REVIEW

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# Hands-On to Heal: A Scoping Review of Educational Design and Outcomes of Hands-On Workshops in Orthopaedic Surgical Training

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**ABSTRACT**

Ethical, legal, and economic considerations, alongside working-hour restrictions, have reduced opportunities for surgical training in the operating theatre, prompting the adoption of hands-on workshops as an alternative approach. These workshops provide trainees with a controlled environment to develop technical skills, decision-making, and confidence using a variety of simulation modalities, including synthetic models, cadaveric specimens, and virtual reality platforms. This scoping review aimed to map the existing literature on hands-on workshops in orthopaedic surgical training and examine how their educational design and outcomes are reported. A systematic search of PubMed, Cochrane Library, Embase, and Google Scholar was conducted for English-language studies published within the past 10 years, focusing on trauma and orthopaedic training for medical students and healthcare professionals. Review articles, letters, and non-English publications were excluded. Forty-five studies met inclusion criteria, most reporting improvements in performance-based outcomes following participation in hands-on workshops. Commonly used modalities included synthetic simulators, arthroscopy trainers, and virtual reality, with fewer studies incorporating cadaveric specimens. Reported outcomes included technical performance, procedural efficiency, and trainee confidence, primarily assessed in simulated or cadaveric settings. Findings were heterogeneous, and evidence linking workshop participation to direct clinical outcomes was limited. Resource considerations, including cost and accessibility, were frequently noted as challenges. Overall, the literature suggests that hands-on workshops and simulation-based interventions are widely employed in orthopaedic training and are associated with improvements in educational outcomes. These findings highlight the potential role of hands-on workshops in surgical education while underscoring the need for further research to clarify their translation into clinical practice and training outcomes.

**Keywords:** Surgical Training, Hands-On Workshops, Skill Development, Simulation-Based Learning, Medical Education.

## INTRODUCTION

Halsted's traditional surgical training method of "see one, do one, teach one" has largely fallen out of favour due to legal and ethical patient safety concerns, working-week restrictions and cost of operative time. 1 Surgical trainees can therefore incorporate learning opportunities away from real patients to improve their performance and approach to error management in a safe learner-centred environment through hands-on workshops[1].

A surgical workshop is an intensive educational programme for a relatively small group of surgeons from a particular speciality. They can be divided into primarily theoretical such as, classroom-based learning, or hands-on workshops, which are practical.

To be 'hands-on', surgical workshops involve a variety of simulators to allow surgical trainees to refine their surgical skills. These can be largely subdivided into organic and inorganic. Organic simulators, such as animal and cadaveric specimens, are high-fidelity and maintain realism. Inorganic simulators tend to be low-fidelity and can be further subdivided into synthetic, such as saw-bone workshops, and electronic such as those involving virtual reality[2].

This scoping review aims to map the existing literature on hands-on workshops in orthopaedic surgical training, examining how they are used and how their outcomes are reported in relation to skill acquisition, technical ability, decision-making, and trainee confidence. It also explores how these approaches are described in relation to traditional learning methods, identifies key elements of effective workshop design, and highlights gaps in the literature, including the potential role of emerging technologies, such as simulation and artificial intelligence, in enhancing surgical training.

Recent reviews have examined simulation-based training in orthopaedic surgery across a range of modalities, including virtual reality and cadaveric simulation. However, these studies typically focus on simulation tools rather than the structured educational format in which they are delivered. This scoping review specifically focuses on hands-on workshops as an educational approach, examining how they are designed, implemented, and evaluated within orthopaedic training.

## METHODOLOGY

This study was conducted as a scoping review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines. A scoping review methodology was selected to map the breadth and nature of existing literature on hands-on workshops in trauma and orthopaedic surgical training.

This approach was considered appropriate given the heterogeneity in study designs, simulation modalities, and outcome measures, which precluded meaningful quantitative synthesis.

The primary objectives of this review were to map the current use of hands-on workshops in trauma and orthopaedic surgical training, examine how outcomes related to skill acquisition, technical performance, decision-making, and trainee confidence are reported, and identify the reported benefits, limitations, and gaps in the literature, including potential future directions for simulation-based education.

A comprehensive literature search was conducted across four electronic databases: PubMed/MEDLINE, Embase, Cochrane Library, and Google Scholar. The search covered the period from January 1, 2015 to March 31, 2025, with the final search executed on March 31, 2025.

Search strategies combined Medical Subject Headings (MeSH) and free-text terms related to orthopaedics, workshops, simulation, training, and education. Boolean operators (AND/OR) were used to optimise retrieval. Searches in PubMed and Embase were limited to title and abstract fields where appropriate. The full search strategies for all databases, including complete search strings and field restrictions, are provided in *Supplementary Appendix 1* to ensure reproducibility.

Due to the high volume and non-transparent ranking of results in Google Scholar, a structured screening approach was applied. Searches were performed using the same core keywords, with results sorted by relevance. The first 200 results were screened, as this approach is considered sufficient to capture the most relevant studies while maintaining feasibility.

