AO SPINE

White paper

Educational technologies for simulation in spine courses

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AO Spine Educational Strategies Taskforce

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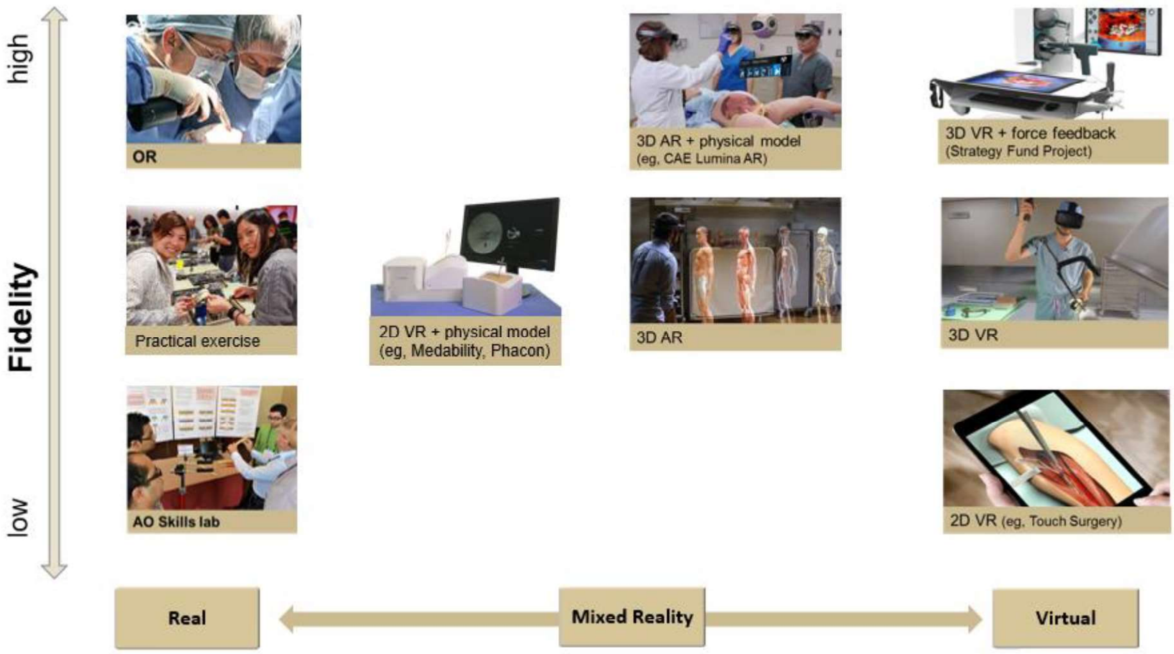
This document has been developed for AO Spine Chairpersons and Faculty designing courses, for national and regional education officers, and for AO Spine Event Owners to help plan educational offerings (ie, to select educationally sound and cost-effective methods to design activities to enhance surgical skills in learners). The opinions expressed are those of the surgeons involved and do not constitute any endorsement of the products discussed. The authors disclose any financial relationship with the companies or products mentioned in the appropriate sections. The list of products is not exhaustive, and new reviews will be added each year if considered valuable.



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1 Introduction and terminology

In the Journal of Orthopaedic Surgery and Research 2014, Stirling et al define simulation as "any technology or process that recreates a contextual background in a way that allows a learner to experience mistakes and receive feedback in a safe environment". It aims to recreate the experience of patient care without compromising patient safety. The ability to modify a situation allows trainees to experience novel but often important situations that may not be commonly experienced in clinical practice. The benefits of simulation are recognized by many specialties and has been advocated by many medical bodies and colleges. The advantages of simulation extend beyond simple technical and procedural skills. Simulation allows trainees to engage with a multi-disciplinary team and focus on individual and team-based cognitive skills including problem solving, decision-making, and team behavior skills.

Stirling summarized the main modalities below and for the purposes of our white paper for AO Spine, we discuss 5 types of simulation technology: Dry bone models and enhanced versions, synthetic anatomical models, telementoring, Virtual Reality (VR), and Augmented Reality (AR).

