Review Article

Artificial intelligence in orthopaedic education: a narrative review

Jan P. Szatkowski^, Elliott Druten^, Chirag Soni^, Dillon C. O'Neill^

Department of Orthopaedic Trauma, Indiana University School of Medicine, Indianapolis, IN, USA

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Correspondence to: Jan P. Szatkowski, MD. Department of Orthopaedic Trauma, Indiana University School of Medicine, 1801 N. Senate Blvd, Suite 535, Indianapolis, IN 46202, USA. Email: szatkowski@gmail.com.

Background and Objective: The integration of artificial intelligence (AI) into medical education is reshaping traditional learning paradigms. In orthopaedic surgery, AI applications such as virtual reality (VR) and augmented reality (AR) simulations and intelligent tutoring systems are being utilized to enhance training. This review aims to explore the current applications, benefits, challenges, and future directions of AI in orthopaedic education, while also addressing relevant ethical and logistical considerations.

Methods: A targeted literature review was conducted using PubMed, prioritizing studies published in 2024 and including relevant articles from 2023. Search terms included "artificial intelligence", "orthopaedic education", "surgical simulation", and related keywords. Studies were selected based on relevance to orthopaedic surgery education, with a particular focus on surgical skill acquisition, diagnostic training, and curriculum development. Both peer-reviewed and selected non-peer-reviewed sources were analyzed to synthesize current trends and emerging practices. Relevant articles were also identified using manual reference searching.

Key Content and Findings: The review highlights a positive shift in attitudes toward AI among educators and learners, particularly for its ability to simulate surgical environments safely and personalize learning. Current applications include AI-powered VR/AR platforms for realistic procedural training, intelligent tutoring systems that tailor feedback to individual learning gaps, and tools for enhancing diagnostic reasoning. Despite these advances, challenges remain, including concerns about overreliance on technology, institutional readiness, and the need for adjustments to the curriculum.

Conclusions: AI presents a transformative opportunity for orthopaedic education by enabling safer, more personalized, and more efficient learning. While current applications show promising results in improving both knowledge and technical skill, ongoing evaluation, thoughtful integration, and structured implementation are necessary to maximize educational value while addressing limitations and ethical concerns.

Keywords: Artificial intelligence (AI); orthopaedic education; personalized learning; education technology; medical training

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^ ORCID: Jan P. Szatkowski, 0000-0002-6421-9736; Elliott Druten, 0009-0007-0088-575X; Chirag Soni, 0009-0003-7191-8425; Dillon O'Neill, 0000-0003-2985-2445.

Introduction

Over the past several decades, technological advancements have transformed medical education. Traditional approaches, such as didactic lectures, textbook-based learning, and the apprenticeship model, are being gradually augmented with innovative, technology-driven methods (1). The emergence of language-based artificial intelligence (AI) is already impacting the way that medical education is delivered (1).

Orthopaedic surgery requires a comprehensive understanding of anatomy, surgical precision, and adaptability. Traditionally, these skills have been developed throughout clinical training.

However, concerns for patient safety have increased interest in alternative training modalities. The advancement of AI-powered virtual reality (VR) and augmented reality (AR) simulation training has created new opportunities for trainees to supplement traditional training in a safer environment (2,3). These training augmentations may provide customized learning pathways, offering tailored feedback and personalized learning plans to enhance learning efficiency and ultimately improve clinical and operative practice (4).

While there are many proposed benefits of AI, its incorporation into orthopaedics presents new challenges. Teaching institutions must address infrastructure, faculty training, and curriculum revision when considering the implementation of AI-based training methodologies (1,4).

Furthermore, existing literature has raised contents regarding the potential for over-dependence on AI technologies (1). As AI continues to develop and become more prevalent, it is essential to assess AI's impact on orthopaedic education. The purpose of this review is to examine the current applications, advantages, challenges, and impact of AI in orthopaedic education, while also exploring ethical considerations and future directions. We present this article in accordance with the Narrative Review reporting checklist (available at https://aoj.amegroups.com/article/view/10.21037/aoj-25-7/rc).

Methods

A literature search was performed utilizing PubMed with a focus on studies published during or after 2024. An expansion of our search included a small number of relevant studies published in 2023. The search strategy incorporated terms such as 'artificial intelligence', 'machine learning', 'orthopaedic education', 'medical education', 'augmented reality', and 'surgical simulation'. Given the breadth of artificial intelligence literature, we prioritized studies with direct relevance to orthopaedic surgery and medical education. Articles were included based on their focus on AI applications in orthopaedic education, specifically surgical training, diagnostic skill improvement, and curriculum development. It is important to note that not all studies identified during the search were included in this review; instead, emphasis was placed on those most pertinent to orthopaedic training and educational applications. Relevant non-peer-reviewed publications were included. Relevant articles were also identified using manual reference searching. Information was extracted and synthesized to highlight key themes, trends, and challenges in the integration of AI within orthopaedic education. Details regarding the search strategy for this review can be found in *Table 1*.