Studies were eligible for inclusion if they described structured hands-on workshops involving active participant engagement in practical skills training in trauma and orthopaedic surgery. For this review, hands-on workshops were defined as organised educational sessions incorporating physical or simulated practice, including synthetic models (e.g. sawbones), cadaveric specimens, or virtual reality platforms. Studies focused solely on didactic or lecture-based teaching without a practical component were excluded. While hands-on workshops were defined as sessions involving active practical engagement, some studies incorporating interactive digital or simulation-based tools without direct physical manipulation were included where they formed part of a structured, skill-focused training intervention. These were considered borderline modalities and are interpreted with caution in the synthesis.

Eligible populations included medical students, surgical trainees, and healthcare professionals involved in orthopaedic training. Studies reporting outcomes related to surgical skill acquisition, technical performance, decision-making, trainee confidence, or educational effectiveness were included. Studies were not required to include a comparator group, as the aim of this scoping review was to map the range of educational approaches and reported outcomes rather than to perform a formal comparative effectiveness analysis.

Only studies published in English between January 1, 2015, and March 31, 2025, were included. Review articles, editorials, letters, conference abstracts, and non-English publications were excluded.

All retrieved records were imported into EndNote X9 (Clarivate) for organisation and duplicate removal.

**Appendices**

*Supplementary Appendix 1 – Full Search Strategy*

The final search was conducted on March 31, 2025, covering the period from January 1, 2015 to this date.

1. PubMed/MEDLINE
("Orthopaedics"[MeSH Terms] OR orthopaedic* OR orthopaedic*)
AND
(workshop* OR "hands-on" OR simulation OR "simulation training" OR "skills lab")
AND
(training OR education OR teaching OR curriculum)
Limits applied:
Language: English
Date range: January 1, 2015, to March 31, 2025
Search fields: Title/Abstract

2. Embase
('orthopaedics'/exp OR orthopaedic*:ti,ab OR orthopaedic*:ti,ab)
AND
(workshop*:ti,ab OR 'hands-on':ti,ab OR simulation:ti,ab OR 'skills lab':ti,ab)
AND
(training:ti,ab OR education:ti,ab OR teaching:ti,ab)
Limits applied:
Language: English
Date range: Inception to January 1, 2015, to March 31, 2025

3. Cochrane Library
(orthopaedic* OR orthopedic*)
AND
(workshop* OR "hands-on" OR simulation OR "skills training")
AND
(training OR education)
Limits applied:
Language: English
Date range: January 1, 2015, to March 31, 2025

4. Google Scholar
Search terms:
orthopaedic workshop simulation training education
Screening approach:
Results sorted by relevance
First 200 results screened
Screening stopped when no additional relevant studies were identified

Prior to formal screening, a pilot screening of a subset of studies was conducted to ensure consistent application of eligibility criteria.

Two reviewers independently screened titles and abstracts, followed by full-text assessment of potentially relevant articles. Discrepancies were resolved through discussion, with involvement of a third reviewer where necessary. The study selection process is illustrated in Figure 1 using a PRISMA flow diagram.

Data were extracted using a standardised charting form that captured study characteristics (author, year, country), participant population, workshop format, simulation modality, outcome measures, and key findings.

Data extraction was performed by one reviewer and verified by a second to ensure accuracy and consistency. Given the heterogeneity of included studies, findings were synthesised descriptively, with results presented as a narrative summary of key themes, reported outcomes, and identified gaps in the literature.

No formal assessment of methodological quality or risk of bias was undertaken, in keeping with scoping review methodology.

## RESULTS

The initial search generated a total of 1030 articles. After removing duplicates and screening titles and abstracts, 97 articles were assessed in full text, with 45 articles meeting the inclusion criteria. The characteristics of the included studies are summarised in Table I.

All included studies were original research articles evaluating the use of hands-on workshops in trauma and orthopaedic surgical training. Across the included literature, workshops were commonly compared

