4 on a five-point Likert scale. Descriptive analyses for each domain are presented in Figure 4. Survey results for the Self-Efficacy domain indicate that students perceived ORISIM as a tool capable of enhancing their competence in wound-care procedures, with an average score of 4.1 out of 5. Students' confidence in performing wound-care procedures using the simulator reached a mean score of 4.2, and their perceived ability to independently carry out wound-care tasks also scored 4.2. These findings suggest that ORISIM provides a supportive learning experience that strengthens students' self-efficacy in wound-care skills.

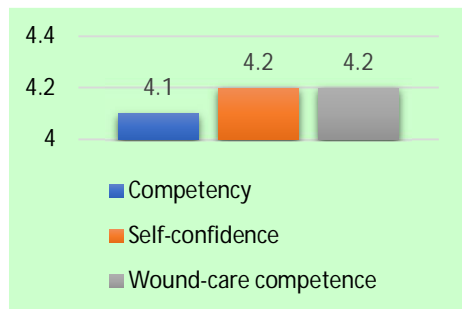


Figure 4. Students' self-efficacy in wound-care learning

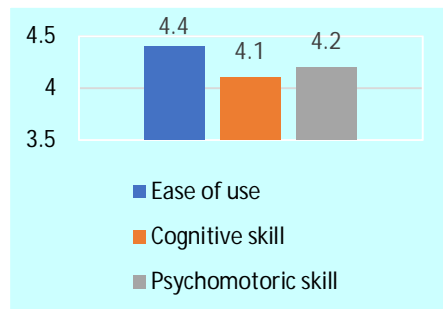


Figure 5. Students' perceived educational value

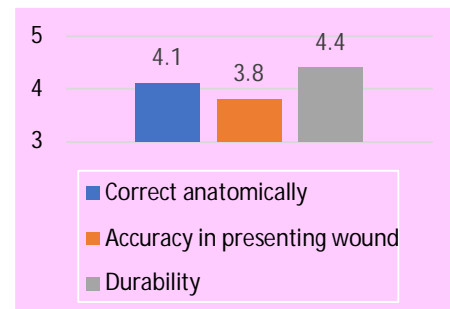


Figure 6. Simulation realism of ORISIM

In the educational value domain, students rated the ease of handling the phantom highly, with a mean score of 4.4, indicating that ORISIM was considered user-friendly and suitable for laboratory-based learning. Cognitive skill development through simulation received a score of 4.1, while support for psychomotor and motor skills was rated at 4.2. Although there remains room for improvement in clinical realism, these scores demonstrate that ORISIM provides strong educational value, particularly in supporting procedural skill acquisition (Figure 5).

For the simulation realism domain, students rated the overall anatomical representation positively, with a mean score of 4.1. However, anatomical accuracy received a slightly lower score of 3.8, indicating the need for refinement in structural detail or anatomical definition. In contrast, the durability of the phantom received the highest score in this domain (4.4), suggesting that students found ORISIM sufficiently robust for repeated practice (Figure 6).

Table 2 shows that the Educational Value domain achieved the highest overall mean score, followed by Self-Efficacy and Simulation Realism. These findings confirm that ORISIM provides strong educational benefits and effectively supports the development of student confidence, although anatomical realism remains an area requiring further enhancement.

Table 2. Mean scores of student evaluations based on MiSSES domains

| Evaluation domain | Mean |
|--------------------|------|
| Self-efficacy | 4.17 |
| Educational value | 4.23 |
| Simulation realism | 4.10 |

Qualitative findings

Short written comments were collected from students after completing the wound-care practice session using the ORISIM phantom. Thematic analysis of these comments produced three major themes: wound realism, material characteristics, and educational value with ease of use.

Wound realism

Several students commented on the realism of the wound appearance, particularly the representation of incisions and ORIF/OREF fixation areas. While most students felt that ORISIM helped them visualize wound-care procedures, some expressed a desire for more clinically accurate visual details. Comments focused on wound contours, tissue color variation, and the appearance of pin-site areas.

"The phantom is helpful, but the incision still doesn't fully resemble an actual surgical wound." (Student 4)

"The fixation part looks similar, but the color still looks like wood material." (Student 12)

These comments highlight the need for improved visual detailing to enhance clinical authenticity.

Material characteristics

Students also provided feedback regarding the material properties of the phantom, especially during repeated use. Some noted that the wound surface occasionally shifted during cleaning or scrubbing.

"The wound area sometimes shifts when being cleaned." (Student 9)

"The phantom's skin feels stiff and different from real skin texture." (Student 7)

These observations suggest the need for improved elasticity and structural reinforcement to better mimic human tissue responses.

Educational Value and Ease of Use

Overall, students perceived ORISIM as an effective and easy-to-use learning medium. The phantom helped them understand procedural steps before encountering real patients, particularly in aseptic technique, wound cleansing, and dressing application according to standard operating procedures.

