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CLINICAL

Immersive Virtual Reality: A Paradigm Shift in Education and Training

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Virtual reality (VR) is both a natural progression and a paradigm shift in orthopaedic training and education. Many orthopaedic surgeons can recall the popularization of arthroscopes, computer-assisted and -navigated procedures, and the use of novel implants based on patient-specific anatomy in regular practice. Incorporation of computing power into orthopaedic practice now provides opportunities for immersive, multisensory training experiences beyond low-fidelity physical constructs, such as bone models and bench-top simulators. Despite this natural technological progression of training modalities, the training environment of novices and established surgeons remains rooted in historic methods of mentorship and direct learning on patients.

Beyond the classic Halstedian "see one, do one, teach one" method of learning are extensively researched learning methods, including the Kolb experiential cycle, deliberate practice, and differential training with interleaving. VR training satisfies those learning methods through access to immersive operative environments for uninterrupted and varied repetition of training scenarios. This shift in education, leveraging new technology, has the potential for more rapid and efficient learning coupled with experiential gains and expertise earlier in training cycles.

Fig. 1 A representative example of an immersive virtual reality operating room suite that interacts with the patient and environment, while permitting failure and collecting performance metrics: (**A**) a patient in supine position on a fracture table so that a user may learn hip arthroscopy portals; (**B**) following fracture principles with added depth of learning in a hip fracture model.

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How VR can improve education

VR was first described in 1986. In more recent years, with advancing computer power, there have been improvements in the realism and immersion of simulations. Currently, VR in surgical education draws from experiences in the gaming and entertainment industries. VR training is widely embraced in many industries for developing expertise through simulated experience-based learning. In such circumstances, VR has exposed trainees to challenging and atypical simulated cases and forces

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QUALITY & RESEARCH

AAOS Launches Strategic Biologics Initiative

The Academy is poised to be a leader in biologics research and knowledge

KERRI FITZGERALD

In November 2019, AAOS announced the launch of its strategic investment in the field of biologics. Over the next five years, AAOS will prioritize research and development for a biologics-focused competency within the Academy's existing member benefits, with a focus on

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them to create more refined, specialized reasoning than what comes from a procedural manual or lecture.

Medical and surgical disciplines have adopted VR simulators following consensus statements on design and reporting standards. Currently, AAOS, the American College of Surgeons, and the Accreditation Council for Graduate Medical Education (ACGME) endorse the use of simulation products in orthopaedic education. To create the immersive experience of VR, a surgeon wears a head-mounted display that provides visual and auditory cues constructed to provide three-dimensional presence. To further the immersion, controllers with sense-of-touch feedback (haptics) allow for interaction with objects in the virtual world. Realistic visuals, including patient positioning, draping, and virtual replicas of surgical instruments and implants, allow for a lifelike simulated training environment (Figs. 1 and 2).

Fig. 2 A learner deciding tibial resection height during revision knee arthroplasty
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For early learners, VR offers repetition of common scenarios with specific and definable technical and nontechnical learning outcomes. Learning in a virtual environment negates both ethical considerations of patient care by trainees and direct patient harm. While learning fundamental orthopaedic skills, trainees can comfortably test the boundaries of their skills and make mistakes. After feedback and reflection, trainees can learn and repeat *ad infinitum* until they are proficient.

VR technologies may allow more rapid and efficient training. Randomized, controlled trials comparing flexible duty hours with standard ACGME working hours, such as by Bilimoria et al., published in *The New England Journal of Medicine*, have shown equivalency in passing examinations but have not commented on technical skill. A recent study by Frank et al., demonstrated that a competency-based framework, rather than time-based, resulted in potentially earlier graduation of most included residents. VR training may benefit residents by providing access to low-volume technical procedures as they strive to reach competency. Incorporation of VR training in a competency-based framework provides a training modality that highlights technical skill achievement with clinical decision-making and knowledge acquisition.

This same feature of error identification and reduction toward technical competency is possible for established surgeons who are adopting new technologies, similar to pilots practicing on new equipment in the aeronautics industry. Studies have shown that surgeons take longer and use more fluoroscopy when learning new techniques. VR allows for simulated fluoroscopy and avoids radiation exposure. Immersive VR systems allow users to pause and reflect, to reconsider cases and objectives, for comprehensive patient experiences and avoidance of surgical "tunnel vision." A finite number of procedures is insufficient to determine expertise in orthopaedics, but rather uniqueness of experience helps to define and redefine skill. Research by Ericsson et al., in behavioral analytics has shown that attainable expertise is not rooted in inherent ability or repetition, but rather a thoughtful, goal-oriented approach to obtaining discrete and manageable skills. VR provides this graduated, user-focused ability to help trainees achieve and maintain expertise, if done with the previously noted principles. Similarly, a unique feature of VR simulators is objective, real-time feedback and available metrics on surgical performance and outcomes.

Practicing surgeons also may consider VR simulators to train on low-volume procedures or to regain confidence when returning from a leave of absence, for example. The technology may also provide surgeons with opportunities to simulate real patient cases before they deliver direct patient care. Deliberate practice may benefit low-volume surgeons who wish to provide service to communities, as well as surgeons from low- to middle-income countries (LMIC). Low-fidelity simulators have been shown to help manage discrepancies of care in general surgery in LMIC, and more immersive VR in orthopaedics may help improve patient outcomes in those populations. VR simulators also can allow training by expert teachers anywhere in the world, negating the environmental, financial, and time costs of traveling to teach and learn.

A peer-reviewed study that is pending publication in the *Journal of Bone & Joint Surgery* compared an immersive VR simulator (PrecisionOS, Vancouver, British Columbia, Canada) to traditional learning methods in senior residents performing shoulder surgery with the Canadian Shoulder and Elbow Society. The study evaluated several residents from multiple institutions in a blinded, randomized trial using validated outcome scores. It demonstrated that VR learning provided increased technical skill and operative efficiency compared to a traditional approach. The VR-trained residents completed their learning activity 570 percent faster than their counterparts and showed improved instrument handling and time to task completion of a cadaveric dissection, along with equivalent written and verbal testing scores. Both residents and expert surgeons provided information to validate the VR simulator in terms of face, content, construct, and transfer of skill validity—significantly favoring VR over the traditional didactic modality.

The study is promising, but VR requires further translational studies to demonstrate validity across orthopaedic subspecialties. Cost-effectiveness of skill acquisition also will need to be ascertained, as will benefit to patients with long-term patient-reported outcomes.

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The number of publications pertaining to VR in orthopaedics continues to rise, and the inclusion of immersive simulators in training and regular practice will provide longitudinal opportunities for further high-quality research.

References for the studies cited can be found in the online version of this article, available at www.aaosnow.org.

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