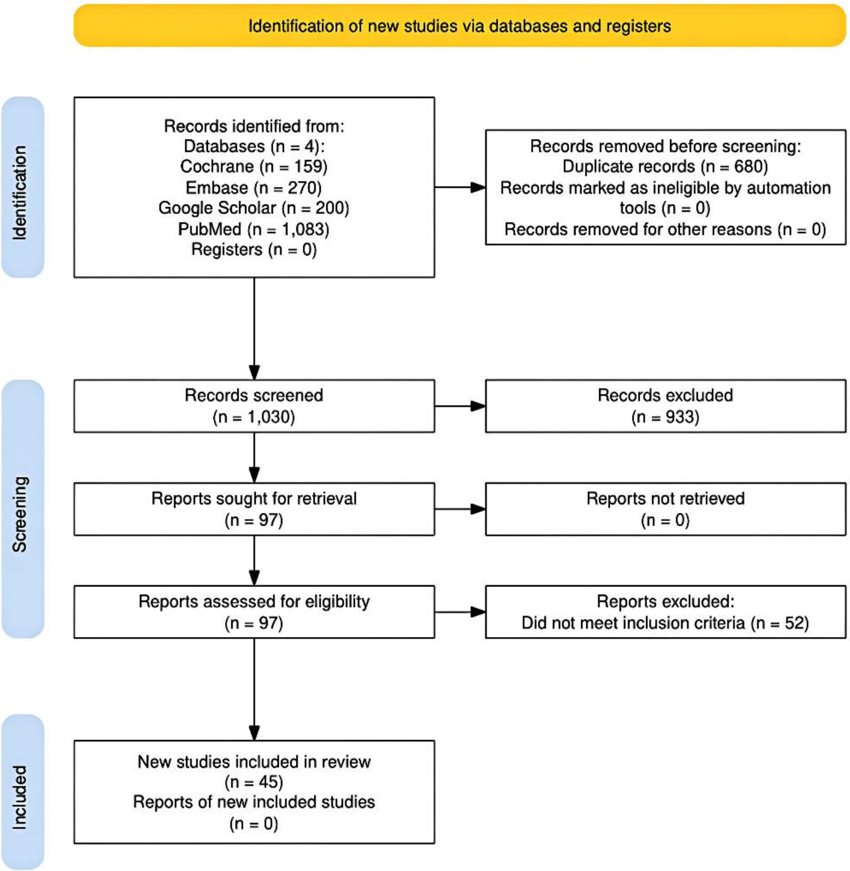


*Fig. 1*

with traditional learning methods such as lectures, video-based instruction or no additional training. A range of study designs were represented, with many studies employing randomised methodologies, although variation in study design was observed. The included studies involved populations of medical students and surgical resident trainees at varying stages of training, including interns, junior trainees and more senior residents. Sample sizes across studies ranged from 14 to 107 participants.

All included studies reported the use of simulation-based approaches to deliver the hands-on component of training. A wide variety of simulation modalities were described, including synthetic models, virtual reality platforms and cadaveric specimens.

Most studies (40/45) utilised inorganic simulators. Of these, 20 studies incorporated synthetic simulators such as sawbone models, which are designed to replicate the feel and resistance of human bone during surgical procedures;[3-,8,10] simple general arthroscopic box trainers11 to teach basic arthroscopic skills, such as grasping, transferring, suture-passing, knot tying, and tissue resection; and more advanced arthroscopic simulators for specific joints like the knee[12].

A further 20 studies utilised virtual reality platforms, often incorporating immersive or computer-based systems to simulate the operating theatre surgical environment and procedures. Topics included general arthroscopy technique,[11,13,14,15] joint specific arthroscopy (knee,[12], shoulder,[16,17] ankle,[18] hip[19]), joint replacement (hip,[20,21] knee[22]), spinal surgery,[23,24] fracture management technique,[3,4,25] and donning personal protective equipment[26].

A smaller number of studies (n = 2) utilised cadaveric models to provide training in procedures such as fasciotomy and external fixation for limb salvage[27]. The remaining three studies compared interactive 3D animation-based learning tools with traditional 2D instructional methods, including expert videos and textbooks, to assess their potential to enhance surgical technique and diagnostic ability in orthopaedic trainees[28].

Across the included studies, a variety of outcomes were reported, including improvements in technical performance[29], operative efficiency[30], decision-making, and trainee confidence[31].Approximately half of the studies also highlighted limitations associated with hands-on workshops, including high costs, resource constraints, and variability in accessibility.

**Table I.** — Simulation and Hands-On Workshops in Orthopaedic Surgical Training: Summary of Included Studies.

| Author (Year) | Country | Study Design | Participants | Intervention (Workshop / Simulation Type) | Comparator | Outcomes |
|---|---|---|---|---|---|---|
| Coughlin et al. (2015) | Canada | Prospective validation study | Medical students, residents, and orthopaedic surgeons (n=49) | Arthroscopic simulation using a box trainer for basic skills (probing, grasping, resection, knot tying) | Comparison across experience levels | Higher performance scores with increasing experience; demonstrated construct validity and strong inter- and intra-rater reliability |
| Frank et al. (2019) | USA | Randomised controlled trial | Participants without prior arthroscopy experience (n=36) | Arthroscopic simulation training using a low-cost triangulation model (30 min sessions over 4 days) | No training | Improved task completion rates, reduced task completion time, and fewer portal movements in the training group |
| Waterman et al. (2016) | USA | Randomised controlled trial | Orthopaedic residents/ trainees (n=22) | Arthroscopic simulation training over 3 months (including VR-based shoulder arthroscopy simulation) | Standard training (no simulator) | Reduced procedure time, improved technical performance (ASSET scores), and improved safety during in vivo arthroscopy; demonstrated transfer validity |
| Dunn et al. (2015) | USA | Randomised controlled trial | Orthopaedic residents (n=17) | Arthroscopic simulation training programme (1-hour session) with intraoperative assessment and 1-year follow-up | Standard training (no simulator) | Improved technical performance and reduced procedure time immediately post-training; no sustained differences at 1-year follow-up (skills not retained) |
| Rahman et al. (2024) | USA | Randomised controlled trial | Orthopaedic residents (n=14) | Hip arthroscopy simulation training using immersive virtual reality (iVR) | Non-immersive virtual reality simulation | No significant difference in technical performance (OSATS/ASSET scores); similar effectiveness with large cost difference |
| Cevallos et al. (2022) | USA | Randomised controlled trial | Medical students and junior orthopaedic residents (n=20) | Virtual reality training (Osso VR) for SCFE guidewire placement with coaching | Study guide and video-based instruction | Trends toward improved accuracy, fewer errors, and reduced procedure time; limited statistical significance |
| Martin et al. (2016) | USA | Prospective observational (pre–post) study | Orthopaedic trainees (n=48) | 4-day arthroscopy training course (didactic, cadaveric, simulation) | Pre-training vs post-training | Significant improvements in efficiency, instrument handling, and task completion time |
| Hooper et al. (2019) | USA | Randomised controlled trial | PGY-1 orthopaedic residents (n=14) | Virtual reality simulation for total hip arthroplasty training | Standard training (no VR simulation) | Improved technical performance in cadaveric THA; no significant improvement in knowledge scores |
| LeBel et al. (2018) | Canada | Comparative study (non-randomised experimental) | Medical students and early surgical trainees (n=90) | Observational learning using VR arthroscopy (expert vs non-expert videos) | Control and comparison between expert vs non-expert observation | Improved performance across all groups; non-expert observation showed superior performance in some metrics |