Overview of AI in medical education

The origin of AI dates back to the mid-20th century with Alan Turing's "Turing Test", questioning a machine's ability to exhibit indistinguishable behavior from that of a human (5). Shortly after, AI emerged within the medical field in the 1970s and 1980s (6). Medical students utilized early systems like MYCIN for infectious disease diagnosis and INTERNIST-I for internal medicine to learn from medical specialists' decision-making (5). These early applications of AI created the foundation for further innovation. Since then, AI systems for medical education have been modernized with new generative tools, such as Chat Generative Pre-trained Transformer (ChatGPT), an AI chatbot created by OpenAI capable of participating in conversation and solving problems (6,7).

Currently, AI is utilized extensively across various medical fields (4,8-12). In radiology, AI algorithms improve pattern recognition and help reduce observational errors, which has made them valuable in radiology resident education for teaching image interpretation (8). In surgery, AI-driven VR and AR platforms allow students to practice procedures in immersive environments, with challenges and feedback tailored to their skill level (9). In anesthesiology, AI-driven simulations teach trainees to manage complex surgical complications and simulate emergency department decision-making in dynamic, multi-patient settings (10,11). In this review, we focus on VR training, intelligent tutoring, and preoperative planning adjuncts as these are the emerging technologies most relevant to orthopaedic

Table 1 The search strategy summary

Items	Specification
Date of search	Nov 15, 2024; Jun 15, 2025
Database searched	PubMed
Search terms used	'artificial intelligence', 'machine learning', 'orthopaedic education', 'medical education', 'augmented reality', 'surgical simulation'
Timeframe	Jan 2023 to Present
Inclusion and exclusion criteria	Inclusion: relevance to orthopaedic surgery, artificial intelligence, and medical education
	Exclusion: non-English studies
Selection process	Independent selection process conducted by J.P.S. and E.D.
Any additional considerations, if applicable	Relevant non-peer reviewed articles were included

providers.

VR and AR for surgical training

The incorporation of AI-driven VR and AR enhances surgical training through realistic, high-quality simulation without compromising patient safety (9). Decision-making algorithms can be simulated while also exposing trainees to vital anatomical structures in a clinically integrated environment using AI-powered VR/AR technology (13). These immersive, three-dimensional depictions of bones, joints, ligaments, and soft tissues enable students to interact with anatomical models in detail (13). Compared to traditional learning methods, AI-powered VR/AR technologies have the potential to combine the interactive environment of a cadaver lab with the immediate accessibility of a textbook, which may improve the overall quality of surgical education moving forward.

Intelligent tutoring systems

One of the benefits of AI in medical education is its ability to assess students' knowledge and skills, pinpoint areas for improvement, and recommend targeted learning strategies and resources. By addressing specific knowledge gaps, intelligent tutoring systems enable orthopaedic professionals to solidify their understanding of foundational principles, ultimately enhancing clinical competency and patient care outcomes (14). In orthopaedic education, this is exemplified by the AnconeusAI algorithm on OrthoBullets learning platform, which analyzes user performance on practice questions, identifying specific areas of weakness (2). The feedback provided by the AI helps learners recognize and address their content gaps, enabling them to make adjustments to their study strategies (2). AI-driven chatbots are increasingly utilized in medical education to simulate patient interactions, answer student questions with precision, and provide feedback on both communication and clinical reasoning skills (15,16). Moldt *et al.* found that both medical students and physicians held a generally positive view toward the integration of AI in medicine (16). In particular, students supported the use of chatbots in medical education for handling routine and supportive tasks, such as answering basic questions, managing appointment scheduling, and providing general information (16). Within orthopaedic surgery training, for example, a chatbot could simulate a patient presenting with chronic knee pain, allowing students to practice asking relevant clinical questions, interpreting responses, and formulating a diagnosis (15).

Inarguably, some of the most essential aspects in orthopaedic training are exposure and repetition. Traditional clinical education rotations often fail to cover all orthopaedic disorders, especially those that are rare or complex (17-19). Bakkum *et al.* demonstrated the use of ChatGPT to create medical case vignettes, which allowed students to encounter artificially generated patient cases during their learning process (20). The orthopaedic surgery equivalent to this would be artificially created cases that can range from simple fractures to complex congenital abnormalities (19). As trainees progress in their learning, the difficulty and complexity of the material can be tailored to their individual abilities and learning needs (20).