"I understand the steps for cleaning OREF wounds with aseptic technique much better now." (Student 1)

Students also appreciated the operational simplicity of the phantom, noting that it did not introduce technical barriers during practice. They described the model as lightweight, stable, and supportive of repeated practice without requiring complex adjustments.

"It's easy to use for practice, and it helps me memorize the steps better." (Student 7)

DISCUSSION

The findings from expert validation and student evaluations demonstrate that ORISIM successfully fulfills its fundamental function as an instructional medium for wound-care skill acquisition. The simulator provides opportunities for students to practice aseptic technique, wound cleansing, and dressing application within the specific context of ORIF and OREF postoperative wounds. These results align with existing evidence indicating that simulation-based learning is broadly effective in enhancing clinical skill mastery and offers a safe environment for practice prior to

real patient encounters. Meta-analyses and systematic reviews consistently affirm that simulation-based interventions improve skill acquisition and self-confidence among nursing students [10].

Despite these strengths, anatomical and wound realism were identified as areas requiring further refinement. This observation is consistent with challenges frequently reported in the literature on low-cost simulators. A systematic review noted that many low-fidelity models lack accuracy in tissue and anatomical representation, which may limit their applicability for advanced training, although they remain valuable for introductory skill development. These findings reinforce the broader understanding that simulation-based nursing education exerts strong effects on psychomotor learning, yet its impact is not solely dependent on the level of realism. Consequently, the use of complementary educational strategies, such as self-debriefing and video-facilitated instructor debriefing remains essential for achieving comprehensive learning outcomes [10].

Although limitations in realism exist, low-cost simulators continue to offer substantial benefits for foundational training, particularly in settings where accessibility and repeated practice are prioritized. Studies on low-cost simulation models have shown that such tools significantly expand training opportunities and reduce barriers to skill development [9]. This aligns with the intended purpose of ORISIM, which was designed to provide an accessible, context-specific instructional tool for wound-care education within nursing programs.

Overall, the results of this study highlight the potential of ORISIM as a cost-effective and educationally relevant simulator. While enhancements in anatomical fidelity are warranted, the model's demonstrated strengths in usability, durability, and its positive impact on learners' self-efficacy support its adoption for laboratory-based nursing skills training. Future development should prioritize material refinement and comparative testing against commercially available simulators to further establish its effectiveness.

Furthermore, ORISIM holds particular significance within the context of nursing education in Indonesia, where practice-based simulation has been shown to play a critical role in bridging theoretical learning with real-world clinical competencies. Simulation-based learning supports the development of technical proficiency, clinical readiness, critical thinking, and problem-solving skills before students enter actual patient care settings. Evidence indicates that simulation enables students to experience repeated clinical scenarios in a safe environment, facilitating mastery of technical skills without posing risks to real patients [11]. The integration of simulation media into nursing skills laboratories also strengthens the implementation of the Objective Structured Clinical Examination (OSCE), an objective and standardized method for assessing clinical competence through structured scenarios [12-21].

Given the limited availability of high-fidelity simulation resources in many Indonesian nursing institutions, the development of low-cost, contextually relevant, and task-specific simulators such as ORISIM becomes highly pertinent. The novelty of this study lies in the creation of a wound-care simulator specifically designed for postoperative ORIF and OREF conditions, an area that remains underrepresented in nursing education literature, particularly in low- and middle-income country contexts. This model has the potential to expand access to repeated clinical skills practice, enhance student readiness for competency-based assessments such as OSCE, and strengthen the implementation of structured laboratory skills training.

CONCLUSION

Overall, the findings of this study indicate that ORISIM demonstrates strong potential as a cost-effective and educationally relevant simulator capable of enhancing students' self-efficacy in wound-care performance. Despite the need for further refinement in anatomical fidelity, ORISIM can serve as a viable alternative to commercially available phantoms for nursing skills-laboratory instruction. Its demonstrated usability, durability, and positive impact on learners' confidence underscore its value as a practical training tool within resource-limited educational settings.

Future development efforts should prioritize improving anatomical fidelity and wound realism to strengthen the simulator's alignment with clinical conditions. In addition, subsequent research should employ experimental or quasi-experimental designs to rigorously evaluate the effectiveness of ORISIM in improving clinical competence, procedural accuracy, and long-term skill retention. Such studies would provide stronger empirical evidence to support the integration of ORISIM into structured simulation curricula and competency-based assessments in nursing education.

Ethical consideration, competing interest and source of funding

-Ethical approval for the research was granted by the Health Research Ethics Committee of Poltekkes Kemenkes Malang (No. DP.04.03/F.XXI.30/00962/2025), ensuring that all procedures adhered to established ethical standards for educational research involving human participants.

-There is no conflict of interest related to this publication.

-Source of funding is authors.