**Table I.** — Simulation and Hands-On Workshops in Orthopaedic Surgical Training: Summary of Included Studies - Continued.

| | | | | | | |
|---|---|---|---|---|---|---|
| Kazum et al. (2019) | Israel | Prospective observational study | Orthopaedic residents and specialists (n=20) | Low-cost drilling simulator for training plunging depth | Comparison between experience levels and pre–post training | Reduced plunging depth following training; improvement particularly in junior trainees with short-term retention |
| McKinney et al. (2022) | USA | Randomised controlled trial | Orthopaedic residents (n=22) | Immersive virtual reality training for unicompartmental knee arthroplasty (UKA) | Traditional technique guide | Improved procedural accuracy, faster completion times, fewer errors, and higher global performance scores in the VR group |
| Rebolledo et al. (2015) | USA | Randomised controlled trial (controlled laboratory study) | Junior orthopaedic residents (n=14) | Arthroscopy simulator training (knee and shoulder) | Didactic teaching with models | Improved arthroscopic performance in cadaveric assessment, including faster completion times and reduced injury scores; trend toward improvement in knee arthroscopy |
| Roberts et al. (2019) | UK | Randomized Controlled Trial | PGY2–3 orthopaedic trainees | Weekly simulation training + standard training | Standard training only | Fewer hand movements, improved motion smoothness, and reduced procedure time during intraoperative knee arthroscopy compared to control |
| Yang et al. (2023) | China | Randomized Controlled Trial | 30 orthopaedic residents with no arthroscopy experience | Spaced simulation retraining (1-day, 2-day, or 1-week intervals) | Comparison between different retraining intervals | 2-day interval retraining resulted in faster task completion and significantly better skill retention at 3 months compared to 1-week interval, indicating optimal spacing improves acquisition and retention of arthroscopic skills |
| Capitani et al. (2024) | Italy | Randomized Controlled Trial | 6 orthopaedic residents | Virtual reality training (4 sessions over 1 month) | No VR training (control) | VR-trained group showed significantly improved intraoperative performance scores and skill transfer compared to control, with evidence of reduced procedure time and effective translation from simulation to surgery |
| Lohre et al. (2020)a | Canada | Randomized Controlled Trial | 19 orthopaedic residents and 7 expert surgeons | Immersive virtual reality training | Traditional learning (journal article) | Immersive VR group demonstrated faster learning and procedure completion, improved OSATS technical skills, and superior skill acquisition compared to control, with equivalent knowledge scores and strong evidence of transfer validity |
| Ruder et al. (2017) | USA | Randomized Controlled Trial | 13 participants (orthopaedic interns and medical students) | Low-cost drilling simulation training with educational session | Pre-training performance and comparison of instructor type (attending vs resident) | Significant reduction in drill plunging depth after training, demonstrating improved technical skill, with no difference between instructor type, supporting effectiveness of low-cost simulation and peer-led teaching |
| Zamani et al. (2019) | USA | Multicenter Observational Study | 25 PGY-1 orthopaedic residents from 7 institutions | Motor skills training course with drilling task assessment | Pre-course vs post-course performance | Significant improvements in drilling performance after training, including reduced overpenetration, decreased skiving, and shorter preparation time, demonstrating effective skill acquisition and objective measurement of technical performance |

**Table I.** — Simulation and Hands-On Workshops in Orthopaedic Surgical Training: Summary of Included Studies - Continued.