Implant templating and preoperative planning

Implant templating and preoperative planning are other

emerging areas of AI application within orthopaedic surgery. This development is logical as many orthopaedic subspecialties are heavily dependent on stock implantable materials. For instance, AI is being used for preoperative planning in patients undergoing total hip and knee arthroplasty, with recent literature demonstrating significant improvements in prosthetic sizing accuracy, reduced operative time and blood loss, and more effective limb length restoration in direct anterior total hip arthroplasty (12). Similar AI-driven tools could be applied across orthopaedic sub-specialties in the future to provide trainees with a more detailed understanding of the relationship between implant design and individual or population-average osteology.

Challenges associated with AI implementation

Many institutions may lack the necessary hardware or resources to support a transition to AI-enhanced learning (21). Integrating AI systems with educational platforms and electronic health record systems represents one of the many potential technological hurdles (21). Faculty may also prefer old teaching techniques and be hesitant about new technology (21). Implementing AI technology can be particularly challenging when the curriculum, evaluation, and certification processes are already firmly established (21). Such changes require time, energy, and shifts in the institutional culture of organizations that already have these systems in place.

A lack of technical background may result in many instructors' inability to apply AI technologies or explain their shortcomings to their students (22). With regular use of AI technology for diagnosis and decision-making, students may rely on AI technologies for diagnosis and decision-making, undermining their clinical judgment and hands-on abilities (1,22,23). Without balancing AI simulations and virtual learning with actual patient encounters, the use of AI could potentially limit the experience of the developing trainee. Increased reliance on AI may also lead to complacency, with some students accepting AI recommendations without critically evaluating them or considering factors that the AI system might overlook (23).

Although VR/AR systems provide learning opportunities to trainees, these systems are typically complex and expensive to implement (9). There is limited evidence regarding the optimal implementation within the current residency training paradigm, and many have concerns that although VR/AR improves technical skills, it limits necessary interpersonal interaction (9).

Predictions for the evolution of orthopaedic training

Mir *et al.* discussed the potential for widespread AI-influenced learning in medical education and the benefits of personalized training (14). This adaptive learning model within AI will likely enable orthopaedic training to become more effective, allowing students to advance according to their skills rather than time-bound schedules (14). VR and AR will likely play an increasingly significant role as these technologies are integrated into training programs and more research is conducted to evaluate their effectiveness (9). Lisacek-Kiosoglous *et al.* explored the future of AI in orthopaedic surgery and suggested that AI would reduce physician workload through its capabilities, ranging from predicting hospital length of stay to identifying patient implants on radiographs (24).

The expanded implementation of AI within clinical systems has the potential to improve quality and efficiency in orthopaedic research substantially. Zsidai *et al.* highlighted the data-driven nature of AI, emphasizing its potential to assist researchers in orthopaedics by facilitating the generation of novel hypotheses and guiding future investigations (25).

Development of new AI-focused courses

As AI becomes increasingly prevalent, dedicated AI courses in orthopaedics are essential to prepare students for its integration into their work (18,26). The University of Illinois College of Medicine, Peoria, has introduced such courses to first-year medical students with the intention of developing AI literacy (26). These courses educate students on using and evaluating AI applications effectively, fostering future collaboration between health practitioners and AI experts. Courses in orthopaedics may cover topics such as machine learning, AI-assisted diagnosis, and healthcare. For example, a course like "AI Applications in Orthopaedic Imaging" could teach students how AI systems analyze radiographs, computed tomography (CT) scans, and magnetic resonance imaging (MRI), while helping them understand the principles, limitations, and biases of these tools (18,26,27). Another course, "AI in Surgical Planning and Simulation", may focus on preoperative preparation through AI-powered planning tools and VR simulations.

Limitations

This review has several limitations that are worth consideration. Most importantly, the relationship between AI and orthopaedic surgery training is a novel area of research interest with a small number of existing publications. Many studies included in this review were small-scale, retrospective, or lacked robust methodological frameworks, which may impact the generalizability of findings. Additionally, the reliance on non-peer-reviewed publications and older articles to supplement emerging AI topics introduces potential biases. Future high-quality, prospective research is needed to validate the efficacy and integration of AI tools in orthopaedic education.

Conclusions

The integration of AI into orthopaedic education is transforming traditional medical training, offering innovative methods to enhance learning efficiency, clinical skills, and surgical precision. While AI presents opportunities to supplement conventional training and improve anatomical understanding, concerns regarding over-dependence on technology and the potential impact on clinical judgment and empathy must be addressed. Successful implementation requires careful attention to institutional infrastructure, faculty training, and curriculum updates, emphasizing the importance of continuous assessment of AI's impact and ethical implications.

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Footnote

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://aoj.amegroups.com/article/view/10.21037/aoj-25-7/rc

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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