Table 1 A summary of the main simulation modalities available to orthopaedic surgery trainees

Simulation model	Advantages	Disadvantages
Cadaveric simulation		Expensive
	High fidelity	Not easily accessible with specialist storage demands
		Time-consuming preparation time
	Shown to develop transferable operative skills	Relies on tissue donation
		Risk of disease transmission
	Allows understanding of relevant clinical anatomy and surgical approaches	Lack of uniformity amongst specimens
Synthetic bone simulation	Relatively inexpensive, portable and widely available	
	Widely available	Does not allow understanding of influence of soft tissues
	Develop understanding and familiarity with orthopaedic instruments and equipment	Lack of true haptic feedback
Arthroscopic simulation	Able to record progress and assess motion analysis	
	Allows for development of hand-eye co-ordination and triangulation	High initial setup costs
	Wide range of procedures may be possible	Limited realism
	Modern simulators can provide haptic feedback	
Virtual reality simulation	Able to record progress and assess motion analysis	
	Wide range of procedures may be possible	High initial setup costs
	Allows for scenario simulation	
Cognitive simulation	Potentially cost free	Limited evidence to support use in clinical training/improvement in technical procedural skills
	Accessible on mobile devices	
	Point of care education	

AR and VR are becoming more common as both operative and teaching tools in spine surgery, although their use is still relatively new and in constant evolution (Yuk et al, 2021). There are three types: VR, where the entire simulation is virtual, AR, a technology that superimposes a computer-generated image onto the view of the real world, and mixed reality (MR) which combines virtual and real experiences.

2 Rationale and goals

2.1 Current state and limitations

Most courses delivered by AO Spine teach surgical skills using dry bone models without any soft tissue or human anatomical specimens (HAS). These methods are both appropriate for enabling participants to complete steps or full procedures and to receive structured feedback from faculty as taught in AO faculty development programs. Peer interaction is enhanced through sharing the exercises between 2 or more participants. However, there are several limitations with these models. HAS are costly, vary in quality, rarely exhibit the relevant pathology, and are unavailable in many countries. Dry bone models, while anatomically correct, do not mimic the soft tissue environment present clinically nor do they provide realistic haptics critical in instrument handling. Finally, while feedback to participants come from course faculty, there is no data collected that could provide an objective assessment of skill acquisition.

The current state and limitations of the addition of newer simulation options remain unknown or unconfirmed within the context of AO Spine courses and education. Reviewing the current literature provides some guidance that we can test in our context.

2.2 Aim and anticipated benefits

The intentions of this white paper are:

- provide information to help chairpersons make good planning decisions based on the available evidence
- encourage everyone to share experiences and outcomes data to plan future educational offerings
- identify and run research projects to answer the key open questions

The anticipated benefits of exploring alternative options on a larger scale are:

- more effective learning for the target audience level
- more cost-effective use of resources
- enhanced learning and teaching
- allow learners to acquire surgical skills in nontraditional environments (outside of courses and the OR). This has become essential as educational paradigms have changed in the post pandemic environment.

2.3 Technology evaluation process and metrics

To provide a structured approach to the assessment of new simulation technology and products, the educational strategies taskforce created a template to collect the following information (which we plan to develop further into more formal metrics for assessment). By collecting data and feedback in a standardized way, we can collate information and make comparisons when we add new reviews.

- Company and product name
- Procedures covered
- Realism
    - Realistic patient tissue (bone, soft tissue, tactile, realistic palpation)
    - Realistic instruments (feel, handling, behavior eg, on bone)
    - Realistic imaging (fluoroscopy, CT, 3D, endoscopy, microscopy)
- Assessment and recording
    - What feedback is provided to the learner?
    - What performance data is gathered (or recorded)?
- Cost and scalability
- Potential uses for AO Spine events and in the curriculum

3 Review of simulation types and platforms

For each type of simulation, we describe the main features and summarize some advantages and limitations. We list the specific products we have reviewed in this area (details on the subsequent pages) and provide abstracts of key articles and additional product and company information in the Appendices.