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|---|---|---|---|---|---|---|
| Logishetty et al. (2019) | UK | Randomized Controlled Trial | 24 surgical trainees with no prior THA experience | 6-week virtual reality training programme | Conventional preparatory materials | VR-trained group demonstrated superior technical and non-technical performance, completed more procedural steps, achieved more accurate component positioning, and performed surgery faster, showing effective transfer of skills to cadaveric THA |
| Giurin et al. (2018) | France | Observational Study | 33 doctors (residents and surgeons) | Low-fidelity nail bed repair simulation model | Pre-implementation vs post implementation clinical outcomes | Simulation model rated highly for realism and educational value, with significant reduction in clinical complications (including revision surgeries and adverse events) after implementation, demonstrating effective skill training and patient outcome improvement |
| Zaid et al. (2022) | USA | Randomized Controlled Trial | 22 orthopaedic surgery trainees | Virtual reality training module for UKA | Traditional preparation (technique guide + video) | VR training demonstrated equivalent surgical performance to traditional methods in terms of OSATS scores and procedure time, with high trainee satisfaction and perceived educational value |
| Baumann et al. (2019) | France | Comparative study | 34 surgeons (novice and experienced) | European arthroscopy training programme using knee simulator | Pre-training performance (and comparison between experience levels) | Training improved overall simulator score (199→203, p=0.02), reduced operative time (185→115.9 s), decreased camera and hook path lengths, and reduced iatrogenic injuries; improvements were greater in inexperienced participants, while experienced participants mainly improved operative time |
| Xin et al. (2020) | China | Randomized controlled trial (double-blind) | 24 young surgeons | Immersive virtual reality surgical simulator training for pedicle screw placement | Conventional training (spinal model observation + teaching video) | VR group showed significantly higher success rate (82.9% vs 74.2%) and accuracy rate (69.6% vs 55.4%) of pedicle screw placement compared to control ($p < 0.05$), demonstrating improved surgical performance with VR training |
| Unal et al. (2024) | Turkey | Comparative study | 20 orthopaedic residents with no TKA experience | Virtual reality headset training for total knee arthroplasty | Traditional training methods | VR group performed better in OSATS domains of "time and motion" and "surgical functioning and fluency," indicating improved real surgical performance; VR considered a useful adjunct for surgical training, though further research is needed |
| Hou et al. (2018) | China | Randomized Controlled Trial | Novice residents (n=10) | Virtual surgical training system (VSTS) | Introductory teaching session | Improved screw accuracy; lower penetration; VR training more effective than traditional method |
| Bhattacharyya et al. (2017) | UK | Randomised controlled trial | Novice orthopaedic trainees (n=16) | Imperial Knee Arthroscopy Cognitive Task Analysis (IKACTA) tool | No additional learning material | Improved ASSET scores; significant enhancement in technical skill; tool rated useful by all participants |
| Seeley et al. (2017) | USA | Observational study | Pediatric orthopaedic surgeons and residents (n=18) | Distal radius fracture reduction and casting simulator | Comparison across experience levels | Improved reduction accuracy and speed with experience; model realistic and useful for teaching basic fracture reduction skills |

**Table I.** — Simulation and Hands-On Workshops in Orthopaedic Surgical Training: Summary of Included Studies - Continued.

| | | | | | | |
|---|---|---|---|---|---|---|
| Langeveld et al. (2019) | Nether-lands | Comparative study | Surgeons and residents (n=36) | Various drilling techniques using index fingers | Comparison across techniques and experience levels | Shooting grip with aiming at opposite index finger improved accuracy and precision; experienced surgeons outperformed novices |
| Wang et al. (2019) | China | Randomised controlled trial | Orthopaedic trainees (n=30) | 3D interactive software for acetabular fracture classification | Traditional 2D tutorial | Improved fracture classification accuracy and higher satisfaction scores compared with 2D tutorial |
| Lohre et al. (2020)b | Canada | Randomised controlled trial | Senior orthopaedic residents (n=18) | Immersive virtual reality (IVR) training for reverse shoulder arthroplasty | Video training | Faster completion, higher OSATS scores, better knowledge transfer, strong correlation with real-world performance, and higher cost-effectiveness |
| Rabinovich et al. (2021) | USA | Prospective observational (pre–post) | Orthopaedic residents (n=28) | Simulation training for pediatric distal radius and forearm fracture reduction and casting | Pre-simulation cases / additional mid-rotation simulation | Improved postreduction angulation, cast index, and lower loss of reduction; additional mid-rotation training showed no extra benefit |
| Pecheur et al. (2025) | France | Randomised controlled trial | Residents and medical students (n=16) | Simulation-based training on synthetic bones for olecranon and humerus osteosynthesis | No simulation training | Improved OSATS and radiological scores for olecranon in residents; no significant improvement for humerus; efficacy may depend on complexity and module |
| Gottschalk et al. (2014) | USA | Blinded randomized controlled trial | Orthopaedic residents (PGY 1–6, n=15) | 3D simulation training with navigational feedback for cervical lateral mass screw placement | No training (control group) | Improved drilling accuracy and trajectory compared with control; 3D navigation enhanced learning and performance |
| Walbron et al. (2020) | France | Prospective comparative, non-randomized (Level II) | First-year orthopaedic residents (n=107) | 6 months of VR arthroscopy simulator training | No training / one-off non-specific training | Significant improvements in time, camera alignment, camera path length, and grasper path length in Periscoping and Catch the Stars exercises; VR training led to better technical mastery |
| Leroux et al. (2015) | Canada | Randomized controlled trial | Surgical novices (n=18) | Electromagnetic-guided distal locking screw insertion | Fluoroscopic-guided insertion | EM group had fewer drill attempts, higher task completion in retention test, and lower radiation exposure; skill acquisition was not compromised |
| Shu et al. (2025) | USA | Randomized controlled trial | Orthopaedic residents (n=24) | Novel pelvis model + educational website | Control (no website/model) | OrthoAcademy group improved survey knowledge scores; junior residents improved fluoroscopic image quality; overall radiograph scores increased in control group |
| Levy et al. (2016) | USA | Comparative study | PGY-1 surgical residents & med students | Operant learning programme using acoustic clicker reinforcement | Demonstration alone | Operant learning group had higher precision in knot-tying and low-angle drilling tasks; time to first knot longer, but overall task completion time similar |
| Serhan et al. (2025) | USA | Observational study | 26 surgeons (residents and attendings; ortho & general surgery) | Repetition-based training using high-fidelity THOR cadaver model | None | Improvement in OSATS scores, procedural accuracy, knowledge scores, and reduced procedure time for residents; attendings improved knowledge and some procedure metrics; no difference between specialties |