REFERENCES

1. Elkalahy RA, Shehata OS, Gad AM. Effect of orthopedic nursing care protocol on nurses' knowledge, performance, and patients' outcomes among patients with external fixators. *Menoufia Nursing Journal*. 2024 Jul 1;9(3):19-40.
2. Rabbani YU, Salsabila Qadri A, Yuar AA, Rahmawati F, Wibawa GE, Nigel P, et al. Tinjauan pustaka terbaru skeletal traksi: indikasi, teknik, dan perannya dalam penanganan fraktur. 2025;6(3):13581-9.
3. Lina K. Fracture management: comprehensive approaches for optimal outcomes. *J Orthop Surg Rehabil*. 2024;8(5):229-38.
4. Putri AZ, Fitria N. Perawatan luka menggunakan povidone iodine 10% dan elastic bandages pada pasien post ORIF dan OREF OS tibia: studi kasus. *MAHESA*. 2023;3(7):2039-54.
5. Yuliati S. Gambaran kualitas hidup pada pasien open reduction external fixation (OREF) ekstremitas bawah di RS Ortopedi Prof. Dr. R. Soeharso Surakarta. Thesis. Surakarta: STIKes Kusuma Husada Surakarta; 2020.
6. Jorge MM, Medeiros LS, Cartaxo CJM, Justino RR, de Jesus CAC, Cauduro FLF. Low-cost simulators for assessing wounds and skin lesions: an experience report. *Cogitare Enferm*. 2025;30:e94184.
7. Toriente Relloso J, Abdullah AbuAlula N, Magtala Medina J, Gatioan Manood E. Nursing skills laboratory as milieu of clinical learning and practice. *Am J Nurs Res*. 2021;9(4):112-7.
8. Fitriyah LL, Nandasari M. Pengembangan media pembelajaran phantom pengambilan darah arteri sederhana bagi mahasiswa di laboratorium Prodi Keperawatan Universitas Sahid Surakarta. *SENRIABDI*. 2022;12(6):1-9.
9. Khan IF, Zidoun Y, Mascarenhas S, Zary N. Promoting simulation-based learning through low-cost simulators: development, skills targeted and implementation. 2021;8(2):92-8.

10. Kim J, Park JH, Shin S. Effectiveness of simulation-based nursing education depending on fidelity: a meta-analysis. *BMC Med Educ.* 2016;16(1):62-8.
11. Hebel K, Steliga A, Lewandowska K, Majkowicz M, Goral-Kubasik A, Buzanowska M, et al. Simulated learning, real emotions: the impact of simulation-based education on nursing students' stress levels during objective structured clinical examination—a longitudinal observational cohort study. *Nurs Rep.* 2025;15(8):52-8.
12. Tseng LP, Hou TH, Huang LP, Ou YK. Effectiveness of applying clinical simulation scenarios and integrating information technology in medical-surgical nursing and critical nursing courses. *BMC Nurs.* 2021;20(1):22-32.
13. Majumder MA, Kumar A, Krishnamurthy K, Ojeh N, Adams OP, Sa B. An evaluative study of objective structured clinical examination (OSCE): students and examiners perspectives. *Advances in Medical Education and Practice.* 2019 Jun 5:387-97.
14. Rushforth HE. Objective structured clinical examination (OSCE): review of literature and implications for nursing education. *Nurse Education Today.* 2007 Jul 1;27(5):481-90.
15. Mitchell ML, Henderson A, Groves M, Dalton M, Nulty D. The objective structured clinical examination (OSCE): optimising its value in the undergraduate nursing curriculum. *Nurse Education Today.* 2009 May 1;29(4):398-404.
16. Alkhateeb N, Salih AM, Shabila N, Al-Dabbagh A. Objective structured clinical examination: Challenges and opportunities from students' perspective. *Plos One.* 2022 Sep 2;17(9):e0274055.
17. Alkhateeb N, Salih AM, Shabila N, Al-Dabbagh A. Objective structured clinical examination: Challenges and opportunities from students' perspective. *Plos One.* 2022 Sep 2;17(9):e0274055.
18. Dewan P, Khalil S, Gupta P. Objective structured clinical examination for teaching and assessment: Evidence-based critique. *Clinical Epidemiology and Global Health.* 2024 Jan 1;25:101477.
19. Aronowitz T, Aronowitz S, Mardin-Small J, Kim B. Using objective structured clinical examination (OSCE) as education in advanced practice registered nursing education. *Journal of Professional Nursing.* 2017 Mar 1;33(2):119-25.
20. Baena AP, Portero FS. The objective structured clinical examination (OSCE): main aspects and the role of imaging. *Radiología (English Edition).* 2023 Jan 1;65(1):55-65.
21. Elshama SS. How to design and apply an objective structured clinical examination (OSCE) in medical education?. *Iberoamerican Journal of Medicine.* 2021;3(1):51-5.