3.1 Dry bone models and enhanced versions

Dry bone models are the standard for our basic hands-on teaching method for practical exercises and is relatively available and transportable. Trainees work on an artificial but anatomically correct bone model that can mimic certain fractures or pathologies. 3-D printed models based on CT or other data have become an option for complex pathology where small numbers are required (may be more suitable for demonstration than having at many workstations). However, the lack of critical soft tissues is one of its main limitations.

Dry bone models with an extra layer of 'soft tissue' simulate, to a certain extent, the intraoperative conditions.

Full trunk models with the full spine, ligaments, dura, muscle, and skin to allow for a more realistic simulation and alleviates some of the issues with the dry bone models that often lack critical structures.

Dry bone models with in-built data monitoring add some performance assessment system through different type of sensors or cameras.

- Example products reviewed
    - Synbone, SurgiSTUD, Medability, DEHST

3.2 Synthetic anatomical models and enhanced versions

Spine model that simulates the bone structures of the real spine with skin, muscle, ligaments, dura, and cerebrospinal fluid. The addition of soft tissue and fluids offer experiences that are much closer to real spinal surgery. They provide realism and fidelity and require less maintenance and preparation compared with cadaveric models. The presence of cerebrospinal fluid also permits simulation of emergency situations. Though these are typically more expensive, they offer features for assessment and feedback options.

- Example products reviewed
    - Realists

3.3 Telementoring (enhancing exercises or operations)

These are systems using video connections to an exercise, lab, or real operation where a faculty member can provide guidance remotely using software tools.

- Example products reviewed

* Proximie, Immertec, Swiss Surgical Video, Rods and Cones

3.4 Virtual reality

Virtual reality (VR) utilizes a computer processing unit with a head-mounted display to provide visual and auditory cues coupled with hand controllers containing position trackers and force feedback, to provide an immersive experience. Based on a systematic review from 2021 analyzing 17 independent studies, immersive VR-trained surgeon groups performed 18% to 43% faster on procedural time to completion compared to control. Immersive VR trainees also demonstrated greater post-intervention scores on procedural checklists and greater implant placement accuracy compared to control. VR incorporation into surgical training programs received also positive user ratings, and it is cost-effective. (Immersive Virtual Reality for Surgical Training: A Systematic Review, Randi Q. Mao,2021, DOI:https://doi.org/10.1016/j.jss.2021.06.045)

VR equipment (goggles and handles) can also be shipped to remote places and in some cases the teaching modules can be saved locally with no need of internet connection. The applications go from procedural training to anatomical models, to virtual classrooms (remote participants are virtually in the same room). Some disadvantages regard the realism and the haptic feedback that is still basic and distant from the one provided by dry bones or synthetic anatomical model or specimens.

* Example products reviewed
    * NonNocere (virtual classroom), Precision OS

3.5 Augmented reality

AR is the superimposition of a computer-generated image onto the view of the real world (virtual component onto physical reality). A systematic review of 18 publications focusing on the impact of AR on motor skills training as compared with traditional techniques showed either no difference or improved performance by using AR. Regarding procedural time the data tended to suggesting use of AR was slower than traditional techniques. With regard to user opinion, AR was favored by surgeons in all but one of the studies—in which cadaveric models were preferred. Subjective opinion-style data must always be treated with caution as the novelty of new technology can sometimes be sufficient to sway opinion regardless of performance. (Augmented reality in surgical training: A systematic review. Available: https://www.researchgate.net/publication/340292072_Augmented_reality_in_surgical_training_A_systematic_review [accessed Aug 19 2022]).

AR has been applied in spine surgery in the form of a heads-up display in the positioning of pedicle screws, in deformity, kyphoplasty, and vertebroplasty. In all the studies it showed some benefits regarding improvement of surgical outcome (The utility of virtual reality and augmented reality in spine surgery. Doi: 10.21037/atm.2019.06.38 :http://dx.doi.org.)

* Example products reviewed
    * Brainlab (mixed reality), Xvision (Augmedics)