**Table I.** — Simulation and Hands-On Workshops in Orthopaedic Surgical Training: Summary of Included Studies - Continued.

| | | | | | | |
|---|---|---|---|---|---|---|
| Brusalis et al. (2017) | USA | Randomized controlled trial | 10 orthopedic surgery residents (PGY 1, 3, 4) | Shoelace ACL Simulation Guide (low-cost, self-directed ACL graft prep model) | Standard instructional video | Intervention group had significantly higher overall performance scores, greater self-confidence, similar improvement in knowledge; participants found model highly useful |
| Rouleau et al. (2019) | Canada | Pre-post evaluation | 57 senior orthopaedic residents | 3-day Annual Shoulder Review Course with simulated arthroscopic Bankart repair (dry model) | Baseline pre-course performance | Significant improvement in written knowledge, surgical task time (4:40 → 2:53 min), technique evaluation (56% → 67%), and anchor placement; anchor entry point did not improve significantly |
| Tsukada et al. (2024) | Japan | Blinded, randomized noninferiority trial | 90 medical, medical technology, and pharmacy students | 30-minute lecture + 360° immersive VR PPE training | Face-to-face PPE training; video-based training | VR training was noninferior to face-to-face training (mean score 17.70 vs 17.57/20) and superior to video training (17.70 vs 15.87/20, P = .02). No significant difference in correct execution between VR and face-to-face groups. |
| Xue et al. (2024) | China | Randomized controlled trial | 89 resident doctors in orthopaedic training | 3D Surgical Training System (3DSTS): real surgical videos + high-definition 3D animations | Conventional surgical videos; textbooks | 3DSTS group scored significantly higher on post-education assessment (procedural steps, surgical techniques), reported lower cognitive load, and higher satisfaction compared with SV and textbook groups. |
| Sugand et al. (2018) | UK | Multicenter validation study | 26 surgeons (novice, intermediate, expert) | FluoroSim: digital fluoroscopic simulator for guide-wire insertion in hip surgery | Comparison between skill groups (novice, intermediate, experts) | Demonstrated construct validity: experts/intermediates outperformed novices in tip-apex distance and cut-out rate. Face and content validity confirmed. Provided safe, inexpensive training without radiation exposure. |
| Martin et al. (2016) | USA | Comparative study | Orthopaedic residents (n=30) | Training sessions on three VR arthroscopic simulators (ARTHRO Mentor, ArthroS, ArthroSim) | Comparison between simulators | ArthroS showed highest overall face validity; ARTHRO Mentor and ArthroS had better external appearance; all simulators had acceptable intra-articular realism and usability |

## DISCUSSION

### *Impact of Hands-On Workshops on Surgical Proficiency*

Hands-on workshops appear to play an important role in surgical training by providing trainees with a controlled and safe environment to develop their technical skills, particularly in higher-risk speciality procedures such as spinal surgery[23]. In contrast to broader simulation-based reviews, this study emphasises the role of hands-on workshops as structured educational interventions rather than focusing solely on individual simulation modalities.

Practice in hands-on workshops has been associated with improvements in technical performance metrics, including efficiency of surgical movements[23] and reductions in operative time[16]. While these improvements may suggest potential for enhanced operative performance, direct evidence linking workshop participation to improved patient outcomes or reduced complication rates remains limited[33]. In addition, workshops provide opportunities for structured and individualised feedback, which may further support skill acquisition[33].

In this review, most studies (42 out of 45; 93%) comparing hands-on workshop participants with control groups reported improvements in performance among those receiving the intervention. However, these findings should be interpreted cautiously, as the included studies varied in design, outcome measures, and methodological quality.

Importantly, many of the observed improvements were demonstrated in simulated or cadaveric environments rather than in live clinical settings. Assessments performed on cadaveric specimens[24] suggest that skills acquired during workshops may transfer to higher-fidelity models, which more closely approximate real surgical conditions. However, the extent to which these improvements translate into routine clinical practice remains less clearly established.

Reported improvements were observed across a range of procedures, including ankle arthroscopy,[18] shoulder arthroscopy,[12,17] and total hip replacement[21]. Training was also applied to technically demanding procedures, such as cervical spine stabilisation via pedicle screw insertion, using a desktop virtual reality programme[24]. This technique requires high accuracy due to the risk of injury to adjacent neural and vascular structures. In the study, trainees who underwent virtual reality training demonstrated improved screw placement accuracy on cadaveric assessment compared to controls. While these findings suggest improved technical performance in a simulated environment, caution is warranted in extrapolating these results directly to patient care.

Improvement in surgical trainee performance was most measured through technical skill metrics. In arthroscopy, this included improvements in visual-spatial ability[21] and triangulation skills,[13] often quantified by measures such as instrument path length and procedural efficiency. For example, trainees who participated in simulation-based workshops demonstrated reduced probe distance travelled during diagnostic shoulder arthroscopy compared to controls[16]. Improvement in these foundational skills is relevant across multiple minimally invasive procedures in orthopaedics.

Attendance at hands-on workshops also demonstrated a contribution to safer surgical practice. Fracture management is a key aspect of orthopaedic surgery, requiring precise drilling for fracture fixation to avoid excessive plunge into deeper structures, which may cause harm. Trainees who participated in hands-on workshops involving sawbones were shown to demonstrate improved surgical safety through reducing plunging drill depths by more than 67% from 1.5cm to 0.5cm[3,4]. Trainees also showed improved pin placement in Slipped capital femoral epiphysis (SUFE) with 50% less articular surface penetration and 18% smaller tip apex distance, a key measure for reducing hip fixation failure through lag screw cut out[25].

Workshops were also shown to have a role in improving decision-making and diagnostic ability. Utilisation of 3D interactive animations significantly improved surgical trainees' ability in identifying and classifying acetabular fractures[34] on radiographs by 11% compared to a control group, an essential skill for any orthopaedic trainee. Participation in workshops has also demonstrated increased confidence in clinical practice amongst surgical trainees[35].

Emerging evidence also suggests that repeated or spaced training sessions may support skill retention. The optimal frequency remains unclear, as these findings are derived from a limited number of studies with varying methodologies. However, an initial study suggests that holding workshops every two days can improve retention of benefits, compared to the typical one-week schedule used for most workshops with multiple sessions[13].

Hands-on workshops were frequently found to be more effective than traditional learning methods still favoured in surgical education, such as didactic lectures, instructional videos or reading materials. Among the studies comparing these approaches, most reported superior performance in workshop-trained groups as assessed by tools such as the Objective Structured Assessment of Technical Skills (OSATS)[12,17,25].

## *Best Practices in Designing and Implementing Hands-On Workshops*

This review identified several commonly reported features of effective surgical workshops. A consistent finding across studies was the importance of active, hands-on participation, reflecting the procedural nature of surgical skill acquisition,[3,4,13,16,25] and allowing development of confidence in a controlled environment[36].

Small group sizes were frequently used in workshop settings and may allow for increased individual practice time and more personalised feedback[24]. Similarly, some studies suggested shorter intervals between training sessions, such as consecutive or closely spaced sessions every 2 days, may enhance learning and retention[11,13]. Nonetheless, weekly sessions have also been associated with improvements in performance,[23] but the ideal training schedule remains uncertain.

Simulation-based tools were commonly incorporated into workshops, with 20 out of 45 studies utilising synthetic simulators. These were particularly prevalent in arthroscopy training, likely reflecting the increased emphasis on minimally invasive surgical techniques, which are associated with reduced postoperative pain and faster recovery[36].

A representative example of an effective workshop design is seen in ankle arthroscopy training[18]. In this study, trainees underwent baseline assessment using both a synthetic simulator and cadaveric specimens, followed by a structured programme of weekly simulation sessions. Post-training assessment demonstrated improved performance using the Arthroscopic Surgery Skill Evaluation Tool (ASSET), with higher scores across multiple domains, including instrument handling and procedural flow. While these findings suggest improved technical competency in a controlled setting, translation to clinical performance was not directly assessed.

## CONCLUSION

Cobb angle measurement reliability is substantially lower among residents than specialists, with significant inter-observer disagreement. Structured training and supervised measurement practice may improve reproducibility and enhance referral accuracy within national scoliosis care pathways.

### *Virtual Reality*

Virtual reality (VR) has emerged as an increasingly utilised modality in surgical education, inspired in part by its successful application in other high-risk industries such as aviation[37]. Virtual reality (VR) is a technology that creates an interactive artificial world for users to engage with, with two main types: immersive VR, which fully replaces the real-world environment with computer-generated images via a head-mounted display, and non-immersive VR, which allows users to remain aware of their real-world surroundings while observing the virtual world through a display device like a computer screen[38].

A substantial proportion of studies in this review evaluated VR-based training, with many reporting improvements in technical performance compared to traditional learning methods. This included orthopaedic procedures such as joint replacement,[21,22,35] arthroscopy,[17,19] and spinal surgery[23,24].

Comparisons between VR and other forms of simulation have yielded mixed results. In one study, although both VR and benchtop (BT) simulator training improved performance within their respective modalities, VR training did not result in superior performance when assessed using a different simulation platform[39]. These findings highlight potential variability in skill transfer between different training modalities.

Cost and accessibility remain important considerations in adopting VR technology. The cost of modern technology in surgical education has been described as “unrealistic”[40] for low- and middle-income countries, with commercially available VR software ranging from $4,000 to $6,000[20]. As a result, there has been a growing push to increase accessibility and inclusivity in surgical education, such as through the development of low-cost box trainers as alternatives to expensive VR equipment[41].

## SUMMARY OF EVIDENCE

Hands-on workshops are increasingly incorporated into surgical education to provide trainees with opportunities to develop technical skills in a controlled, learner-centred environment. This scoping review maps a broad body of literature suggesting that such interventions are commonly associated with improvements in performance-based outcomes, including technical proficiency, procedural efficiency and trainee confidence. A large proportion of included studies (42/45) reported improved performance among participants exposed to hands-on workshop training compared with control groups.

However, these findings should be interpreted in the context of substantial heterogeneity in study design, participant populations, and outcome measures. Most studies evaluated performance using simulator-based or cadaveric assessments, with relatively limited investigation of translation to clinical practice. While improvements observed in cadaveric settings suggest progression toward higher-fidelity performance, the extent to which these gains translate to improved patient outcomes or operative performance in real-world settings remains uncertain.

This review also highlights several gaps in the current literature. Notably, most studies focus predominantly on technical skill acquisition, with comparatively limited attention given to non-technical competencies. Surgical performance extends beyond procedural ability to include communication, situational awareness, teamwork, and decision-making under pressure. These human factors are essential for safe and effective practice but remain underrepresented in simulation-based training within trauma and orthopaedic surgery.

In addition, practical considerations for implementing hands-on workshops were frequently identified. These include the financial and logistical demands associated with simulation equipment, faculty time, and access to training resources, particularly as simulation technologies become more advanced. Such factors may influence the scalability and accessibility of workshop-based training across different training environments.

## LIMITATIONS

The literature search was restricted to articles published in English, which may exclude some relevant studies.

Most included studies also had relatively small sample sizes and were conducted at single centres, which may limit generalisability and reflect practical constraints such as simulator cost and faculty availability. In addition, most outcomes were assessed in simulated or cadaveric environments rather than clinical settings, meaning conclusions regarding real-world application should be interpreted with caution.

Also, although simulation is a valuable training tool, synthetic models may not fully replicate the complexity of human anatomy[33]. While cadaveric specimens offer greater realism, their use is associated with considerations such as cost, availability and ethical requirements[42].

## FUTURE DIRECTIONS

This review highlights several areas for future exploration in surgical education. There appears to be an opportunity to further integrate human factors into hands-on surgical training. Drawing on approaches used in other high-risk industries such as aviation, a more comprehensive approach that combines technical skill development with non-technical competencies—such as communication, situational awareness, and teamwork—may support the development of well-rounded surgical trainees.

### *Integrating Human Factors*

The potential relevance of human factors training to surgical education has been recognised in healthcare literature, including frameworks such as the "Dirty Dozen" which outline common contributors to error[43,44]. However, the studies included in this review largely evaluated surgical training using technical performance metrics (e.g. OSATS, procedural time, accuracy), with comparatively limited assessment of non-technical domains[12]. In contrast, these skills are routinely integrated into simulation-based training in aviation[37].

Some evidence from other healthcare contexts suggests that human factors training can enhance team performance and patient outcomes;[45] however, this has not been widely integrated into surgical education[46]. Within the studies included in this review, their it remains unclear how widely such approaches have been incorporated. Notably, even when advanced modalities such as virtual reality were employed, training scenarios typically focused on procedural steps and anatomical tasks, without simulating the broader operating theatre environment or team interactions, highlighting an important gap in the current literature and warranting further investigation.

### *Applications for Artificial Intelligence*

Further research could continue to explore the role of immersive virtual reality in surgical training, particularly by extending beyond technical skills to incorporate elements of the broader operating environment and team interactions. While emerging technologies such as artificial intelligence (AI) have the potential to support simulation-based training—for example, by analysing performance metrics and providing personalised feedback[47,48]—current evidence in orthopaedic hands-on workshops is limited. Future investigations should prioritise evaluating how such technologies might complement existing workshop designs, with careful attention to accessibility and inclusivity, rather than assuming a central role for AI in training at this stage.

## CONCLUSION

In conclusion, the literature suggests that hands-on workshops and simulation-based interventions have potential educational benefits in orthopaedic surgical training. Studies indicate improvements in technical performance, procedural efficiency, and trainee confidence across a range of procedures, including arthroscopy, joint replacement, and fracture management. However, the evidence is heterogeneous, often limited to surrogate outcomes such as performance on simulators or cadaveric specimens, and rarely assesses direct patient outcomes. Challenges, including cost, accessibility, and scalability—particularly in low-resource settings—are frequently noted. Emerging technologies, such as virtual reality and the potential future role of artificial intelligence, may offer additional avenues for training, but their integration and effectiveness remain to be further evaluated. Overall, these findings support the growing role of hands-on workshops in orthopaedic surgical training, while highlighting the need for further research to better define their impact on clinical practice.

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